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Data inputs for the PAU 7 stock assessment in 2008

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EXECUTIVE SUMMARY

McKenzie, A.; Smith, A.N.H. (2009). Data inputs for the PAU 7 stock assessment in 2008.

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This document summarises the data inputs for the 2008 stock assessment of blackfoot paua in PAU 7 (upper South Island). The work was conducted by NIWA under Ministry of Fisheries contract PAU200704, Objective 1.

The seven sets of data fitted in the assessment model were: (1) a standardised CPUE series covering 1983–2001 based on FSU/CELR data, (2) a standardised CPUE series covering 2002–2007 based on PCELR data, (3) a standardised research diver survey index (RDSI), (4) a research diver survey proportions-at-lengths series, (5) a commercial catch sampling length frequency series, (6) tag-recapture length increment data, and (7) maturity-at-length data. Catch history was an input to the model, encompassing commercial, recreational, customary, and illegal catch.

Three of the data sets were updated for the assessment: (1) the standardised CPUE series based on PCELR data, (2) the commercial catch sampling length frequency series, and (3) the catch history. Details of the analyses for the updated data sets are given, but not for the others.

CONTENTS

1. INTRODUCTION

This document summarises the data inputs for the 2008 stock assessment of PAU 7. The work was conducted by NIWA under Ministry of Fisheries contract PAU200704, Objective 1. A separate document details the stock assessment of PAU 7 (McKenzie & Smith 2009).

The fishing year for paua is from 1 October to 30 September. In this document, we refer to fishing year by the second year that it covers; thus we call the 1997–98 fishing year "1998".

The PAU 7 area covers the upper part of the South Island and is delineated by the fine scale statistical areas P701 to P797 (Figure 1). The larger scale statistical areas 17, 18, 36, 37, 38, and 39 all have coastline that is at least partially contained within PAU 7 (although there is only one record from area 37, in 1993). However, previous stock assessments for PAU 7 have included only areas 17 and 38 because of issues with some of the other areas straddling two paua Quota Management Areas (QMAs), and that data from research diver surveys and commercial length frequency measurements only exist for these two areas (Breen et al. 2001, Breen & Kim 2003, 2005). Most of the catch is taken from these two areas, so the 2008 stock assessment followed the approach of previous years, and focused only on areas 17 and 38.

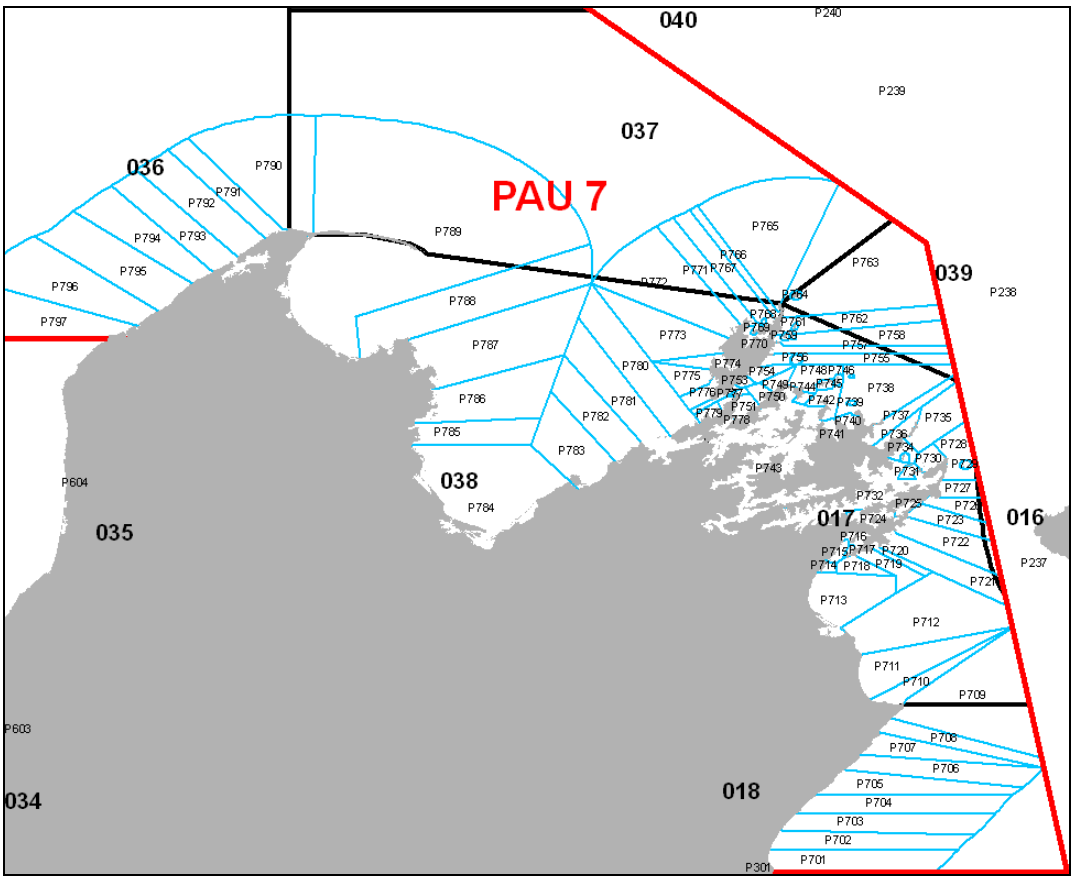


Figure 1: PAU 7 and the old and new statistical areas.

PAU 7 was assessed in 2005 (Breen & Kim 2005) and before that in 2003 (Breen & Kim 2003). As in previous assessments, the 2008 assessment was restricted to areas 17 and 18 and the observational data fitted to were:

1. A standardised CPUE series covering 1983–2001 based on FSU/CELR data.
2. A standardised CPUE series covering 2002–2007 based on PCELR data.
3. A standardised research diver survey index (RDSI).
4. A research diver survey proportions-at-lengths series (RDLF).
5. A commercial catch sampling length frequency series (CSLF).
6. Tag-recapture length increment data.
7. Maturity-at-length data.

New observational data available for 2008 were two more years of PCELR data, and the additional years 2006 and 2007 for the CSLF. Also there are another three more years for the catch history.

The updated catch history is presented first. Following this, the analyses of the new observational data are given (PCELR and CSLF), then the unchanged observational data are represented.

2. CATCH HISTORY

2.1.1 Commercial catch

The catch history was estimated by Murray & Akroyd (1984) for 1974–83, who stated that landings before 1974 were unreliable. Schiel (1989) presented estimates for 1984–88. Schiel (1992) revisited the estimates for 1981–85, and previous PAU 7 assessments have used the Schiel (1992) estimates as a base case. The effect of this change (affecting mostly the 1981 and 1982 catches) was explored by Andrew et al. (2000a) and found to be small. The 1986 catch appears suspiciously low, and as in previous years the average of 1985 and 1987 catches is used (Table 1)

Catches from 1989 onwards were captured on QMR forms and reported in Plenary documents (e.g., Annala et al. 2003). Catches from the 2005 assessment (Breen & Kim 2005) were used up to 2001, and recent data for 2002–2007 were supplied by MFish. The industry agreed to shelve 15% of the TACC for 2004–2007. There will be no shelving in 2008, so the commercial catch is assumed to be equal to the TACC.

For 2002–2007 the catch history was calculated using data supplied by MFish and following the methodology of the 2005 assessment (Breen & Kim 2005). In order to confine the stock assessment to areas 17 and 38, the percentage of the catch that came from these two areas was estimated using the estimated catches from the catch effort database. Table 2 shows the estimated catch from the PCELR forms from between 2002 and 2007 in all areas. In Table 3, the percentage of the catch that was taken from 17 and 38 was calculated using the PCELR data. This averages 88% over the six years, and is generally increasing over time, indicating that the other areas are becoming less favoured by fishers. These percentages were then used to estimate the total catch from 17 and 38, by multiplying each years catch (from Monthly Harvest Returns (MHR)) by the percentages. For 2008, the proportion of the catch coming from area 17 and 38 was assumed to be the mean of the previous five years.

A slight anomaly was uncovered by comparing the proportion of estimated catch that was from areas 17 and 38 in previous assessments and the proportions derived for the present assessment. It appears that the paua area P764 has been included in statistical area 17, when in fact it lies within area 39

(Figure 2). The proportions match correctly when P764 is included in statistical area 17, so to maintain consistency P764 was placed into 17 rather than in 39 where it actually lies.

The estimated catches from each statistical area from the years of PCELR data are shown in Figure 3. This shows that 17 has the vast majority of catches. The estimated catches from the PCELR data are shown in Table 4 , divided among the main new paua statistical areas. Many areas were excluded from this table due to the release clause that prevents the presentation of data from fewer than three vessels, so only the consistently fished areas are shown here. The areas where the highest consistent catches were taken are 714, 721, 722, 727, and 728, which are all on the east coast of the Marlborough Sounds.

2.1.2 Recreational fisheries

The 1996 National Marine Recreational Fishing Survey estimated 23 000 paua taken in PAU 7. The 1999–2000 and 2000–2001 national surveys estimated 15.8 t and 7.7 t respectively. The Marine Recreational Fisheries Technical Working Group (RFTWG) considered the harvest estimates from the national surveys and concluded that the estimates from the 1996 survey are unreliable due to a methodological error. The RFTWG also concluded that some harvest estimates from the 1999–2000 and 2000–2001 surveys for some fish stocks were unbelievably high. For the stock assessment, the Shellfish Fisheries Assessment Working Group agreed to assume that recreational catch was 5 t in 1974 and that it increased linearly to 15 t in 2000, and then remained at 15 t subsequently (see Table 1).

2.1.3 Maori customary fisheries

Customary catch was incorporated into the PAU 7 TAC in 2002 as an allowance of 15 t. No historical estimates are available. The Working Group agreed to assume that customary catch was 4 t in 1974, increasing linearly to 10 t between 1974 and 2000, and then remained at 10 t subsequently (see Table 1).

2.1.4 Illegal catch

The Working Group agreed to assume that illegal catch was 1 t in 1974 and that it increased linearly to 15 t between 1974 and 2000, remaining at 15 t from 2000 to 2005, and then decreased linearly to 7.5 t in 2008 (Table 1).

2.1.5 Total catch for areas 17 and 38

The total catch trajectory for the 2008 stock assessment, based on the sum of the commercial and non-commercial catches for areas 17 and 38, is shown in Table 1. The catch trajectory is plotted in Figure **4**, split by commercial and non-commercial catch.

Table 1 Catch data used in the 2008 stock assessment of PAU 7. The table shows the sources of the data, the (fishing) year, the "All PAU 7" catch calculated from the QMA or Monthly Harvest Returns (MHR). "CELR/QMR" is a test of the accuracy of the previous column, by taking the ratio of the (P)CELR estimated catches to the reported catches. Next is the proportion of the catch that is estimated to come from areas 17 and 38, which was then used to estimate the total commercial catch for these two areas. Next are the allowances for illegal, recreational and customary catch, the official TACC, and the actual TACC after shelving. In the last, those in which shelving has occurred are indicated by an asterisk. All catches are in kilograms.

