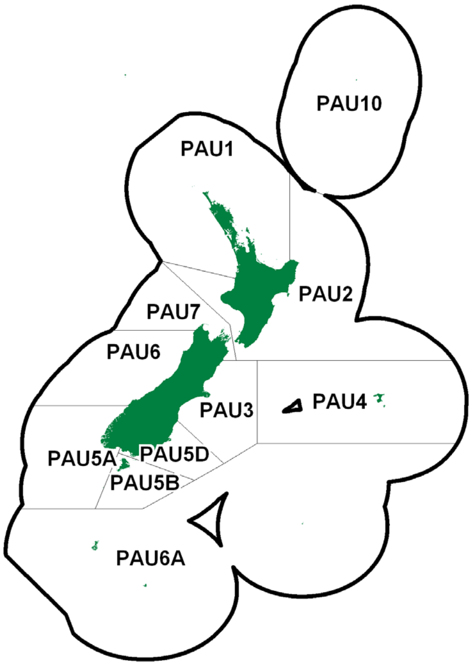
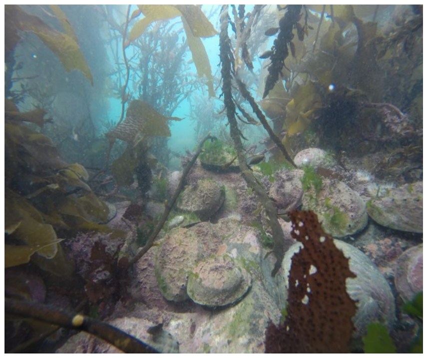
PĀUA (PAU)

(*Haliotis iris, Haliotis australis*)





1. INTRODUCTION

Specific Working Group reports are given separately for PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D, and PAU 7. The TACC for PAU 1, PAU 6, and PAU 10 is 1.93 t, 1 t, and 1 t, respectively. Commercial landings for PAU 10 since 1983 have been 0 t.

1.1 Commercial fisheries

The commercial fishery for pāua dates from the mid-1940s. In the early years of this commercial fishery the meat was generally discarded and only the shell was marketed, however by the late 1950s both meat and shell were being sold. Since the 1986–87 fishing season, the eight Quota Management Areas have been managed with an individual transferable quota system and a total allowable catch (TAC) that is made up of total allowed commercial catch (TACC), recreational and customary catch, and other sources of mortality.

Fishers gather pāua by hand while free diving. The use of underwater breathing apparatus (UBA) is not permitted except in the PAU 4 fishery. Due to safety concerns of great white shark interactions, the use of UBAs has been permitted in the Chatham Island pāua fishery (PAU 4) since 2012. Most of the catch is from the Wairarapa coast southwards: the major fishing areas are in the South Island, Marlborough (PAU 7), Stewart Island (PAU 5A, 5B, and 5D) and the Chatham Islands (PAU 4). Virtually the entire commercial fishery is for the black-foot pāua, *Haliotis iris*, with a minimum legal size for harvesting of 125 mm shell length. The yellow-foot pāua, *H. australis* is less abundant than *H. iris* and is caught only in small quantities; it has a minimum legal size of 80 mm. Catch statistics include both *H. iris* and *H. australis*.

In 2016, there were PAU 7 TACC reductions and voluntary ACE shelving by quota owners foregoing catching a portion of their quota, by 50%. A further 10% of the PAU 7 TACC was shelved in 2017 to remove any excess commercial fishing effort in areas either side of the earthquake closure; this shelving is still current for the 2020–21 fishing year.

Up until the 2002 fishing year, catch was reported by general statistical areas, however from 2002 onwards, a finer scale system of pāua specific statistical areas was put in place throughout each QMA (refer to the QMA specific Plenary chapters). Figure 1 shows the historical landings for the main PAU stocks. On 1 October 1995 PAU 5 was divided into three separate QMAs: PAU 5A, PAU 5B, and PAU 5D.

