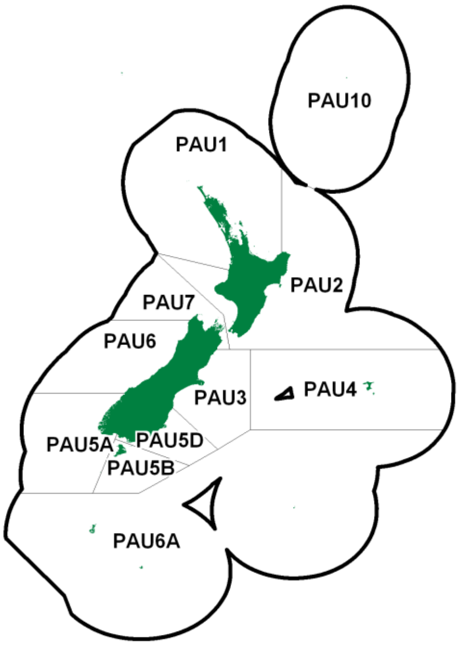
PAUA (PAU)

(*Haliotis iris, Haliotis australis*)



1. INTRODUCTION

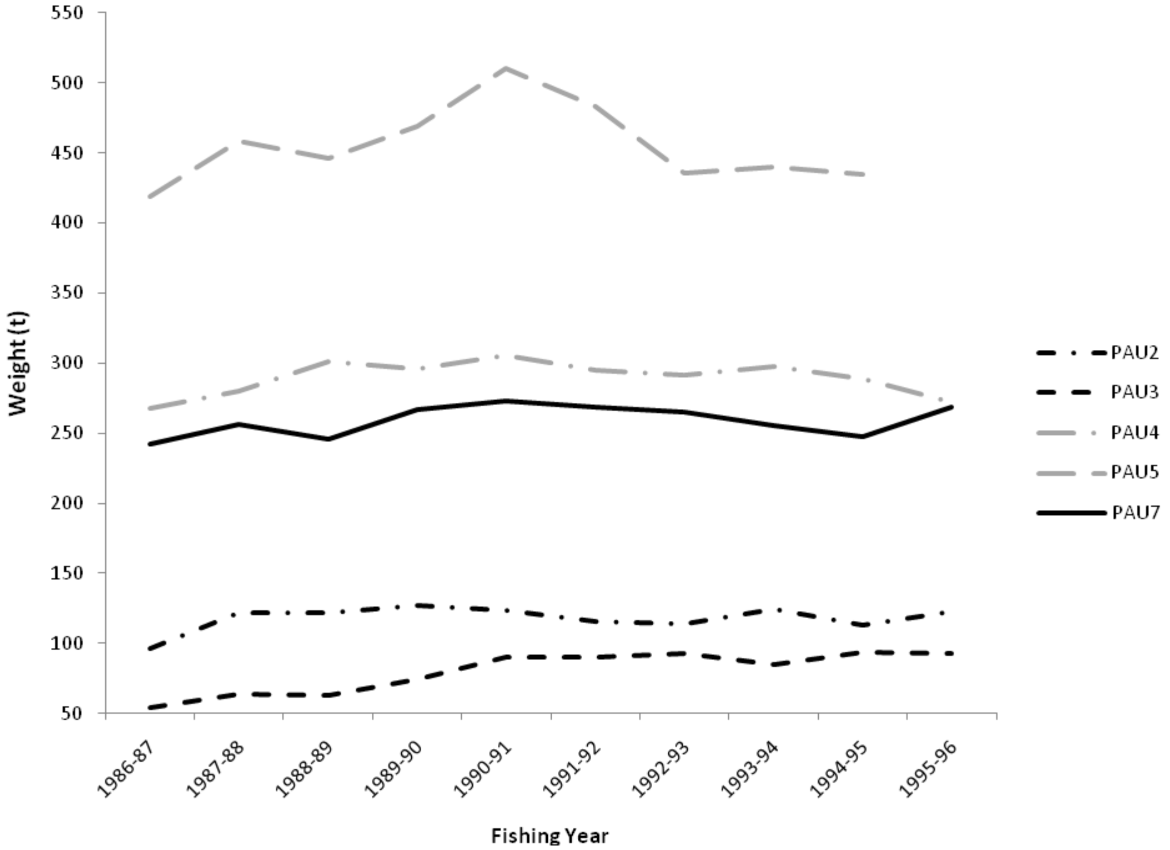
Specific Working Group reports are given separately for PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D and PAU 7. The TACC for PAU 1, PAU 6 and PAU 10 is 1.93 t, 1 t and 1 t respectively. Commercial landings for PAU 10 since 1983 have been 0 t.