Source	Year	All PAU 7	CELR/ QMR	% 17 & 38	Comm. 17&38	Illegal	Rec.	Cust.	Total 17&38	TACC (t)	TACC after shelving
Murray &	1974	147 440		100	147 440	1 000	5 000	4 000	157 440		
Akroyd	1975	197 910		100	197 910	1 538	5 385	4 231	208 987		
1984	1976	141 880		100	141 880	2 077	5 769	4 462	154 034		
	1977	242 730		100	242 730	2 615	6 154	4 692	255 961		
	1978	201 170		100	201 170	3 154	6 538	4 923	215 478		
	1979	304 570		100	304 570	3 692	6 923	5 154	319 955		
	1980	223 430		100	223 430	4 231	7 308	5 385	239 892		
Schiel	1981	490 000		100	490 000	4 769	7 692	5 615	507 538		
1992	1982	370 000		100	370 000	5 308	8 077	5 846	388 615		
	1983	400 000	52	100	400 000	5 846	8 462	6 077	419 692		
	1984	330 000	83	100	330 000	6 385	8 846	6 308	350 769		
	1985	230 000	75	100	230 000	6 923	9 231	6 538	251 846		
Breen &	1986	236 090	38	100	236 090	7 462	9 615	6 769	259 013		
Kim 2005	1987	242 180	45	100	242 180	8 000	10 000	7 000	266 180	250	250
	1988	255 944	24	100	255 944	8 538	10 385	7 231	281 021	250	250
	1989	246 029	25	100	246 029	9 077	10 769	7 462	272 183	250	250
	1990	267 052	80	100	266 509	9 615	11 154	7 692	293 740	263.53	263.53
	1991	273 253	83	98	268 782	10 154	11 538	7 923	297 090	266.24	266.24
	1992	268 309	93	93	249 789	10 692	11 923	8 154	279 173	266.17	266.17
	1993	264 802	91	96	255 045	11 231	12 308	8 385	285 507	266.17	266.17
	1994	255 472	101	97	248 285	11 769	12 692	8 615	279 823	266.17	266.17
	1995	247 108	104	96	237 571	12 308	13 077	8 846	270 187	266.17	266.17
	1996	268 742	92	90	242 057	12 846	13 462	9 077	275 749	267.48	267.48
	1997	267 594	91	86	230 570	13 385	13 846	9 308	265 339	267.48	267.48
	1998	266 655	89	82	218 479	13 923	14 231	9 538	254 325	267.48	267.48
	1999	265 050	87	87	229 198	14 462	14 615	9 769	266 121	267.48	267.48
	2000	264 642	111	75	198 419	15 000	15 000	10 000	238 419	267.48	267.48
	2001	215 920	120	65	140 731	15 000	15 000	10 000	180 731	267.48	*213.98
From data	2002	187 152	99	74	138 492	15 000	15 000	10 000	178 492	240.73	240.73
extract	2003	187 222	98	88	164 755	15 000	15 000	10 000	204 755	187.24	187.24
Dec-07	2004	159 551	99	91	145 191	15 000	15 000	10 000	185 191	187.24	*159.15
	2005	166 940	99	86	143 568	15 000	15 000	10 000	183 568	187.24	*159.15
	2006	183 363	101	95	174 195	12 500	15 000	10 000	211 695	187.24	*159.15
	2007	176 052	98	93	161 968	10 000	15 000	10 000	196 968	187.24	*159.15
assumed	2008	187 240		91	169 565	7 500	15 000	10 000	202 065	187.24	187.24

Table 2: Estimated catch histories for PAU 7 by statistical area from paua-specific catch effort landing return forms (PCELR), which began in 2002. All catches are in kilograms.

Fishing year	17	38	18	036	Grand total
2002	132 610	4 727	41 810	5 617	184 764
2003	150 653	11 797	20 102	1 662	184 214
2004	134 572	9 488	13 814	95	157 969
2005	132 089	9 303	13 450	10 422	165 264
2006	163 008	13 540	5 897	2 828	185 273
2007	148 967	10 507	10 078	2 788	172 340
Grand total	861 899	59 362	105 151	23 412	1 049 824

Table 3: The catches from the MHR, multiplied by the proportion of catches from 17 and 38 as estimated by the estimated catches from PCELR data, to arrive at a figure for the catch from these two areas only. All catches are in kilograms.

Fishing year	Catch (MHR)	Multiplier (proportion of catch from 17 and 38)	Catch for 17 and 38
2002	187 152	74%	138 492
2003	187 222	88%	164 755
2004	159 551	91%	145 191
2005	166 940	86%	143 568
2006	183 363	95%	174 195
2007	176 052	92%	161 968

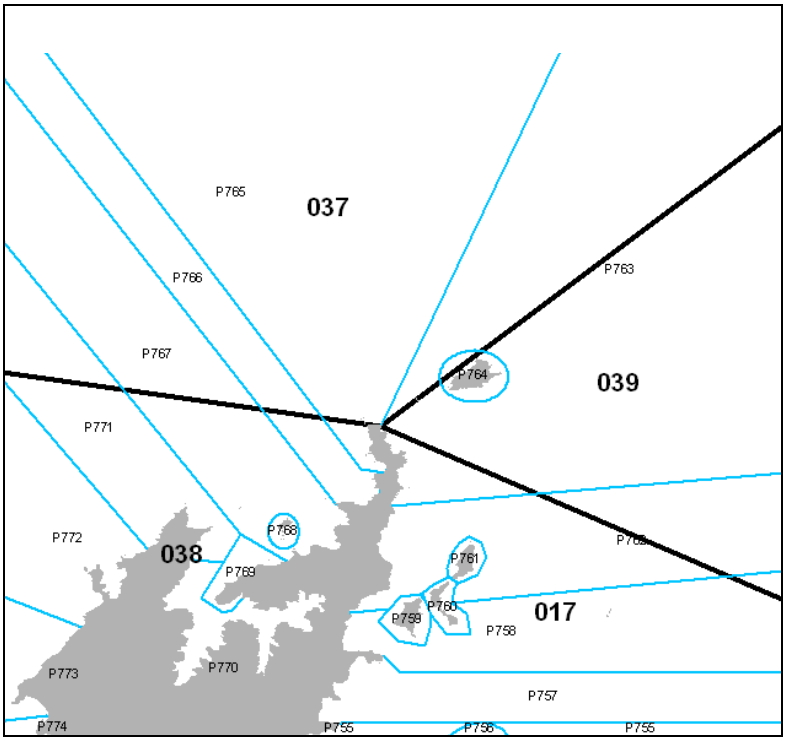


Figure 2: The tip of D'Urville Island, where four general statistical areas meet, and Stephens Island. This shows that Stephens Island, P764, physically lies within statistical area 39.

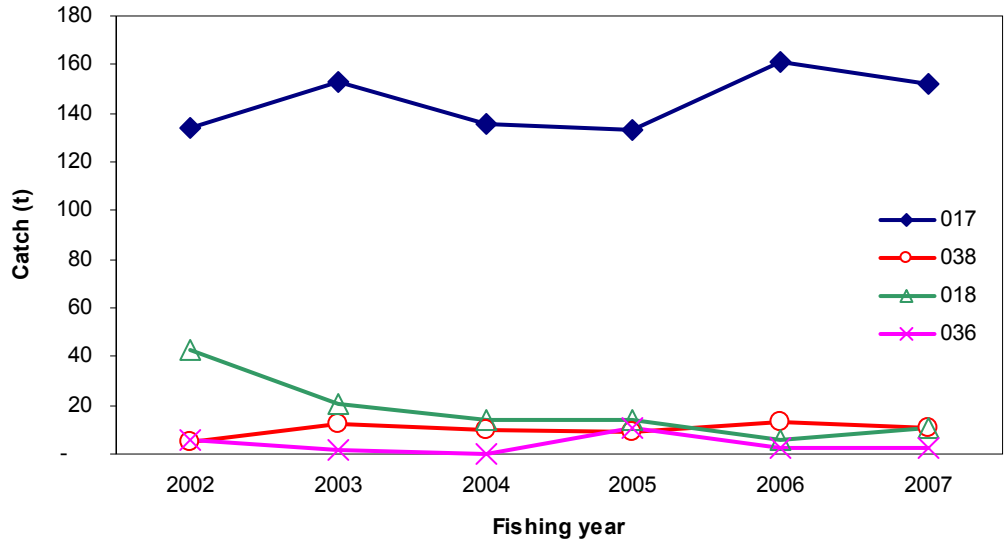


Figure 3: The estimated catches from PCELR data for each general statistical area.

Table 4: Estimated catch (t) from PCELR data for the main paua statistical areas. Some areas are not shown, in keeping with the requirements of the project release clauses.

Statistical area	2002	2003	2004	2005	2006	2007
P705	9.33	2.20	1.47	1.35	0.49	1.51
P707	5.58	4.28	2.73	2.07	0.62	2.00
P709	12.39	5.55	6.31	4.62	3.27	2.79
P710	2.37	4.66	4.84	1.69	1.47	3.35
P714	10.47	7.89	10.17	8.02	10.84	8.74
P715	5.02	7.64	5.82	7.89	8.35	8.84
P718	5.42	5.05	3.72	4.60	7.66	6.57
P719	7.19	7.00	5.83	6.62	9.52	6.73
P721	11.21	11.97	10.76	11.90	14.96	12.40
P722	11.96	10.16	13.89	14.09	17.29	14.01
P723	6.93	5.74	7.07	5.83	8.24	7.35
P724	1.00	1.69	1.41	3.35	2.53	0.96
P725	6.23	6.79	6.14	5.66	5.37	5.26
P726	7.52	7.21	6.99	6.99	9.49	8.89
P727	7.69	8.19	9.92	10.61	15.99	9.42
P728	7.80	11.50	10.87	10.68	13.23	12.83
P733	1.52	1.96	1.92	1.10	2.30	1.61
P734	3.56	5.57	6.78	5.51	6.89	7.90
P735	2.25	1.27	1.83	0.68	2.36	1.28
P736	3.04	4.87	1.28	1.27	2.23	2.01
P737	2.07	1.68	0.73	1.27	0.94	1.18
P738	5.42	5.11	4.36	3.91	2.49	4.48
P739	0.84	1.63	1.36	0.46	1.83	1.34
P763	3.80	5.38	3.35	3.97	3.93	2.96
P764	4.28	6.12	3.66	2.95	2.08	2.38
P765	0.97	0.91	1.35	1.12	0.94	1.43
P766	1.26	4.48	3.26	3.38	4.99	2.81
P767	0.46	2.43	1.84	1.80	4.87	2.47
P773	-	0.93	0.92	0.93	0.92	1.82
P793	1.39	0.71	-	2.32	-	-

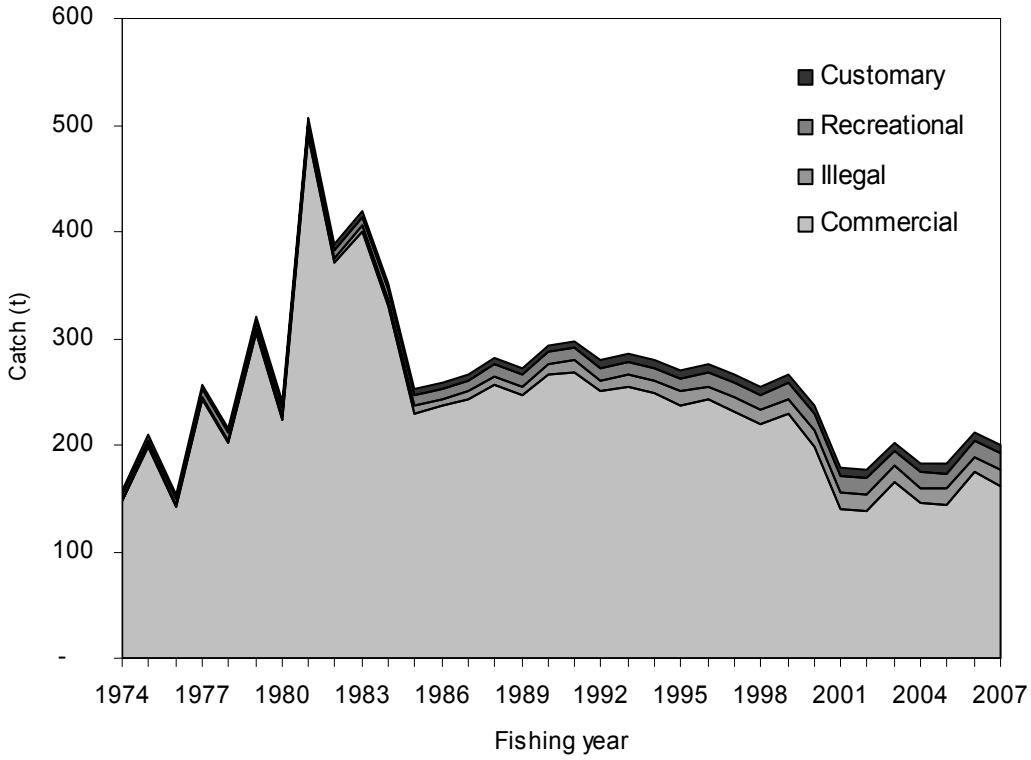


Figure 4: The commercial and other catches in areas 17 and 38 since 1974.