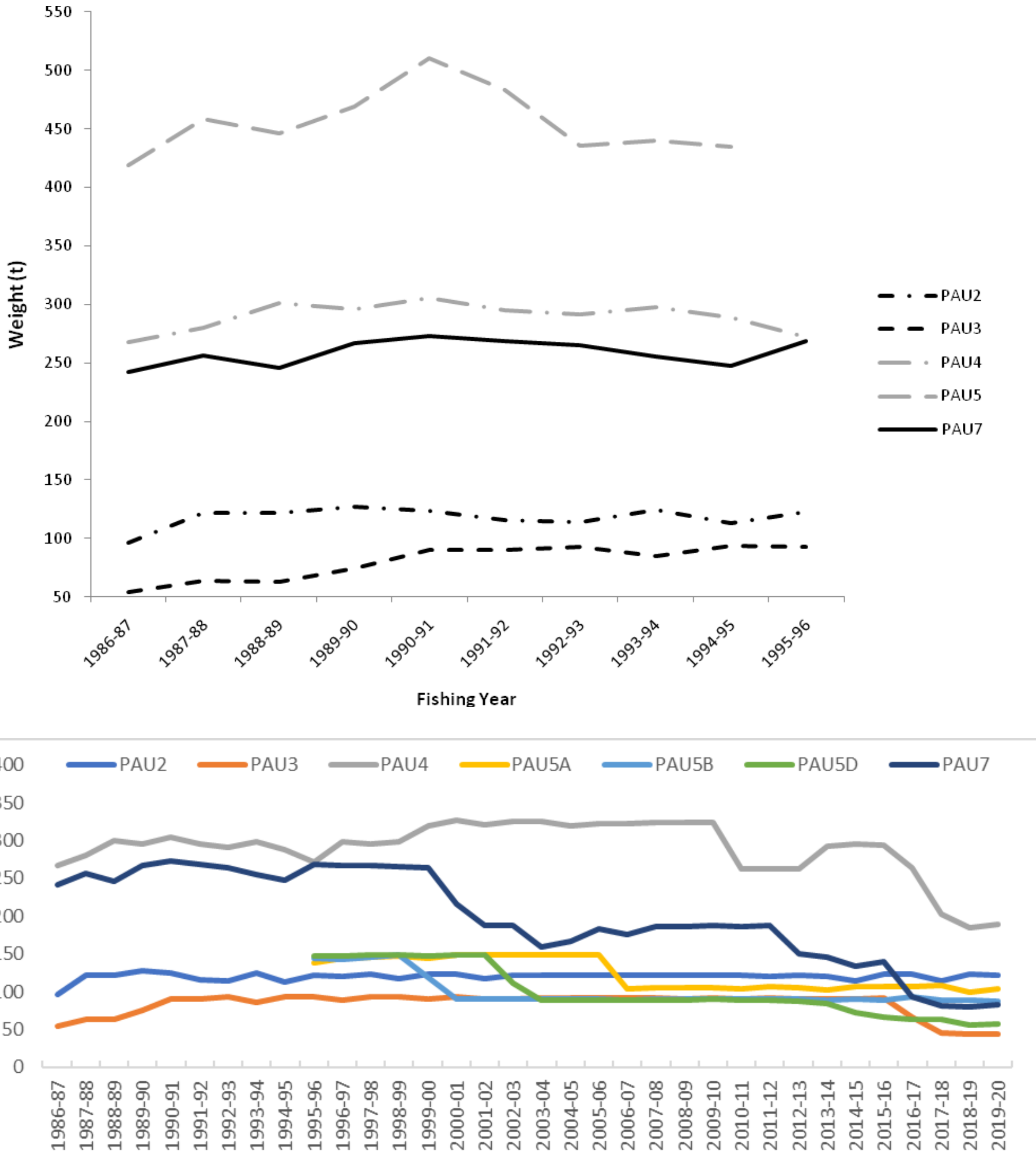


Figure 1:Historic landings for the major pāua QMAs from 1983–84 to 1995–96 (top) and from 1996–97 to 2019–20 (lower).

Landings for PAU 1, PAU 6, PAU 10, and PAU 5 (prior to 1995) are shown in Table 1. PAU 1 landings have been below the TACC since its introduction to the QMS in 1986–87, with no landings recorded for 2017–18 and just 0.22 t recorded in 2018–19. Landings increased to 1.36 t in 2019–20, close to the TACC and at a level not seen since 1992–93. In contrast PAU 6 landings have been close to the TACC since the fishing year 2006–07. For information on landings specific to other pāua QMAs refer to the specific Working Group reports.

1.2 Recreational fisheries

There is a large recreational fishery for pāua. Estimated catches from telephone and diary surveys of recreational fishers (Teirney et al 1997, Bradford 1998, Boyd & Reilly 2002, Boyd et al 2004) are shown in Table 2.

Table 1: TACCs and reported landings (t) of pāua by Fishstock from 1983–84 to present.