1.1 Commercial fisheries

The commercial fishery for paua 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 paua by hand while free diving (use of underwater breathing apparatus is not permitted). 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 paua, *Haliotis iris*, with a minimum legal size for harvesting of 125 mm shell length. The yellow-foot paua, *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*.

Up until the 2002 fishing year, catch was reported by general statistical areas, however from 2002 onwards, a more finely scaled system of paua specific statistical areas were put in place throughout each QMA (refer to the QMA specific Working Group reports). 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.



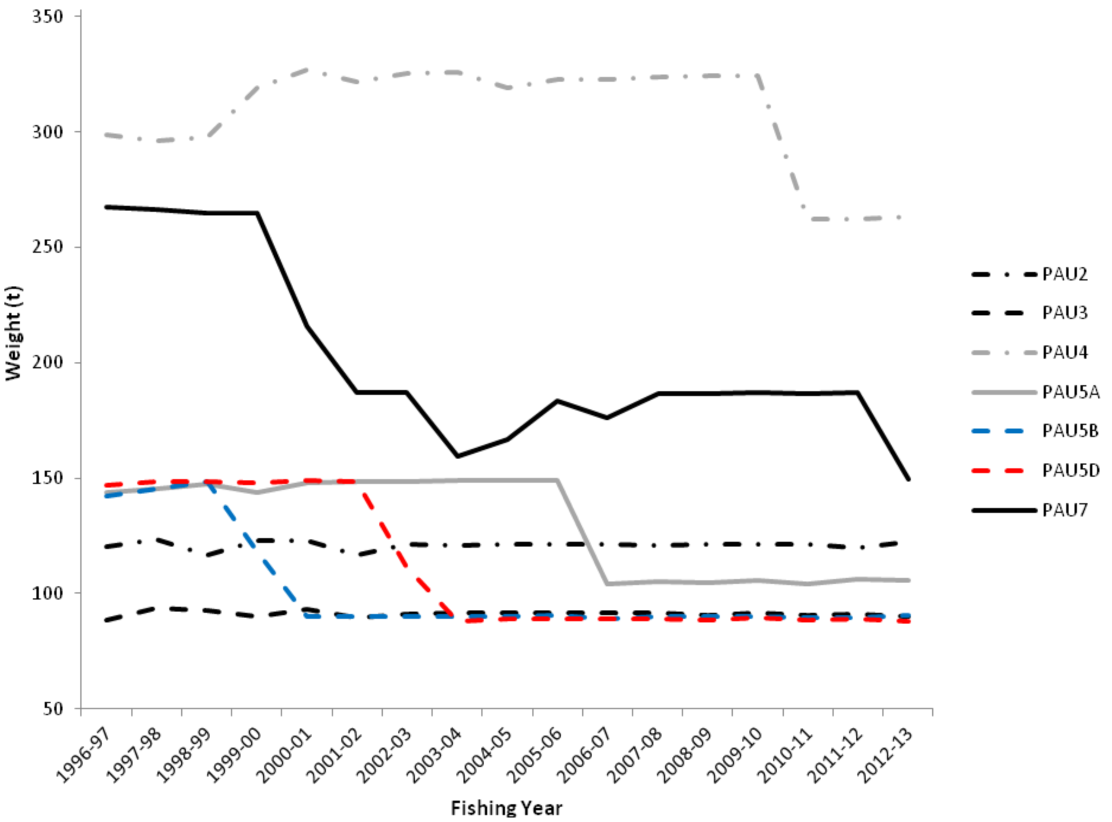


Figure 1: Historic landings for the major paua QMAs from 1983–84 to 1995–96 (top) and from 1996–97 to present (lower).