3. CPUE DATA

3.1 Overview

In the 2005 PAU 7 stock assessment (Breen & Kim 2005) two standardised CPUE indices were used: (1) one based on FSU/CELR data covering 1983–2001, and (2) another based on PCELR data covering 2002–2005. In this section three standardised CPUE indices are presented.

1. One using FSU/CELR data covering 1983–2001. This is not a new analysis, but simply a re-presentation of the index that was used in the last assessment.

2. An updated index using PCELR data covering 2002–2007. In a variation on the updated model, another model is explored with interaction terms.

3. A combined index using FSU/CELR data and PCELR data covering 1983–2005. This is compared to the two separate (FSU/CELR and PCELR) indices.

The Shellfish Working Group decided to use two separate indices in the stock assessment (one based on the FSU/CELR data, the other on the PCELR data), and the combined index covering all years was not used in the assessment.

For all series standardised catch per unit effort (CPUE) analyses were carried out using Generalised Linear Models (GLMs), based on the procedure explained by Vignaux (1994), and as modified by Francis (2001). The aim behind this type of analysis is to remove the effect of changes in fishing

patterns and conditions (e.g., where and when fishing was done) on the catch rate, leaving a component that is presumed to be proportional to the biomass of fish present.

A step forward procedure was used to select predictor variables, and they were entered into the model in the order which gave the maximum decrease in the Akaike Information Criterion (AIC). Predictor variables were accepted into the model only if they explained at least 1% of the deviance.

3.2 FSU/CELR data: 1983–2001

The standardised index from the 2005 assessment is re-presented here. The unit of catch used was the total estimated daily catch for a vessel. As the diver hours field on the CELR forms contains a high number of errors, the unit of effort used is the total number of diver days (total number of divers on a vessel for a day). Records were restricted to those from vessels that fished the top 75% of catch in any given year, and from areas 17 and 18 (Breen & Kim 2005). The standardised index is shown in Table 5 and Figure 5.

Table 5: Standardised CPUE indices from CELR data for areas 17 and 38 of PAU 7. The standard error shown is on the index in log space. The table is extracted from Breen & Kim 2005.

Fishing year	Standardised CPUE (kg/day)	SE	Diver days
1983	228.8	0.0322	726
1984	225.5	0.0288	1 060
1985	220.2	0.0310	626
1986	199.7	0.384	378
1987	185.2	0.393	562
1988	196.4	0.0470	373
1989	163.0	0.0429	355
1990	137.7	0.0249	1 292
1991	136.3	0.0224	1 415
1992	115.6	0.0226	1 894
1993	133.0	0.0235	1 544
1994	130.9	0.0250	1 624
1995	126.0	0.0246	1 630
1996	124.6	0.0245	1 632
1997	109.9	0.0245	1 736
1998	111.1	0.0253	1 601
1999	118.8	0.0264	1 529
2000	80.7	0.0257	2 111
2001	60.0	0.0274	2 246

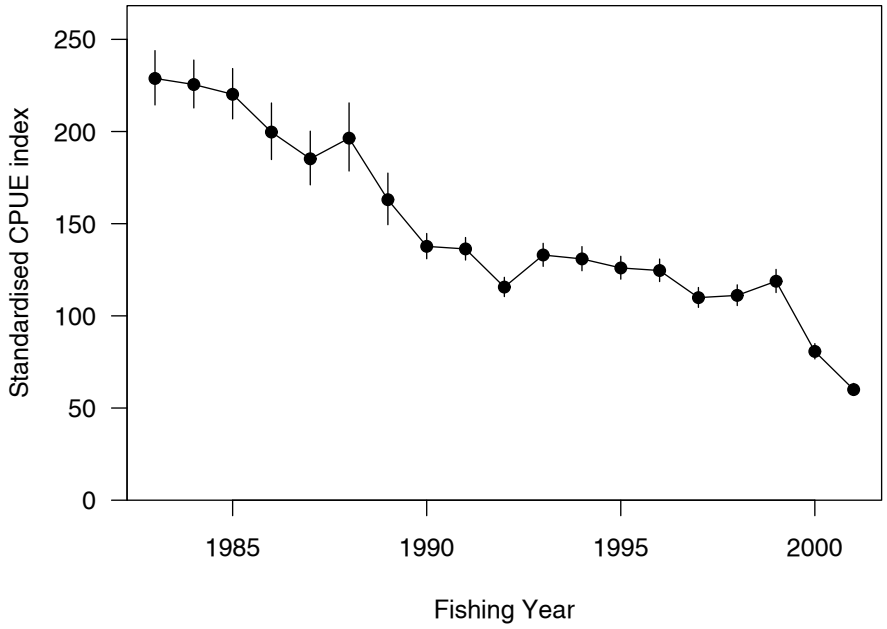


Figure 5: Standardised CPUE (kg/diver day) from areas 17 and 18 combined, taken from FSU/CELR data.

3.3 PCELR data: 2002–2007

3.3.1 The data set

PCELR data were extracted in January 2008 for the time frame 1 October 2001 to 31 September 2007. Only records for which the species was blackfoot paua (species code PAI) were retained (14 625 records). The data were groomed to ensure that records contained the information needed for analysis such as diver keys, diving condition, and vessel key (Table 6).

A further reduction of the data set was made based on the landed catch (greenweight) taken by vessels. For each year, the vessels were ordered in terms of decreasing landed catch. Corresponding to each vessel in this ordering is a cumulative total catch, reaching 100% for the last vessel, which lands the least catch. For each year, records were retained only from vessels in the top 75% for the cumulative total catch landed (Table 6). Lastly, just records from the large scale statistical areas 17 and 38 were retained, leaving 8642 records in the final CPUE data set (Table 6).

The number of vessels in the original PAI and final CPUE data sets is shown in Table 7.

Table 6: Number of records in the data sets and removed by grooming.

Year	2002	2003	2004	2005	2006	2007	Total
Total PAI records	2 861	3 088	2 635	2 422	1 848	1 771	14 625
No Diver key	0	1	0	1	0	0	2
No Diving condition	112	64	74	66	55	69	440
No Vessel key	0	12	15	3	0	0	30
PCPUE>200 kg/h	6	4	2	1	0	0	15
Top 75%	1 867	2 108	1 827	1 550	962	955	9 269
Areas 17 and 38 only	1 552	1 952	1 768	1 380	921	889	8 642

Table 7: Number of vessels for each year in the original and final data sets.

Fishing year	2002	2003	2004	2005	2006	2007
Original PAI data set	76	61	48	45	44	42
Final CPUE data set	25	19	17	18	13	14

3.3.2 Some descriptive analysis

Most of the catch and effort is outside the winter months of June to September (Figure 6–7).

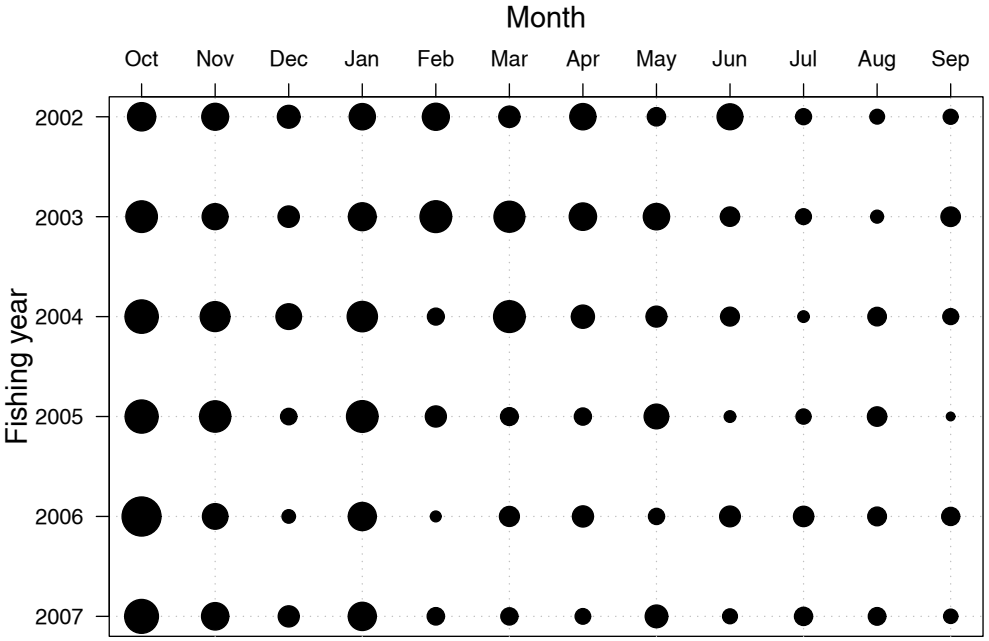


Figure 6: Graphical representation of the catch totalled by month and year for the CPUE data set. The area of a circle is proportional to the catch; the largest circle represents 24 020 kg.

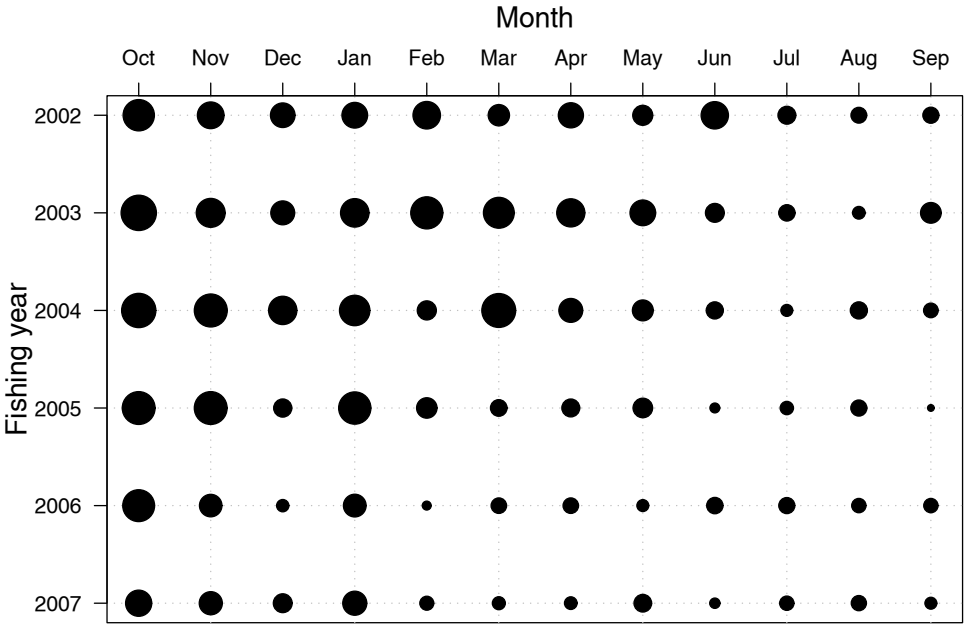


Figure 7: Graphical representation of the total diver effort (hours) by month and year for the CPUE data. The largest circle represents 1400 hours.