Fishstock	PAU 1		PAU 5		PAU 6		PAU 10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	1	–	550	–	0.00	–	0.00	–
1984–85*	0	–	353	–	3.00	–	0.00	–
1985–86*	0	–	228	–	0.00	–	0.00	–
1986–87*	0.01	1.00	418.9	445	0.00	1.00	0.00	1.00
1987–88*	0.98	1.00	465	448.98	0.00	1.00	0.00	1.00
1988–89*	0.05	1.93	427.97	449.64	0.00	1.00	0.00	1.00
1989–90	0.28	1.93	459.46	459.48	0.00	1.00	0.00	1.00
1990–91	0.16	1.93	528.16	484.94	0.23	1.00	0.00	1.00
1991–92	0.27	1.93	486.76	492.06	0.00	1.00	0.00	1.00
1992–93	1.37	1.93	440.15	442.85	0.88	1.00	0.00	1.00
1993–94	1.05	1.93	440.39	442.85	0.10	1.00	0.00	1.00
1994–95	0.26	1.93	436.13	442.85	18.21H	1.00	0.00	1.00
1995–96	0.99	1.93	–	–	28.62H	1.00	0.00	1.00
1996–97	1.28	1.93	–	–	0.11	1.00	0.00	1.00
1997–98	1.28	1.93	–	–	0.00	1.00	0.00	1.00
1998–99	1.13	1.93	–	–	0.00	1.00	0.00	1.00
1999–00	0.69	1.93	–	–	1.04	1.00	0.00	1.00
2000–01	1.00	1.93	–	–	0.00	1.00	0.00	1.00
2001–02	0.32	1.93	–	–	0.00	1.00	0.00	1.00
2002–03	0.00	1.93	–	–	0.00	1.00	0.00	1.00
2003–04	0.05	1.93	–	–	0.00	1.00	0.00	1.00
2004–05	0.27	1.93	–	–	0.00	1.00	0.00	1.00
2005–06	0.45	1.93	–	–	0.00	1.00	0.00	1.00
2006–07	0.76	1.93	–	–	1.00	1.00	0.00	1.00
2007–08	1.14	1.93	–	–	1.00	1.00	0.00	1.00
2008–09	0.47	1.93	–	–	1.00	1.00	0.00	1.00
2009–10	0.20	1.93	–	–	1.00	1.00	0.00	1.00
2010–11	0.12	1.93	–	–	1.00	1.00	0.00	1.00
2011–12	0.77	1.93	–	–	1.00	1.00	0.00	1.00
2012–13	1.06	1.93	–	–	1.00	1.00	0.00	1.00
2013–14	0.71	1.93	–	–	1.00	1.00	0.00	1.00
2014–15	0.47	1.93	–	–	1.00	1.00	0.00	1.00
2015–16	0.13	1.93	–	–	0.84	1.00	0.00	1.00
2016–17	0.25	1.93	–	–	1.06	1.00	0.00	1.00
2017–18	0.00	1.93	–	–	1.04	1.00	0.00	1.00
2018–19	0.22	1.93	–	–	1.00	1.00	0.00	1.00
2019–20	1.36	1.93	–	–	1.00	1.00	0.00	1.00

H experimental landings
* FSU data

Table 2: Estimated annual harvest of pāua (t) by recreational fishers from telephone-diary surveys*.

Fishstock	PAU 1	PAU 2	PAU 3	PAU 5	PAU 5A	PAU 5B	PAU 5D	PAU 6	PAU 7
1991–92	–	–	35–60	50–80	–	–	–	–	–
1992–93	–	37–89	–	–	–	–	–	0–1	2–7
1993–94	29–32	–	–	–	–	–	–	–	–
1995–96	10–20	45–65	–	20–35	–	–	–	–	–
1996–97	–	–	–	N/A	–	–	22.5	–	–
1999–00	40–78	224–606	26–46	36–70	–	–	26–50	2–14	8–23
2000–01	16–37	152–248	31–61	70–121	–	–	43–79	0–3	4–11

*1991–1995 Regional telephone/diary estimates, 1995/96, 1999/00 and 2000/01 National Marine Recreational Fishing Surveys.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a national panel survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The panel survey was repeated in 2017–18 (Wynne-Jones et al 2019). Harvest estimates for pāua are given in Table 3 (from Wynne-Jones et al 2014 using mean weights from Hartill & Davey 2015 and from Wynne-Jones et al 2019).

Table 3: Recreational harvest estimates for pāua stocks from the national panel survey in 2011–12 (Wynne-Jones et al 2014) and 2017–18 (Wynne-Jones et al 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015).

Stock	Fishers	Events	Number of pāua	CV	Total weight (t)	CV
2011–12 (national panel survey)						
PAU 1	39	63	43 480		12.16	0.27
PAU 2	158	378	286 182		81.85	0.15
PAU 3	35	67	60 717		16.98	0.31
PAU 5A	2	3	1 487		0.42	0.76
PAU 5B	5	5	2 945		0.82	0.50
PAU 5D	41	84	80 290		22.45	0.30
PAU 7	19	41	50 534		14.13	0.34
PAU total	299	641	525 635		148.82	0.11
2017–18 (national panel survey)						
PAU 1	27	41	27 707	0.34	8.74	0.34
PAU 2	151	367	283 240	0.15	83.22	0.15
PAU 3	21	46	28 140	0.35	8.79	0.35
PAU 5A	3	4	2 419	0.76	0.85	0.76
PAU 5B	10	21	15 361	0.45	9.85	0.45
PAU 5D	48	88	55	0.21	19.28	0.21
PAU 6	E	e	3 076	0.60	0.95	0.61
PAU 7	11	16	10 576	0.36	3.02	0.36
PAU total	274	590	425 661		134.70	

1.3 Customary fisheries

There is an important customary use of pāua by Maori for food, and the shells have been used extensively for decorations and fishing devices. Limited quantitative information on the level of customary take is available from Fisheries New Zealand (Table 4). These numbers are likely to be an underestimate of customary harvest as only the catch in kilograms and numbers are reported in the table. In addition, many tangata whenua also harvest pāua under their recreational allowance and these are not included in records of customary catch.