Landings for PAU 1, PAU 6, PAU 10 and PAU 5 (prior to 1995) are shown in Table 1. For information on landings specific to other paua QMAs refer to the specific Working Group reports.

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

	PAU 1		PAU 5		PAU 6		PAU 10	
PAU	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

H experimental landings
* FSU data

1.2 Recreational fisheries

There is a large recreational fishery for paua. Estimated catches from telephone and diary surveys of recreational fishers (Teirney et al 1997, Bradford 1998, Boyd & Reilly 2004, Boyd et al 2004, Wynne-Jones et al 2014) are shown in Table 2. In 1996–97 sufficient diary data were available for an estimate in PAU 5D only (Bradford 1998, NIWA unpublished data). The Marine Recreational Fisheries Technical Working Group (RFTWG) has reviewed the harvest estimates from the national surveys. Due to a methodological error in the methodology, the harvest estimates for 1991–92 to 1993–94 and 1996–97 are not considered to be reliable. The harvest estimates for the 1999–2000 and 2000–01 surveys may be very inaccurate and some implausibly high. This may be due to a number of factors including the accuracy of the mean weight used to derive total harvest weight from the estimated numbers of paua caught by diarists, and the small number of diarists harvesting the stock in some areas. However relative comparisons can be made between stocks within the surveys.

Table 2: Estimated annual harvest of paua (t) by recreational fishers*.

Fishstock	PAU 1	PAU 2	PAU 3	PAU 5	PAU5A	PAU5B	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
2011–12	12.6	81.85	16.98	-	0.42	0.82	22.45	-	14.13

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

1.3 Customary fisheries

There is an important customary use of paua by Maori for food, and the shells have been used extensively for decorations and fishing devices. Limited data is available for reported customary landings in PAU 3; however no information is available for current levels of customary take for any other paua QMA. Kaitiaki are now in place in many areas and estimates of customary harvest can be expected in the future.

1.4 Illegal catch

Current 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 paua stock assessments, nominal illegal catches are used.

1.5 Other sources of mortality

Paua may die from wounds caused by removal desiccation or osmotic and temperature stress if they are bought to the surface. Sub-legal paua 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 paua (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 paua 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 paua very unlikely (although abrasions and shell damage may occur). Gerring (2003) estimated that in PAU 7, 37% of paua 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 paua are kept out of the water for a prolonged period or returned onto sand. To date, the stock assessments developed for paua have assumed that there is no mortality associated with capture of undersize animals.

2. BIOLOGY

Paua 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. Paua are broadcast spawners and spawning is thought to be annual. Habitat related factors are an important source of variation in the post-settlement survival of paua. Growth, morphometrics, and recruitment can vary over short distances and may be influenced by factors such as wave exposure, habitat structure, availability of food and population density. A summary of generic estimates for biological parameters for paua are presented in Table 3. Parameters specific to individual paua QMAs are reported in the specific Working Group reports.

Table 3: Estimates of biological parameters for paua (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 paua 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. STOCK ASSESSMENT

The dates of the most recent survey or stock assessment for each QMA are listed in Table 4.

Table 4: Recent survey and stock assessment information for each paua QMA

QMA	Type of survey or assessment	Date	Comments
PAU 1	No surveys or assessments have been undertaken		
PAU 2	Relative abundance estimate using standardised CPUE index based on commercial catch	2014	Standardised CPUE showed slight oscillation without trend between 1992 and 2001 and has remained flat from 2002 until 2014.
PAU 3	Quantitative assessment using a Bayesian length based model	2013	For the 2013 stock assessment nine model runs where 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 at 52%B_0
PAU 4	Quantitative assessment using a Bayesian length based model	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	2014	The 2014 stock assessment was conducted over two subareas of the QMA. The SFWG was satisfied that the stock assessment for both the Southern and Northern areas was reliable based on the available data. The status of the stocks was estimated at 41%B_0 for the Southern area and 47%B_0 for the Northern area
PAU 5B	Quantitative assessment using a Bayesian length based model	2013	The SFWG were satisfied that the stock assessment provided a reliable estimate of the status of the stocks in PAU 5B. Sensitivity trials addressed uncertainties associated with various aspects of the input data and model assumptions. The status of the stock was estimated to be at 44%B_0
PAU 5D	Quantitative assessment using a Bayesian length based model	2012	Four assessment runs were presented and all considered to be equally plausible. All runs showed that it was Very Unlikely the stock will fall below the soft or hard limits over the next three years at current levels of catch, and suggested that biomass would increase. However, the four runs differed in their assessment of the status of the stock relative to the target.
PAU 6	Biomass estimate	1996	This fishery has a TACC of 1 t