3.3.3 Standardisation model: updated

For the updated model, the same standardisation model was used as in Breen & Kim (2005). Catch rate (the dependent variable) was modelled as log(daily catch per diver hour) with a normal error distribution. Variables offered to the model were fishing year, month, diver key, statistical area, and diving conditions,. The year variable was forced into the model at the start, as the aim of a standardised CPUE analysis is to produce a relative biomass indexed by year. Seventy five divers (out of 302) who caught less then 50 kg across all years were combined and treated as a single diver.

All variables were accepted into the model (Table 8), which explained 52.1% of the variability in CPUE. Most of the variability was explained by the diver predictor (25.8%); both month and diving conditions explained less than 3% of the variability each. The effects appear plausible and the diagnostics are satisfactory (Figure 8).

The standardised PCPUE index is similar to the unstandardised indices, but is slightly steeper (Figure 9), It is essentially flat for the first three years, increasing for the next two years, then flat for the last two years (Figure 10, Table 9).

Table 8: Variables included in the standardisation model (1% additional deviance explained), and the order in which they were accepted into the model. Shown in the columns are degrees of freedom (Dof) and Akaike Information Criterion (AIC).

	Dof	AIC	Percentage deviance explained	Additional % deviance explained
fishing year	4	11230	16.9	16.9
Diver	244	8579	42.6	25.8
statistical area	52	8080	46.6	3.9
Month	11	7636	49.4	2.9
diving conditions	4	7413	50.8	1.4
Vessel	38	7256	52.1	1.3

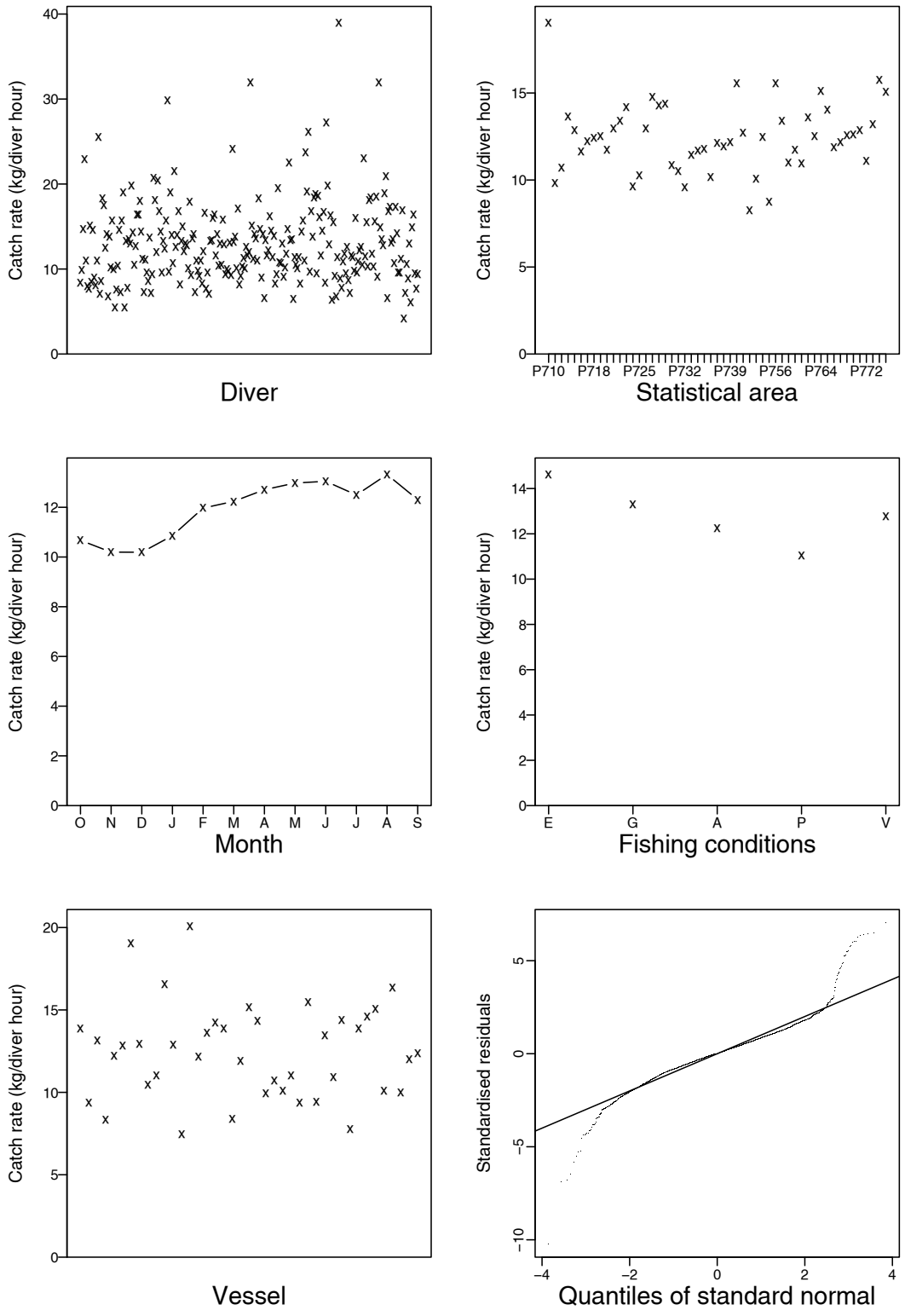


Figure 8: Effects and diagnostics for the updated standardisation model. Effects catch rates are calculated with other predictors (e.g., diver, area, and month) fixed at the level for which median catch rates are obtained. The diagnostic plot is shown in the bottom right-hand corner, and shows the sorted normalised residuals from the standardisation model (y-axis) plotted against the corresponding quantiles of the standard normal distribution (x-axis).

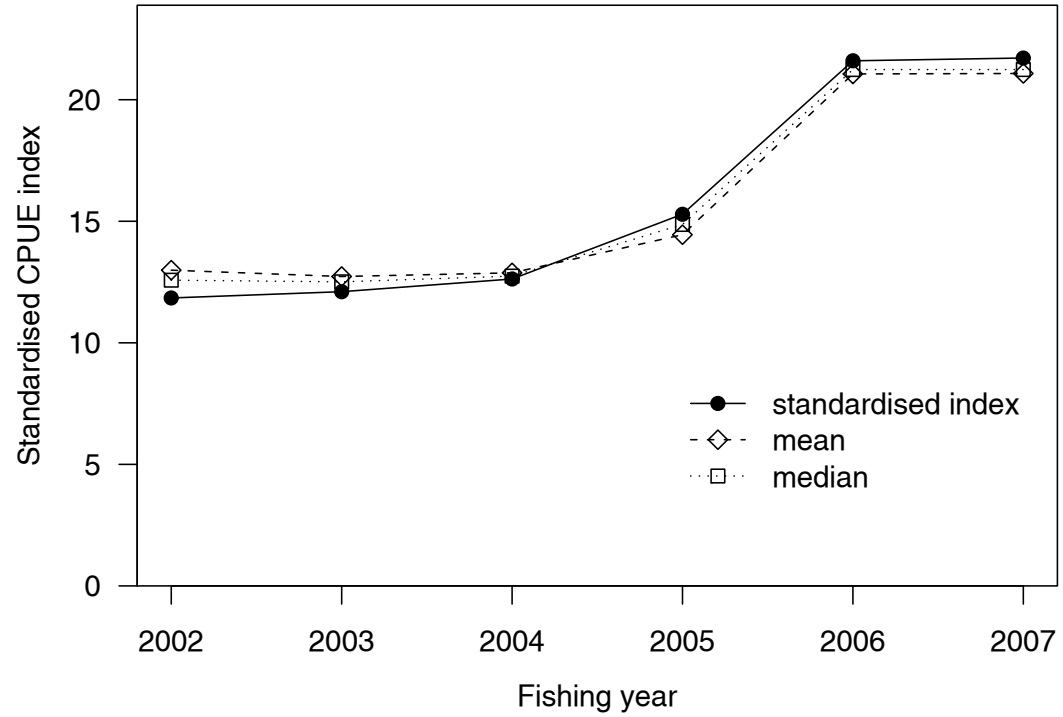


Figure 9: The standardised PCPUE compared to the mean and median. The unstandardised indices in both cases are scaled so as to have the same mean as the standardised PCPUE index.

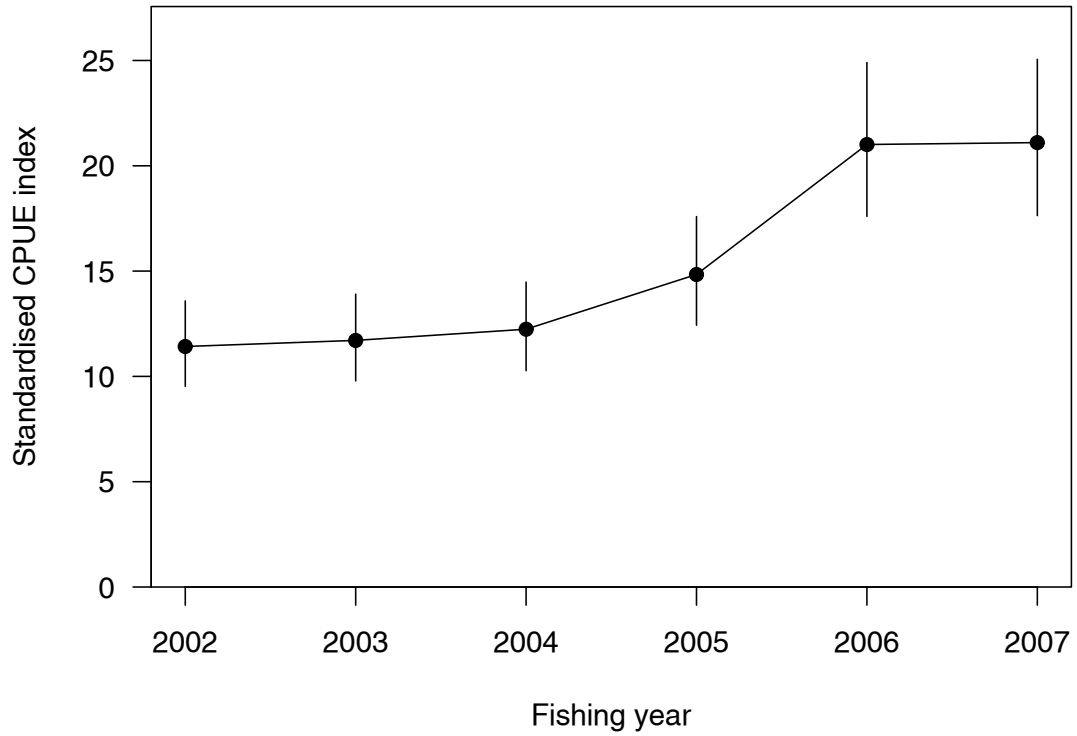


Figure 10: The standardised CPUE index with 95% confidence intervals.

Table 9: Standardised PCPUE index and c.v.s.

Fishing year	Number of records	Index	c.v.
2002	1 552	11.4	0.089
2003	1 952	11.7	0.088
2004	1 768	12.2	0.086
2005	1 380	14.8	0.087
2006	921	21.0	0.087
2007	889	21.1	0.088

3.3.4 Standardisation model: including interaction terms

This model is the same as the updated model, except the interactions vessel:month and area:month are also offered to the standardisation model. Both of these interaction terms are accepted into the model, after the same main effects that were accepted into the updated model (Table 10). Together the interaction terms explain an additional 9.1% variation. The main effects look similar to when there were no interaction terms in the model, except the month effect has a different trend and is more irregular (Figure 11). The year effects are very similar to those for the model in which no interactions were included: the index is slightly steeper then the unstandardised indices (Figure 12). The c.v.s for the year effects are all higher at about 0.43 (0.09 without interactions), which is a consequence of fitting many more parameters in the model with interactions.