Table 4: Fisheries New Zealand records of customary harvest of pāua (reported as weight (kg) and numbers), since 1998-99. – no data. [Continued next 2 pages]

	PAU 1				PAU 2			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
1998–99	–	–	–	–	40	40	–	–
1999–00	–	–	–	–	–	–	1 400	820
2000–01	–	–	–	–	–	–	–	–
2001–02	–	–	–	–	–	–	–	–
2002–03	–	–	30	30	–	–	–	–
2003–04	–	–	184	146	–	–	4 805	4 685
2004–05	–	–	240	220	–	–	2 780	2 440
2005–06	125	100	40	40	–	–	5 349	4 385
2006–07	705	581	2 175	1 925	–	–	7 088	3 446
2007–08	460	413	2 155	1 618	–	–	11 298	6 164
2008–09	491	191	2 915	2 228	–	–	30 312	24 155
2009–10	184	43	2 825	2 225	–	–	5 505	4 087
2010–11	154	129	5 915	3 952	–	–	20 570	17 062
2011–12	25	8	470	470	243	243	29 759	23 932
2012–13	20	20	1 305	1 193	10	6	51 275	27 653
2013–14	–	–	–	–	–	–	61 486	30 129
2014–15	45	33	700	536	–	–	25 215	16 449
2015–16	50	9	1 425	756	–	–	11 540	6 383
2016–17	–	–	2 190	618	–	–	13 698	6 877
2017–18	15	15	4 612	3 127	–	–	6 960	1 942
2018–19	–	–	1 348	690	–	–	8 585	3 209
2019–20	–	–	50	50	–	–	–	–

	PAU 3*				PAU 4			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
1998–99	–	–	–	–	–	–	–	–
1999–00	–	–	–	–	–	–	–	–
2000–01	–	–	300	230	–	–	–	–
2001–02	200	50	6 239	4 832	–	–	–	–
2002–03	–	–	3 422	2 449	–	–	–	–
2003–04	–	–	–	–	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	1 580	1 220	–	–	–	–
2006–07	–	–	5 274	4 561	–	–	–	–

Table 4: [Continued]

PAU 3* and PAU 4

	PAU 3* Weight (kg)		PAU 3* Numbers		PAU 4 Weight (kg)		PAU 4 Numbers	
Fishing year	**Approved**	**Harvested**	**Approved**	**Harvested**	**Approved**	**Harvested**	**Approved**	**Harvested**
2007–08	–	–	7 515	5 790	–	–	–	–
2008–09	–	–	10 848	8 232	–	–	–	–
2009–10	–	–	8 490	6 467	–	–	635	635
2010–11	–	–	8 360	7 449	–	–	–	–
2011–12	–	–	5 675	4 242	–	–	–	–
2012–13	–	–	15 036	12 874	–	–	–	–
2013–14	–	–	10 259	7 566	–	–	110	110
2014–15	–	–	8 761	7 035	–	–	150	150
2015–16	–	–	14 801	11 808	–	–	320	120
2016–17	–	–	11 374	9 217	–	–	366	366
2017–18	–	–	2 708	1 725	53	85	820	764
2018–19	–	–	480	278	330	330	–	–
2019–20	–	–	30 288	21 527	–	–	–	–

PAU 5A and PAU 5B

	PAU 5A Weight (kg)		PAU 5A Numbers		PAU 5B Weight (kg)		PAU 5B Numbers	
Fishing year	**Approved**	**Harvested**	**Approved**	**Harvested**	**Approved**	**Harvested**	**Approved**	**Harvested**
1998–99	–	–	–	–	–	–	–	–
1999–00	–	–	–	–	–	–	–	–
2000–01	–	–	–	–	–	–	50	50
2001–02	–	–	80	70	–	–	610	590
2002–03	–	–	–	–	–	–	–	–
2003–04	–	–	–	–	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	–	–	–	–	140	90
2006–07	–	–	–	–	–	–	485	483
2007–08	–	–	100	100	–	–	2 685	2 684
2008–09	–	–	100	100	–	–	3 520	3 444
2009–10	–	–	150	150	–	–	2 680	2 043
2010–11	–	–	150	150	–	–	2 053	1 978
2011–12	–	–	512	462	–	–	495	495
2012–13	–	–	590	527	–	–	1 875	1 828
2013–14	–	–	–	–	–	–	130	130
2014–15	–	–	–	–	–	–	–	–
2015–16	–	–	255	50	–	–	2 195	2 003
2016–17	–	–	–	–	–	–	75	75
2017–18	–	–	200	200	–	–	2 245	2 245
2018–19	–	–	–	–	–	–	1 405	1 337
2019–20	–	–	–	–	–	–	835	815