Table 4 [continued]

QMA	Type of survey or assessment	Date	Comments
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 at 18% B_0 and likely as not to be below the soft limit, with fishing intensity to be very likely to be above the overfishing threshold
PAU 10	No surveys or assessments have been undertaken		

4.1 Estimates of fishery parameters and abundance

For further information on fishery parameters and abundance specific to each paua 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 as it is possible to maintain high catch rates despite a falling biomass. This occurs because paua tend to aggregate and in order to maximise their catch rates divers' move from areas that have been depleted of paua, 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 paua 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) and Haist V (2010 MPI .FRR) 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 paua 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 not to be informative 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.

4.2 Biomass estimates

Biomass was estimated for PAU 6 in 1996 (McShane et al 1996). However the survey area was only 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 4). For further information on biomass estimates specific to each paua QMA refer to the specific Working Group report.

4.3 Yield Estimates and Projections

Yield estimates and projections are estimated as part of the stock assessment process. Both are available for PAU3, PAU 5A, PAU5B, PAU5D and PAU7. For further information on yield estimates and projections specific to each paua QMA refer to the specific Working Group report.

4.4 Other factors

In the last few years the commercial fishery have been implementing voluntary management actions in the main QMAs. These management actions include raising the minimum harvest size and subdividing QMAs into smaller management areas and capping catch in the different areas

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

5.1. Ecosystem role

Paua are eaten by a range of predators, and smaller paua are generally more vulnerable to predation. Smaller paua are consumed by blue cod (Carbines and Beentjes 2003), snapper (Francis 2003), banded wrasse (Russell 1983), spotties (McCardle 1983), triplefins (McCardle 1983) and octopus (Andrew & Naylor 2003). Large paua are generally well protected by their strong shells, but are still vulnerable to rock lobsters (McCardle 1983), the large predatory starfishes *Astrostole scabra* and *Coscinasterias muricata* (Andrew & Naylor 2003). Large paua 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 paua.

Paua 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 paua abundance and the abundance or distribution of other species, with the exception of kina which, at very high densities, appear to exclude paua (Andrew et al 2000). Research at D'Urville Island and on Wellington's south coast suggests that there is some negative association between paua and kina (Andrew & MacDiarmid 1999).

5.2. Fish and invertebrate bycatch

Because paua are harvested by hand gathering, incidental bycatch is limited to epibiota attached to, or within the shell. The most common epibiont on paua 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 paua). Several boring and spiral-shelled polychaete worms are commonly found in and on the shells of paua. 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 paua shell Handley, S. (2004). This species; however, has been reported to burrow into limestone, or attach its tube to the holdfasts of algae (Read 2004). It is also not uncommon for paua harvesters to collect predators of paua (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 paua caused by predation).

5.3. Incidental catch (seabirds, mammals, and protected fish)

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

5.44. Benthic interactions

The environmental impact of paua harvesting is likely to be minimal because paua are selectively hand gathered by free divers. Habitat contact by divers at the time of harvest is limited to the area of paua foot attachment, and paua 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.

5.5. Other considerations

5.5.1 Genetic effects

Fishing, 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 paua stocks with artificially-reared juveniles has the potential to lead to genetic effects if inappropriate broodstocks are used.

5.5.2 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 paua 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 paua in Fiordland, which appears to be devoid of *Undaria* (R. Naylor, personal observation). 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 http://www.biosecurity.govt.nz/pests/undaria).

6. STATUS OF THE STOCKS

The status of paua 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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