However, many of the interaction terms are very poorly estimated. For the vessel:month interaction, 22% of the vessel/month combinations have no records, and only 46% have more than 10 records (Table 11). Similarly, for the area:month interaction, 30% of the area/month combinations have no records, and only 35% have more than 10 records (Table 11).

As the interaction terms are poorly estimated it is recommended that they are not included in the standardisation model, as including them may lead to poor estimates of main effect terms, such as the year effects. In this particular instance, for the PCPUE standardisation, the year effects are very similar whether or not interaction terms are included.

Table 10: Variables included in the standardisation model with interaction terms (1% additional deviance explained), and the order in which they were accepted into the model. Shown in the columns are degrees of freedom (Dof) and Akaike Information Criterion (AIC).

	Dof	AIC	Percentage deviance explained	Additional % deviance explained
fishing year	4	11 230	16.9	16.9
Diver	244	8 579	42.6	25.8
statistical area	52	8 080	46.6	3.9
Month	11	7 636	49.4	2.9
diving conditions	4	7 413	50.8	1.4
Vessel	38	7 256	52.1	1.3
vessel : month	331	6 955	57.3	5.1
statistical area: month	383	6 900	61.2	4.0

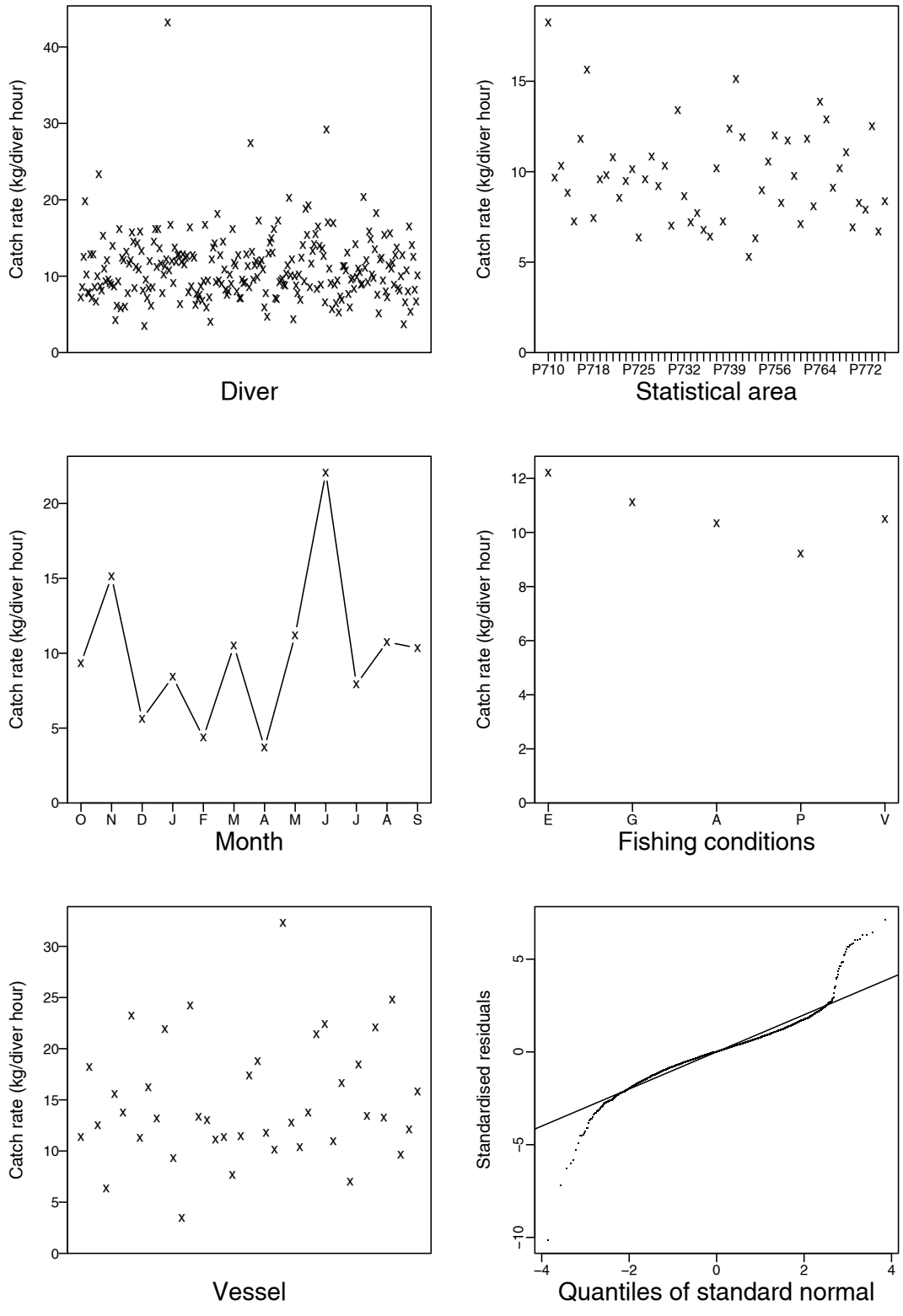


Figure 11: Effects and diagnostics for the standardisation model with interaction terms. Effects catch rates are calculated with other predictors (e.g., diver, area, and month) fixed at the level for which median catch rates are obtained. The diagnostic plot is shown in the bottom right-hand corner, and shows the sorted normalised residuals from the standardisation model (y-axis) plotted against the corresponding quantiles of the standard normal distribution (x-axis).

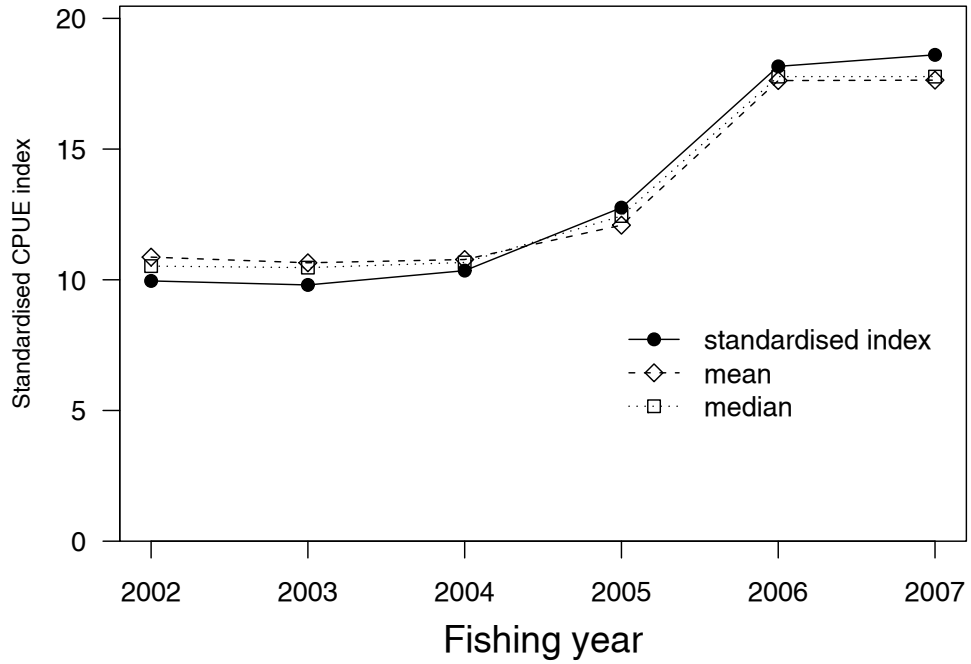


Figure 12: The standardised PCPUE for the model with interaction terms compared to the mean and median. The unstandardised indices in both cases are scaled so as to have the same mean as the standardised PCPUE index.

Table 11: Percentage of interaction combinations that have 0, 5 or fewer, or 10 or fewer records associated with them.

Interaction	0	5	10
vessel:month	22	42	54
area:month	30	52	65

3.4 Combined (FSU/CELR and PCELR) series: 1983–2007

3.4.1 The data set

For 1983–2001 the groomed data set from the 2005 stock assessment was used. For 2002–2007 the updated PCELR data set was used but collapsed into the CELR format, then restricted to the top 75% of vessels by landings, and to areas 17 and 18.

3.4.2 Some descriptive analysis

Catch and effort declined in 1986, increased again in 1990, and then remained relatively constant apart from a decrease of catch and effort in the winter months from about 2002 (Figure 13 and Figure 14)

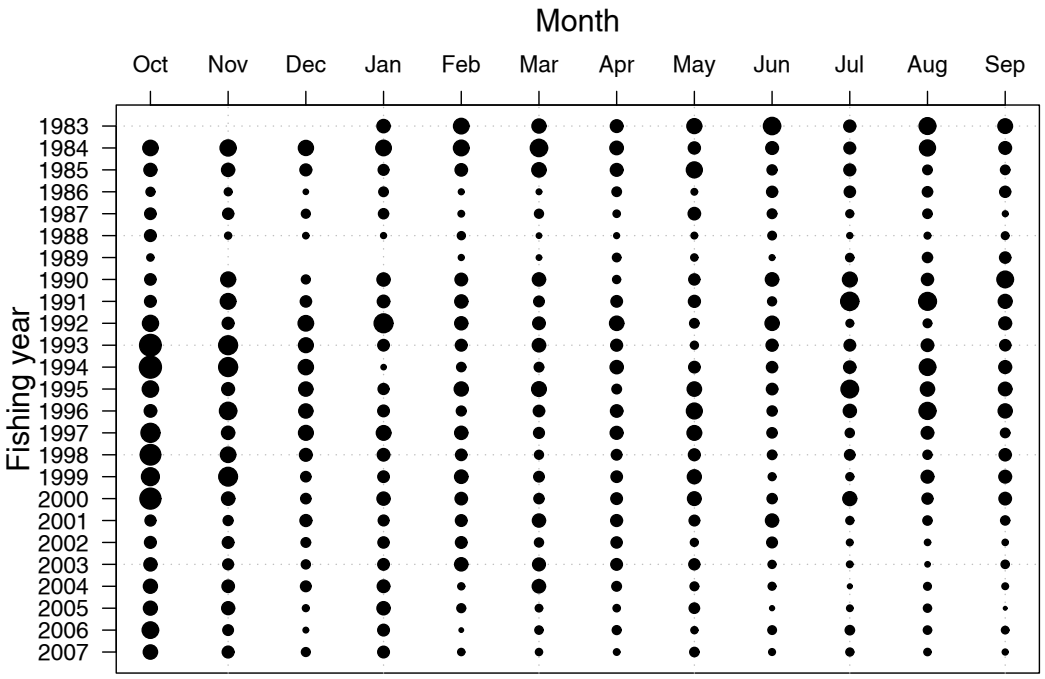


Figure 13: Estimated catch totalled by month and fishing year. The area of the circles is proportional to the estimated catch; the largest circle represents 44 833 kg.