PAU 5D and PAU 6

	PAU 5D Weight (kg)		PAU 5D Numbers		PAU 6 Weight (kg)		PAU 6 Numbers	
Fishing year	**Approved**	**Harvested**	**Approved**	**Harvested**	**Approved**	**Harvested**	**Approved**	**Harvested**
1998–99	–	–	–	–	–	–	–	–
1999–00	–	–	–	–	–	–	–	–
2000–01	–	–	665	417	–	–	–	–
2001–02	–	–	5 530	3 553	–	–	–	–
2002–03	–	–	2 435	1 351	–	–	–	–
2003–04	–	–	–	–	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	1 560	1 560	–	–	–	–
2006–07	–	–	2 845	2 126	–	–	100	100
2007–08	–	–	5 600	5 327	–	–	60	60
2008–09	–	–	6 646	6 094	–	–	–	–
2009–10	–	–	4 840	4 150	–	–	–	–
2010–11	–	–	15 806	15 291	–	–	230	130
2011–12	–	–	7 935	7 835	–	–	–	–
2012–13	–	–	10 254	8 782	–	–	–	–
2013–14	–	–	5 720	5 358	–	–	–	–
2014–15	–	–	–	–	–	–	–	–
2015–16	–	–	15 922	13 110	–	–	50	50
2016–17	–	–	3 676	3 576	–	–	80	80
2017–18	–	–	3 588	3 310	–	–	–	–
2018–19	–	–	950	894	–	–	–	–
2019–20	–	–	6 905	6 439	–	–	–	–

PAU 7

	Weight (kg)		Numbers	
Fishing year	**Approved**	**Harvested**	**Approved**	**Harvested**
1998–99	–	–	–	–
1999–00	–	–	–	–
2000–01	–	–	–	–
2001–02	–	–	–	–
2002–03	–	–	–	–
2003–04	–	–	–	–

Table 4: [Continued]

				PAU 7
	Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested
2004–05	–	–	–	–
2005–06	–	–	–	–
2006–07	–	–	–	–
2007–08	–	–	1 110	808
2008–09	–	–	1 270	1 014
2009–10	–	–	1 085	936
2010–11	–	–	60	31
2011–12	–	–	20	20
2012–13	–	–	–	–
2013–14	–	–	–	–
2014–15	–	–	–	–
2015–16	–	–	–	–
2016–17	–	–	–	–
2017–18	–	–	–	–
2018–19	–	–	–	–
2019–20	–	–	–	–

* Data before 2010–11 exclude the area between the Hurunui River and the South Shore (just north of Banks Peninsula), as Tangata Tiaki were not appointed there until November 2009.

1.4 Illegal catch

There are qualitative data to suggest significant illegal, unreported, unregulated (IUU) activity in this fishery. Current quantitative levels of illegal harvests are not known. In the past, annual estimates of illegal harvest for some Fishstocks were provided by MFish Compliance based on seizures. In the current pāua stock assessments, nominal illegal catches are used.

1.5 Other sources of mortality

Pāua may die from wounds caused by removal desiccation or osmotic and temperature stress if they are brought to the surface. Sub-legal pāua may be subject to handling mortality by the fishery if they are removed from the substrate to be measured. Further mortality may result indirectly from being returned to unsuitable habitat or being lost to predators or bacterial infection. Gerring (2003) observed pāua (from PAU 7) with a range of wounds in the laboratory and found that only a deep cut in the foot caused significant mortality (40% over 70 days). In the field this injury reduced the ability of pāua to right themselves and clamp securely onto the reef, and consequently made them more vulnerable to predators. The tool generally used by divers in PAU 7 is a custom made stainless steel knife with a rounded tip and no sharp edges. This design makes cutting the pāua very unlikely (although abrasions and shell damage may occur). Gerring (2003) estimated that in PAU 7, 37% of pāua removed from the reef by commercial divers were undersize and were returned to the reef. His estimate of incidental mortality associated with fishing in PAU 7 was 0.3% of the landed catch. Incidental fishing mortality may be higher in areas where other types of tools and fishing practices are used. Mortality may increase if pāua are kept out of the water for a prolonged period or returned onto sand. To date, the stock assessments developed for pāua have assumed that there is no mortality associated with capture of undersize animals.

2. BIOLOGY

Pāua are herbivores which can form large aggregations on reefs in shallow subtidal coastal habitats. Movement is over a sufficiently small spatial scale that the species may be considered sedentary. Pāua are broadcast spawners and spawning is usually annual. Habitat related factors are an important source of variation in the post-settlement survival of pāua. Growth, morphometrics, and recruitment can vary over short distances and may be influenced by factors such as water temperature, wave exposure, habitat structure and the availability of food. Naylor et al (2016) analysed demographic variation in pāua in New Zealand. They concluded that there were large differences in the growth rates and maximum size over a large latitudinal range. Their analysis indicated that water temperature, as indicated by sea surface temperature, was an important determinant of these. Pāua become sexually mature when they are about 70–90 mm long, or 3–5 years old. A summary of generic estimates for biological parameters for pāua is presented in Table 5. Parameters specific to individual pāua QMAs are reported in the specific Working Group reports.