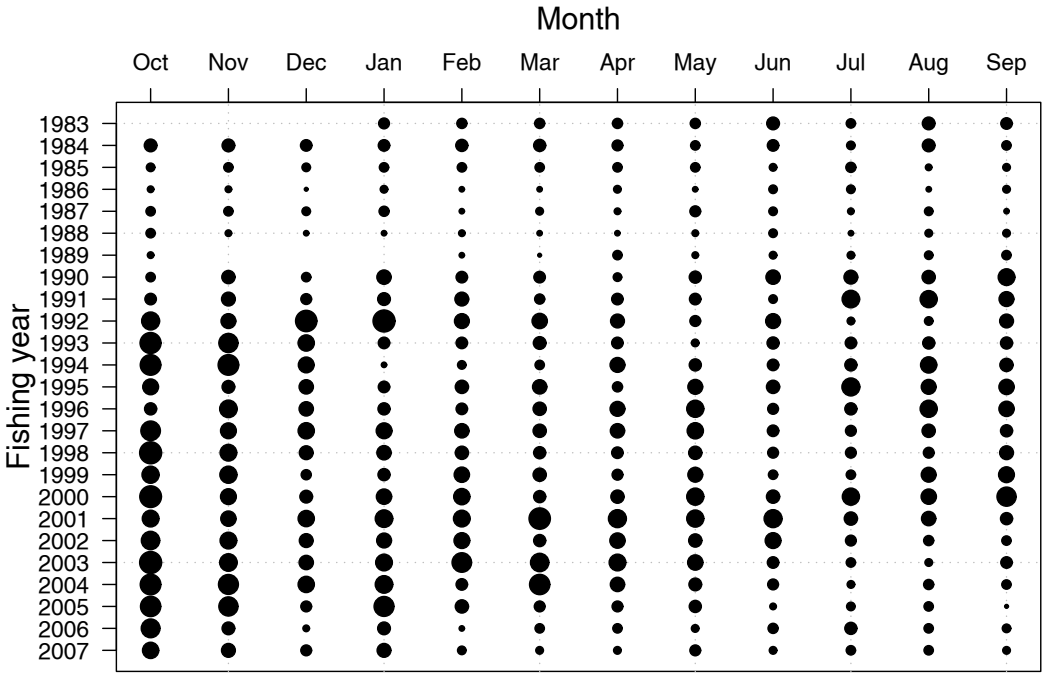


Figure 14: Total number of diver days by fishing year and month. The area of the circles is proportional to the total; the largest circle represents 330 diver days.

3.4.3 Standardisation model: updated

Catch rate (the dependent variable) was modelled as log(total daily catch per diver day) with a normal error distribution. Variables offered to the model were fishing year, month, statistical area, vessel, and an interaction between statistical area and month. The year variable was forced into the model at the start, as the aim of a standardised CPUE analysis is to produce a relative biomass indexed by year.

Only the vessel predictor variable was accepted into the model (Table 12), which explained 44.7% of the variability in CPUE in total. The vessel effect shows a three-fold difference in catch rates which seems plausible (Figure 15). Model diagnostics indicate that there are more low catch rate data than assumed by the model, but not significantly so (Figure 15). The year effects (Table 13, Figure 16) differ most from the raw mean and median before 1990 (Figure 17). There is little difference between the combined standardised indices and the separate FSU/CELR and PCELR standardised indices (Figure 18).

Table 12: Variables included in the standardisation model denoted by an asterisk (1% additional deviance explained), and the order in which they were accepted into the model. Shown in the columns are degrees of freedom (Dof) and Akaike Information Criterion (AIC).

	Dof	AIC	Percentage deviance explained	Additional % deviance explained
fishing year*	23	36 694	23.9	23.9
vessel*	149	31 344	44.7	20.8
Month	11	31 278	45	0.3
Area	1	31 242	45.1	0.1
month : area	11	31 237	45.2	0.1

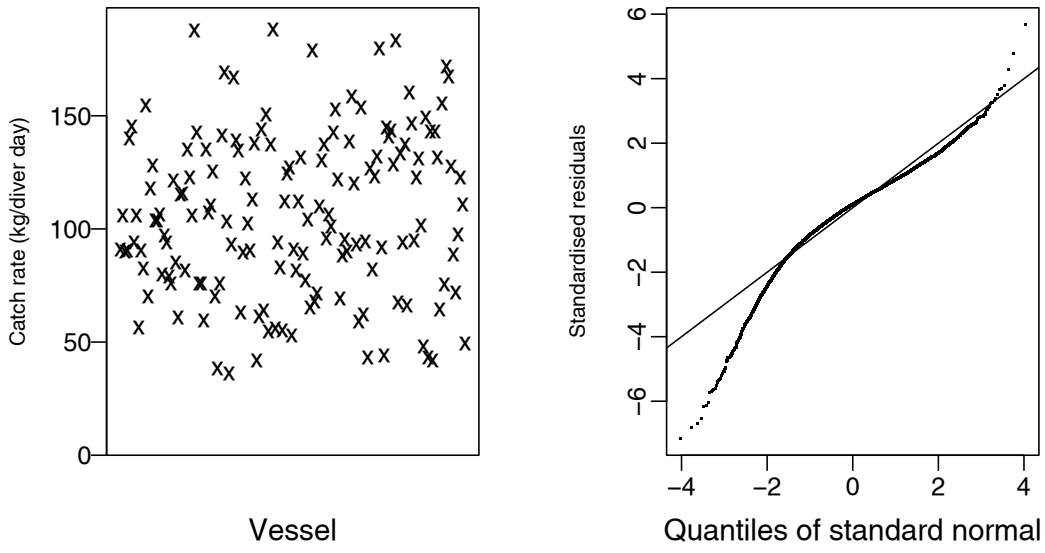


Figure 15: Vessel effects and diagnostics for the combined standardisation model.

Table 13: The standardised combined index. The c.v.s. are in natural space.

Fishing Year	Number of records	PCPUE	c.v.
1983	534	198.3	0.059
1984	811	195.3	0.057
1985	546	190.7	0.058
1986	307	172.5	0.062
1987	364	160.1	0.063
1988	244	170.4	0.069
1989	212	141.6	0.065
1990	792	119.7	0.054
1991	892	118.8	0.052
1992	945	100.8	0.052
1993	796	115.8	0.052
1994	781	113.6	0.052
1995	814	109.0	0.051
1996	885	108.0	0.051
1997	939	95.3	0.051
1998	834	96.5	0.050
1999	832	104.0	0.050
2000	1 155	72.1	0.048
2001	1 174	54.3	0.047
2002	777	61.8	0.046
2003	858	61.0	0.045
2004	742	61.6	0.047
2005	609	65.9	0.051
2006	428	95.2	0.055
2007	428	98.0	0.060

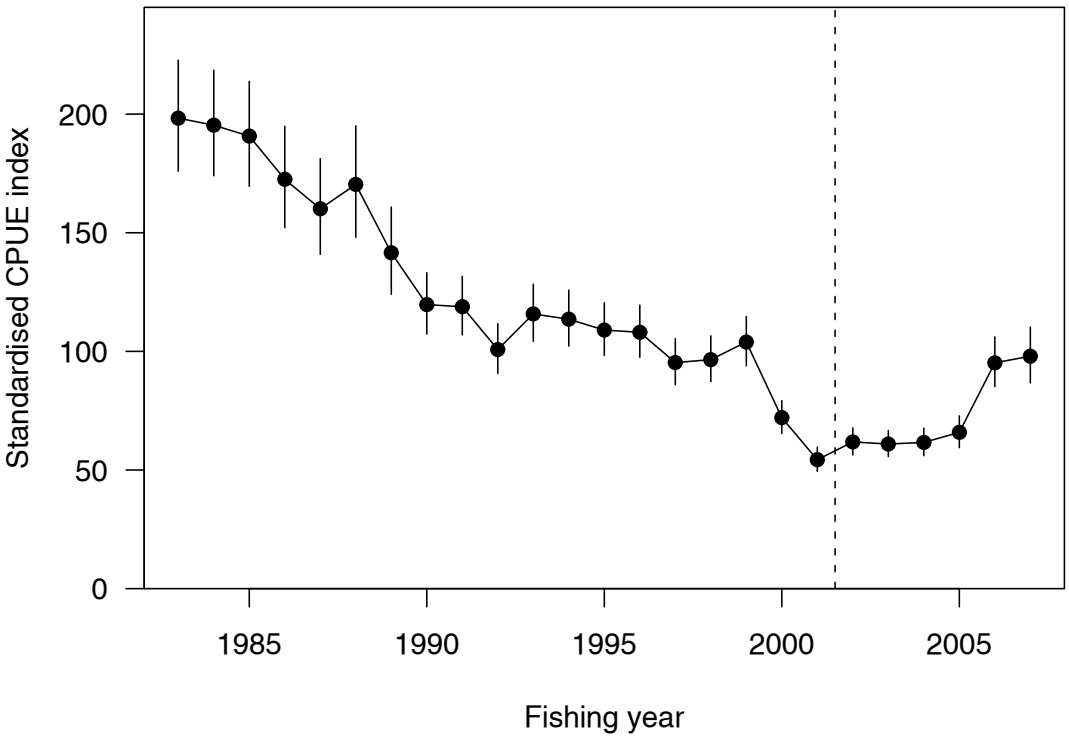


Figure 16: The combined standardised CPUE with 95% confidence intervals. The vertical dashed line separates FSU/CELR and PCELR data.

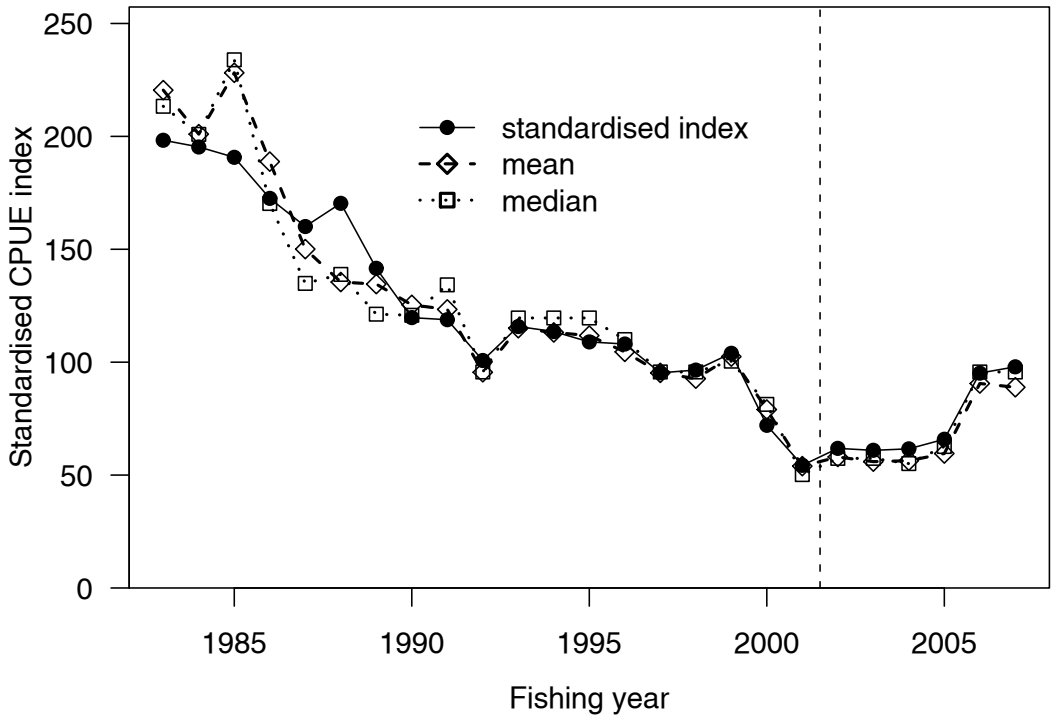


Figure 17: The combined standardised CPUE index compared to the mean and median. The unstandardised indices in both cases are scaled so as to have the same mean as the standardised CPUE index (over the fishing years for which they are defined). The vertical dashed line separates FSU/CELR and PCELR data.