Table 5: Estimates of biological parameters for pāua (*H. iris*).

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
All		0.02–0.25	Sainsbury (1982)
2. Weight = a (length)^b (weight in kg, shell length in mm)			
	a = 2.99E^{-08}	b = 3.303	Schiel & Breen (1991)

3. STOCKS AND AREAS

Using both mitochondrial and microsatellite markers Will & Gemmell (2008) found high levels of genetic variation within samples of *H. Iris* taken from 25 locations spread throughout New Zealand. They also found two patterns of weak but significant population genetic structure. Firstly, *H. iris* individuals collected from the Chatham Islands were found to be genetically distinct from those collected from coastal sites around the North and South Islands. Secondly a genetic discontinuity was found loosely associated with the Cook Strait region. Genetic discontinuities within the Cook Strait region have previously been identified in sea stars, mussels, limpets, and chitons and are possibly related to contemporary and/or past oceanographic and geological conditions of the region. This split may have some implications for management of the pāua stocks, with populations on the south of the North Island, and the north of the South Island potentially warranting management as separate entities; a status they already receive under the zonation of the current fisheries regions, PAU 2 in the North Island, and PAU 7 on the South Island.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2021 Fishery Assessment Plenary. A more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review 2019–20 (Fisheries New Zealand 2020), online at https://www.mpi.govt.nz/dmsdocument/40980-aquatic-environment-and-biodiversity-annual-review-201920.

4.1 Ecosystem role

Pāua are eaten by a range of predators, and smaller pāua are generally more vulnerable to predation. Smaller pāua are consumed by blue cod (Carbines & Beentjes 2003), snapper (Francis 2003), banded wrasse (Russell 1983), spotties (McCardle 1983), triplefins (McCardle 1983) and octopus (Andrew & Naylor 2003). Large pāua are generally well protected by their strong shells but are still vulnerable to rock lobsters (McCardle 1983) and the large predatory starfishes *Astrostole scabra* and *Coscinasterias muricata* (Andrew & Naylor 2003). Large pāua are also vulnerable to predation by eagle rays (McCardle 1983), but Ayling & Cox (1982) suggested that eagle rays feed almost exclusively on Cook's turban. There are no known predators that feed exclusively on pāua.

Pāua feed preferentially on drift algae but at high densities they also feed by grazing attached algae. They are not generally considered to have a large structural impact upon algal communities but at high densities they may reduce the abundance of algae. There are no recognised interactions with pāua abundance and the abundance or distribution of other species, except for kina which, at very high densities, appear to exclude pāua (Naylor & Gerring 2001). Research at D'Urville Island and on Wellington's south coast suggests that there is some negative association between pāua and kina (Andrew & MacDiarmid 1999).

4.2 Fish and invertebrate bycatch

Because pāua are harvested by hand gathering, incidental bycatch is limited to epibiota attached to, or within the shell. The most common epibiont on pāua shell is non-geniculate coralline algae, which, along with most other plants and animals which settle and grow on the shell, such as barnacles, oysters, sponges, bryozoans, and algae, appears to have general habitat requirements (i.e., these organisms are not restricted to the shells of pāua). Several boring and spiral-shelled polychaete worms are commonly found in and on the shells of pāua. Most of these are found on several shellfish species, although within New Zealand's shellfish, the onuphid polychaete *Brevibrachium maculatum* has been found only in pāua shell (Read 2004). This species, however, has also been reported to burrow into limestone, or attach its tube to the holdfasts of algae (Read 2004). It is also not uncommon for pāua harvesters to collect predators of pāua (mainly large predatory starfish) while fishing and to effectively remove these from the ecosystem. The levels of these removals are unlikely to have a significant effect on starfish populations (nor, in fact, on the mortality of pāua caused by predation).

4.3 Incidental catch (seabirds, mammals, and protected fish)

There is no known bycatch of threatened, endangered, or protected species associated with the hand gathering of pāua.

4.4 Benthic interactions

The environmental impact of pāua harvesting is likely to be minimal because pāua are selectively hand gathered by free divers. Habitat contact by divers at the time of harvest is limited to the area of pāua foot attachment, and pāua are usually removed with a blunt tool to minimise damage to the flesh. The diver's body is also seldom in full contact with the benthos. Vessels anchoring during or after fishing have the potential to cause damage to the reef depending on the type of diving operation (in many cases, vessels do not anchor during fishing). Damage from anchoring is likely to be greater in areas with fragile species such as corals than it is on shallow temperate rocky reefs. Corals are relatively abundant at shallow depths within Fiordland, but there are seven areas within the sounds with significant populations of fragile species where anchoring is prohibited.

4.5 Other considerations

4.5.1 Genetic effects

Fishing, and environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species and there is some evidence to suggest that genetic changes may occur in response to fishing of abalones. Miller et al (2009) suggested that, in *Haliotis rubra* in Tasmania, localised depletion will lead to reduced local reproductive output which may, in turn, lead to an increase in genetic diversity because migrant larval recruitment will contribute more to total larval recruitment. Enhancement of pāua stocks with artificially-reared juveniles has the potential to lead to genetic effects if inappropriate broodstocks are used.

4.5.2 Biosecurity issues

Undaria pinnatifida is a highly invasive opportunistic kelp which spreads mainly via fouling on boat hulls. It can form dense stands underwater, potentially resulting in competition for light and space which may lead to the exclusion or displacement of native plant and animal species. *Undaria* may be transported on the hulls of pāua dive tenders to unaffected areas. Bluff Harbour, for example, supports a large population of *Undaria*, and is one of the main ports of departure for fishing vessels harvesting pāua in Fiordland, which appears to be devoid of *Undaria* (R. Naylor pers. comm.). In 2010, a small population of *Undaria* was found in Sunday Cove in Breaksea Sound, and attempts to eradicate it appear to have been successful (see https://www.mpi.govt.nz/biosecurity/marine-pest-disease-management/fiordland-marine-biosecurity-programme/).

4.5.3 Kaikōura Earthquake

Research was undertaken to investigate the influence of the November 2016 Kaikōura earthquake on pāua stocks along the Kaikōura coastline. The results estimated that the seabed uplift led to a loss of up to 50% of the pre-earthquake fished area across PAU 3 statistical areas. More details can be found in the PAU 3 Working Group report.

4.5.4 Marine heatwave

A baseline report summarising trends in climatic and oceanographic conditions in New Zealand that are of potential relevance for fisheries and marine ecosystem resource management in the New Zealand region was completed by Hurst et al (2012). There is also an updated chapter on oceanic trends in the Aquatic Environment and Biodiversity Annual Review 2018 (Ministry for Primary Industries 2019). Any effects of recent warmer temperatures (such as the high surface temperatures off the WCSI during the 2016 and 2017 spawning seasons, marine heatwaves, and general warming of the Tasman Sea (Sutton & Bowen 2019) on fish distribution, growth, or spawning success have yet to be determined.

Shellfish fisheries have been identified as likely to be vulnerable to ocean acidification (Capson & Guinotte 2014). A recent project that has just reached completion describes the state of knowledge of climate change-associated predictions for components of New Zealand's marine environment that are most relevant to fisheries (Cummings et al 2021). Past and future projected changes in coastal and ocean properties, including temperature, salinity, stratification and water masses, circulation, oxygen, ocean productivity, detrital flux, ocean acidification, coastal erosion and sediment loading, wind and waves are reviewed. Responses to climate change for these coastal and ocean properties are discussed, as well as their likely impact on the fisheries sector, where known.

A range of decision support tools in use overseas were evaluated with respect to their applicability for dissemination of the state of knowledge on climate change and fisheries. Three species, for which there was a relatively large amount of information available were chosen from the main fisheries sectors for further analysis. These were pāua, snapper, and hoki (shellfish, inshore, and middle-depths/deepwater fisheries, respectively). An evaluation of the sensitivity and exposure of pāua to climate change-associated threats, based on currently available published literature and expert opinion, assessed pāua vulnerability to climate change effects as 'low' (Cummings et al 2021).

5. STOCK ASSESSMENT

The dates of the most recent survey or stock assessment for each QMA are listed in Table 6.

Table 6: Recent survey and stock assessment information for each pāua QMA. [Continued next page]

QMA	Type of survey or assessment	Date	Comments
PAU 1	No surveys or assessments have been undertaken		
PAU 2	Base case: length-based Bayesian stock assessment	2021	A large proportion of PAU 2, including the Wellington south coast and west of Turakirae, is either a Marine Reserve or voluntarily closed to commercial fishing. This means that the data collected from the commercial fishery are exclusive of this large area and therefore the assessment only applies to the south east component of PAU 2 (Wairarapa). Lack of contrast in catch, CPUE, and length frequency makes estimation of stock status and biomass trajectories difficult. The 2019–20 year was excluded from the PCELR CPUE series because of concerns about the comparability with previous years due to the effects of COVID-19 on export markets, and ERS reporting issues. This may continue into the future.
PAU 3	Quantitative assessment using a Bayesian length-based model	2013	For the 2013 stock assessment nine model runs were conducted. The Shellfish Working Group agreed on a base case model, which estimated M within the model but fixed the growth parameters, as providing a reliable estimate of the status of the stocks in PAU 3 with the caveat that the model most likely underestimated uncertainty in growth but adequately estimated uncertainty in natural mortality. The status of the stock was estimated to be 52% B_0.

Table 6 [Continued]: Recent survey and stock assessment information for each pāua QMA.