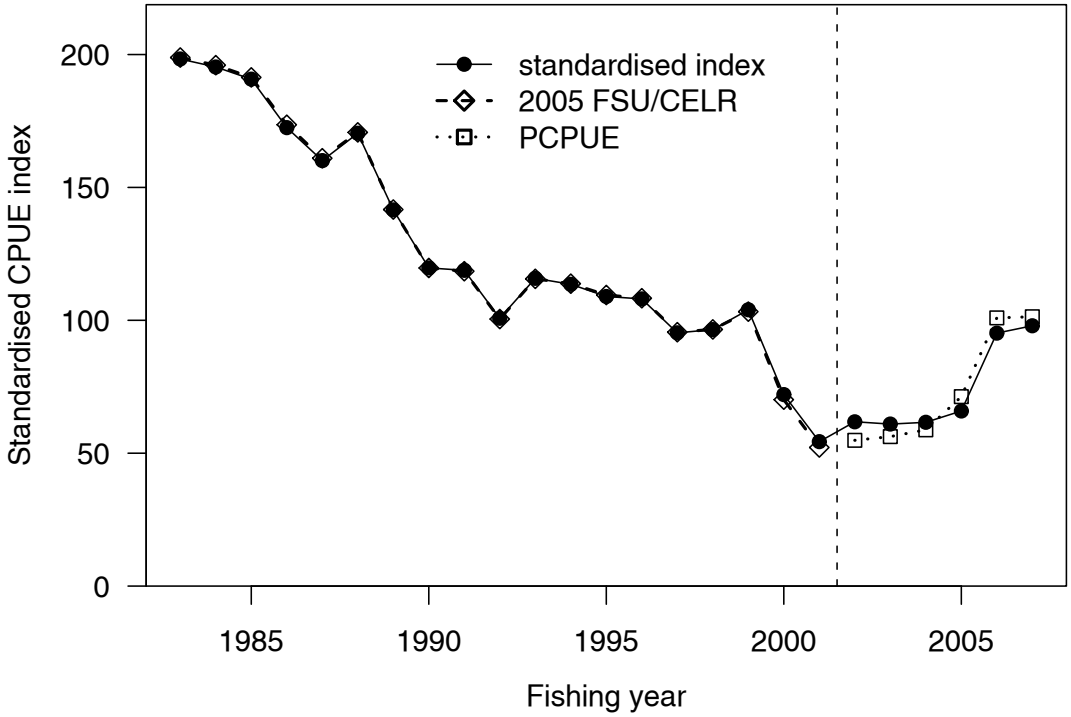


Figure 18: The combined standardised CPUE compared to: (a) the FSU/CELR standardised index from 2005 (Breen and Kim 2005) and (b) the updated PCPUE index.

4. CATCH SAMPLING LENGTH FREQUENCY (CSLF)

4.1 Extracting and grooming

A new extract of Catch Sampling Length Frequency (CSLF) data was made from the market database on 14 February 2008. This totalled 13 164 records containing 101 886 measurements from 1990–94 and 1999–2007. Deducing the statistical area of each record required some archaeology, as it is not straightforward for much of the dataset. Table 14 details records that were removed for various reasons. Statistical area information was obtained for 92% of records using a variety of fields in the data and lookup tables provided from previous assessments. Fifteen records were removed for having lengths less than 108 or higher than 200. Finally, records that were not from statistical areas 17 or 38 were then removed. A search was made for duplicated records (by combining the *landing_no* and *lgth* fields), but none were found. After grooming, 9 552 records containing 82 371 measurements remained (Table 14).

Table 14: Number of records in the CSLF data that were removed for each reason, and the number that remained post-grooming.

Groom	No. records	No. fish
No area info	1 557	7 437
Length < 108 mm	14	54
Length = 241 mm	1	3
Not areas 17 or 38	2 040	12 021
Remaining	9 552	82 371
Total	13 164	11 886

The numbers of remaining records in each year were then compared with the 2005 stock assessment, and they differed in only 3 out of the 12 years. The differences were not large, and were probably due to slightly different approaches to deducing the statistical area.

The numbers of records from each statistical area in each fishing year are shown in Table 15. Note that no area information was available for the 990 records from fishing year 1998.

Table 15: Number of paua measured in each statistical area in fishing year.

		Statistical area					
Fishing year	Removed	17	38	18	036	Unknown	Total
1990		1 736	2 990				4 726
1991		4 716	4 861	2 837			12 414
1992		6 771	1 988	655	643		10 057
1993	54	4 863	2 475	1 623			9 015
1994		7 037	1 715	924			9 676
1998						990	990
1999		4 143	1 056	95			5 294
2000		4 952	218	424	409	1 886	7 889
2001		3 167	299	773	705	1 740	6 684
2002		6 101	170	1 331		337	7 939
2003		6 237	445	1 277	189	690	8 838
2004		4 305				673	4 978
2005		4 022		136		579	4 737
2006		2 641				542	3 183
2007	3	5 463					5 466
Total	57	66 154	16 217	10 075	1946	7437	11 886

4.2 Weighting

As for previous assessments, each year's length frequencies were weighted by the relative catches in each statistical area within that year. The weighted frequencies, $L_{l,s,year}$, were calculated from the raw frequencies, $L'_{l,s,year}$, by the normalised catch in each statistical area and fishing year:

$$L_{l,s,year} = L'_{l,s,year} * \frac{C_{s,year}}{\sum_{s} C_{year}}$$

where $C_{s,year}$ is the estimated catch in a statistical area s (either 17 or 38) in fishing year *year*.

Samples from area 38 were slightly smaller than those from 17 (Figure 19), from where most of the catch is taken (see Figure 3). Figure 20 and Figure 21 show the weighted proportions and cumulative proportions at length. These demonstrate that the paua are far smaller in the years since 2001.

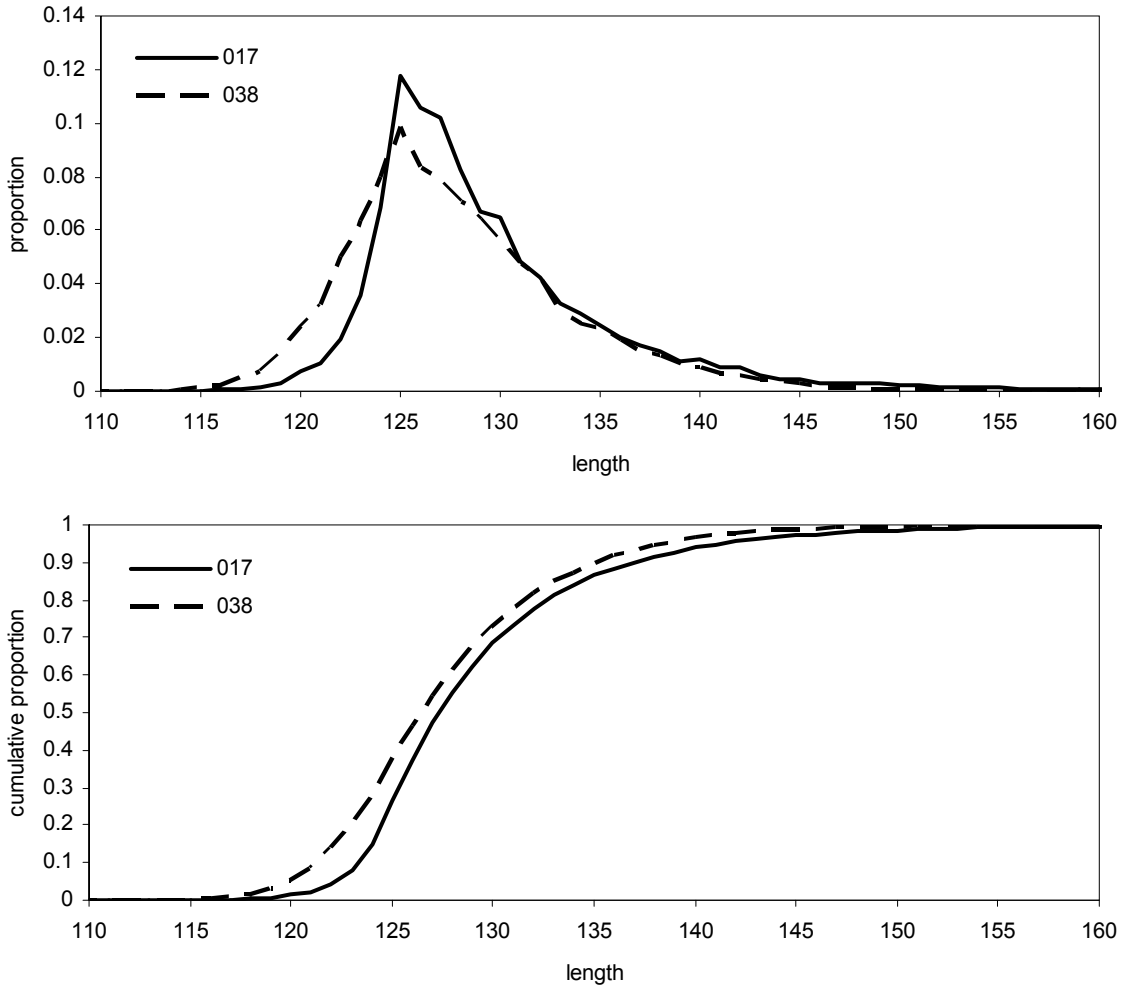
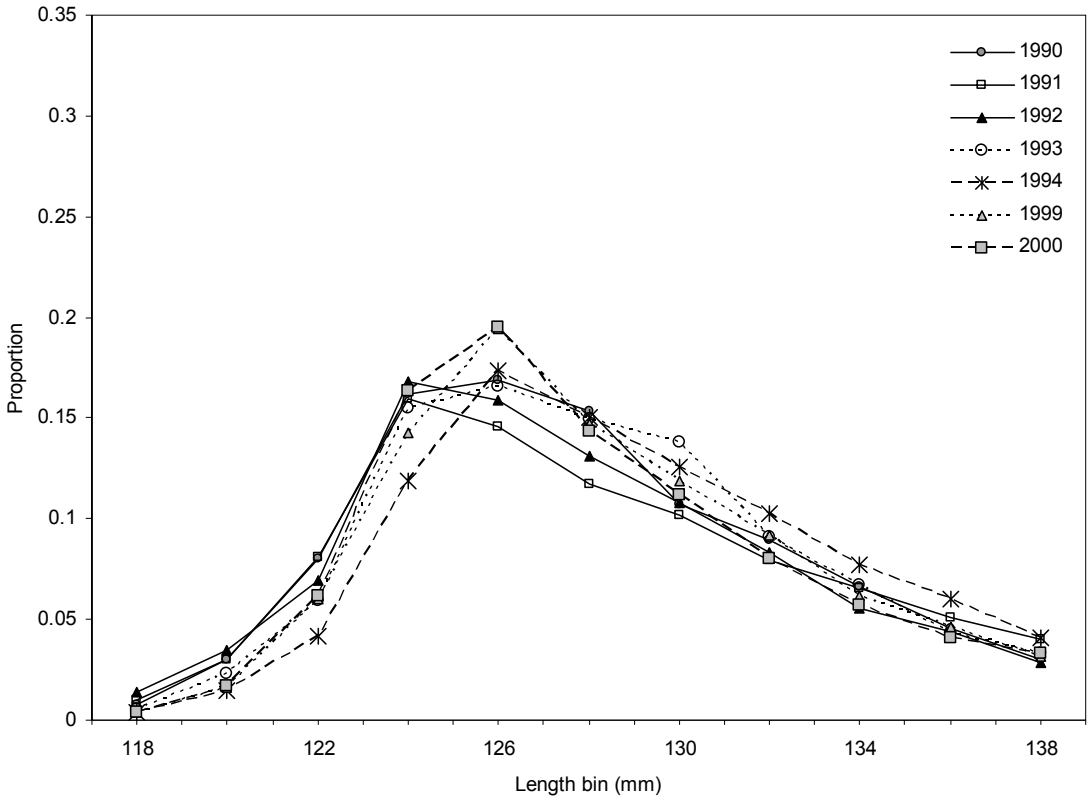


Figure 19: The proportion and cumulative proportion of lengths in statistical areas 17 and 38, summed over years.