PAU 4	CPUE Standardisation	2016	In February 2010 the Shellfish Working Group (SFWG) agreed that, due to the lack of data of adequate quality to use in the Bayesian length-based model, a stock assessment for PAU 4 using this model was not appropriate. In 2016 an analysis of the last 14 years of CPUE data was done. This report showed a potential decline in the fishery since the early 2000s, however the poor data quality is causing considerable uncertainty about the real trend in the fishery.
PAU 5A	Quantitative assessment using a Bayesian length-based model	2020	The 2020 stock assessment was implemented as a single area model together with a three-area spatial model to corroborate findings from the single area model. The status of the stock was estimated to be 51% B_0. At current levels of catch spawning stock biomass is projected to remain nearly unchanged at 51% B_0 after 3 years, with an equilibrium value of 50% of B_0.
PAU 5B	Quantitative assessment using a Bayesian length-based model	2018	The 2018 Plenary accepted this assessment as best scientific information. The status of the stock was estimated to be 47% B_0.
PAU 5D	Quantitative assessment using a Bayesian length-based model	2019	The reference case model estimated that the unfished spawning stock biomass (B_0) was about 2029 t (1673–2535 t) and the spawning stock population in 2018 (B_{2018}) was about 40% (25–65%) of B_0. The model projection made for three years assuming 2018 catch levels (which includes commercial catch) and using recruitment re-sampled from the recent model estimates, suggested that the spawning stock abundance would remain at 42% (28–52%) B_0 over the following three years. The projection also indicated that the probability of the spawning stock biomass being above the target (40% B_0) will decrease from about 52% in 2018 to 49% by 2021.
PAU 6	Biomass estimate	1996	This fishery has a TACC of 1 t.
PAU 7	Quantitative assessment using a Bayesian length based model	2015	The SFWG agreed that the stock assessment was reliable based on the available data. Currently, spawning stock biomass is estimated to be 18% B_0 and is about as likely as not to be below the soft limit, with fishing intensity very likely to be above the overfishing threshold.
PAU 10	No surveys or assessments have been undertaken		

5.1 Estimates of fishery parameters and abundance

For further information on fishery parameters and abundance specific to each pāua QMA refer to the specific Working Group report.

In 2014 standardised CPUE indices were constructed to assess relative abundance in PAU 2. In QMAs where quantitative stock assessments have been undertaken, standardised CPUE is also used as input data for the Bayesian length-based stock assessment model. There is however a large amount of literature on abalone which suggests that any apparent stability in CPUE should be interpreted with caution and CPUE may not be proportional to abundance because it is possible to maintain high catch rates despite a falling biomass. This occurs because pāua tend to aggregate and, to maximise their catch rates, divers move from areas that have been depleted of pāua to areas with higher density. The consequence of this fishing behaviour is that overall abundance is decreasing while CPUE is remaining stable. This process of hyperstability is believed to be of less concern in PAU 3, PAU 5D, and PAU 7 because fishing in these QMAs is consistent across all fishable areas.

In PAU 4, 5A, 5B, 5D, and 7 the relative abundance of pāua has also been estimated from independent research diver surveys (RDS). In PAU 7, seven surveys have been completed over a number of years but only two surveys have been conducted in PAU 4. In 2009 and 2010 several reviews were conducted (Cordue 2009, Haist 2010) to assess: i) the reliability of the research diver survey index as a proxy for abundance; and ii) whether the RDS data, when used in the pāua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. The reviews concluded that:

- Due to inappropriate survey design the RDS data appear to be of very limited use for constructing relative abundance indices.
- There was clear non-linearity in the RDS index, the form of which is unclear and could be potentially complex.
- CVs of RDS index 'year' effects are likely to be underestimated, especially at low densities.
- Different abundance trends among strata reduces the reliability of RDS indices, and the CVs are likely to be uninformative about this.
- It is unlikely that the assessment model can determine the true non-linearity of the RDS index-abundance relationship because of the high variability in the RDS indices.
- The non-linearity observed in the RDS indices is likely to be more extreme at low densities, so the RDSI is likely to mask trends when it is most critical to observe them.
- Existing RDS data is likely to be most useful at the research stratum level.

5.2 Biomass estimates

Biomass was estimated for PAU 6 in 1996 (McShane et al 1996). However, the survey area was limited to the area from Kahurangi Point to the Heaphy River.

Biomass has been estimated, as part of the stock assessments, for PAU 4, 5A, 5B, 5D, and 7 (Table 6). For further information on biomass estimates specific to each pāua QMA refer to the specific Working Group report.

5.3 Yield Estimates and Projections

Yield estimates and projections are estimated as part of the stock assessment process. Both are available for PAU 3, PAU 5A, PAU 5B, PAU 5D, and PAU 7. For further information on yield estimates and projections specific to each pāua QMA refer to the specific Working Group report.

5.4 Other factors

In the last few years, the commercial fisheries have been implementing voluntary management actions in the main QMAs. These management actions include raising the minimum harvest size, subdividing QMAs into smaller management areas, and capping catch in the different areas and in some QMAs, not catching the full Annual Catch Entitlement (ACE) in a particular fishing year.

6. STATUS OF THE STOCKS

The status of pāua stocks PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D, and PAU 7 are given in the relevant Working Group reports.

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