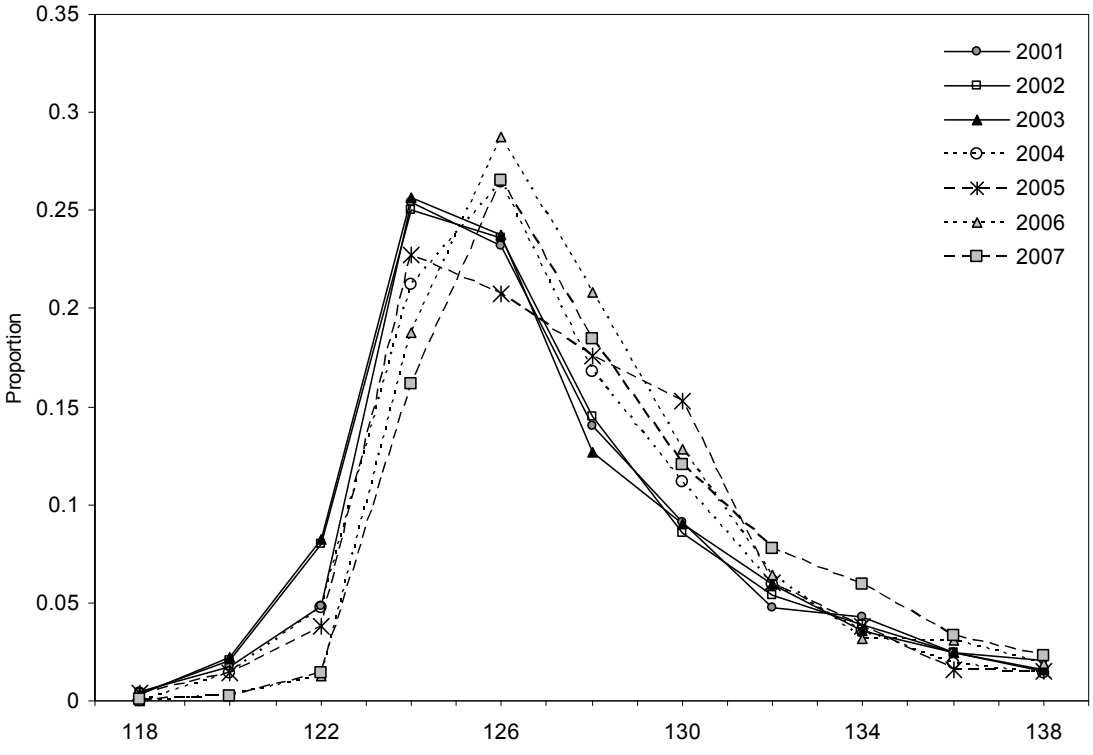
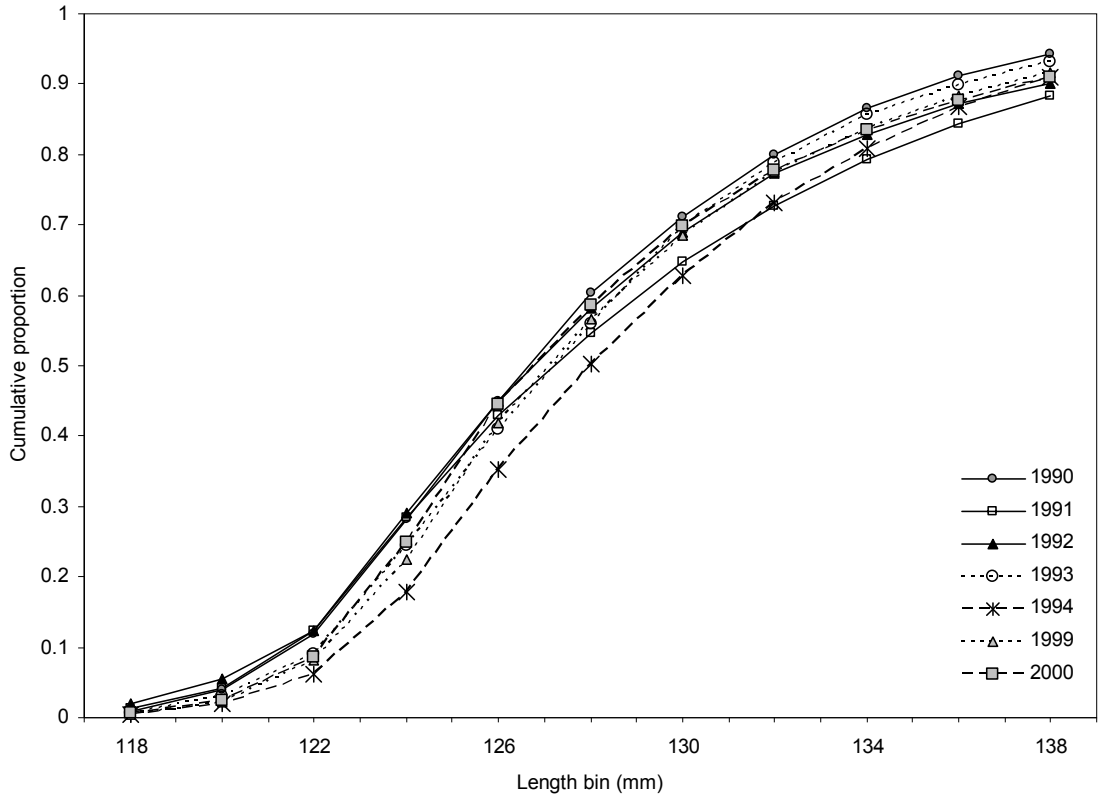


Figure 20: Weighted proportions at length.



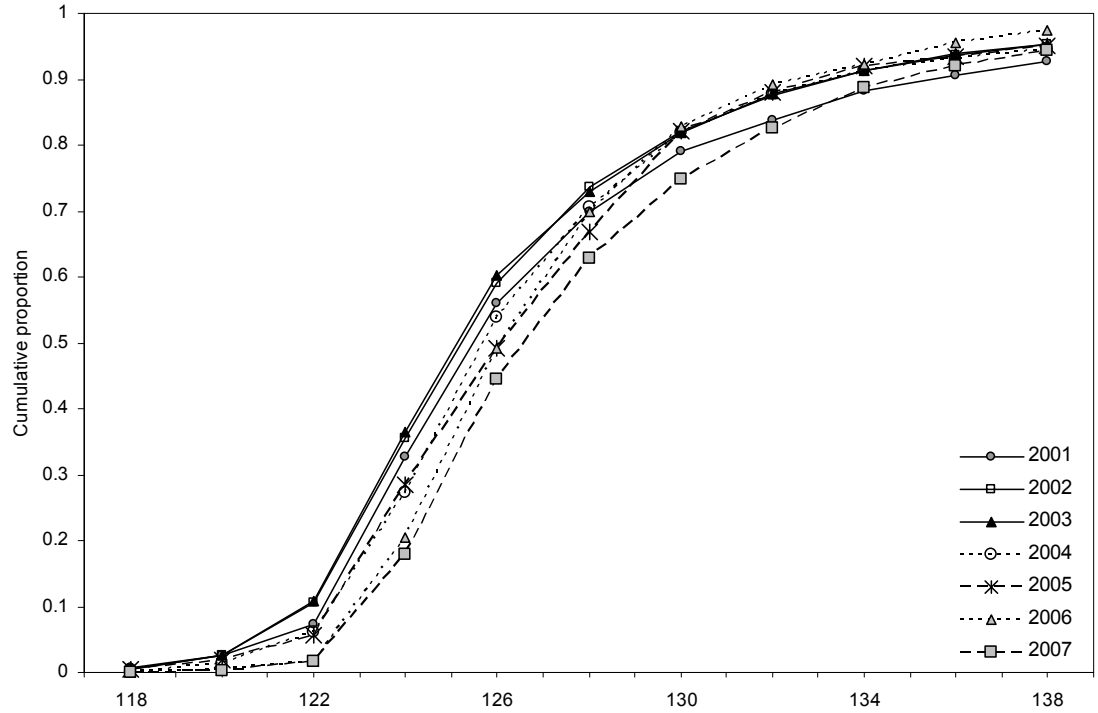


Figure 21: Weighted cumulative proportions at length.

5. RESEARCH DIVER SURVEY INDEX (RDSI)

The RDSI is a fishery-independent research diver survey of relative abundances (Andrew et al. 2000b), for which a standardised version is used in the assessment (see Breen & Kim (2005) for full details). There is no new RDSI data for PAU 7 since the 2005 stock assessment, so the standardised RDSI from then is used again (Table 16, Figure 22).

Although the 2005 standardised index was used, this was compared with an alternative method of standardisation which used the negative binomial error distribution, following the work of Breen & Smith (2008). The resulting index differed very little from the index used in the 2005 assessment (Middleton 2008).

Table 16: Standardised RDSI for areas 17 and 38 of PAU 7. The first two columns show the year effect and its standard error; the last column shows the standardised abundance (number per 10-minute swim).

Year	Index	SE	Std RDSI
1993	0.863	0.120	93.8
1995	1.508	0.191	163.9
1996	1.363	0.140	148.2
1999	0.689	0.104	74.9
2001	0.621	0.103	67.5
2003	1.062	0.119	115.4
2005	1.239	0.109	134.6

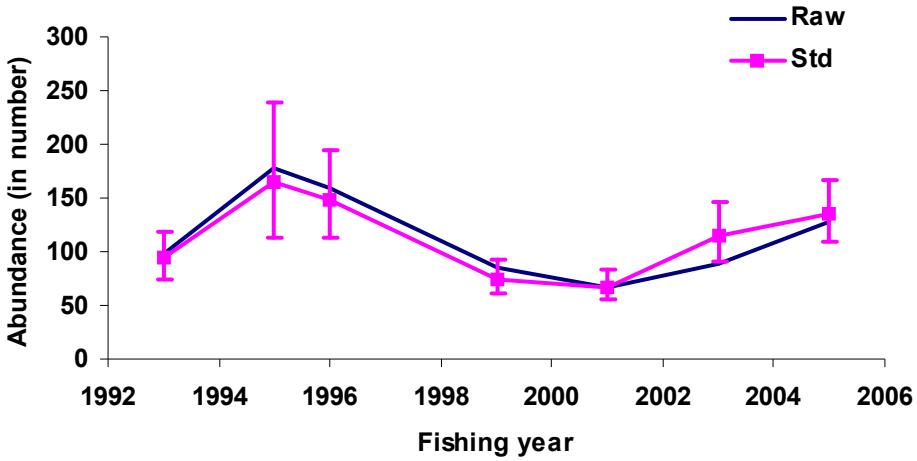


Figure 22: Raw (black line) and standardised (grey line) RDSI from areas 17 and 38 combined. Vertical bars show the 95% confidence intervals. Extracted from Breen & Kim (2005).

6. RESEARCH DIVER LENGTH FREQUENCIES (RDLFs)

Research divers remove some paua from each patch sampled for length measurements. These raw length measurements are then scaled by abundance estimates for the sample and the number of swims (see Breen & Kim (2005) for full details). There are no new RDLFs for PAU 7 since the 2005 stock assessment, so the scaled RDLFs from then are used again (Figure 23).

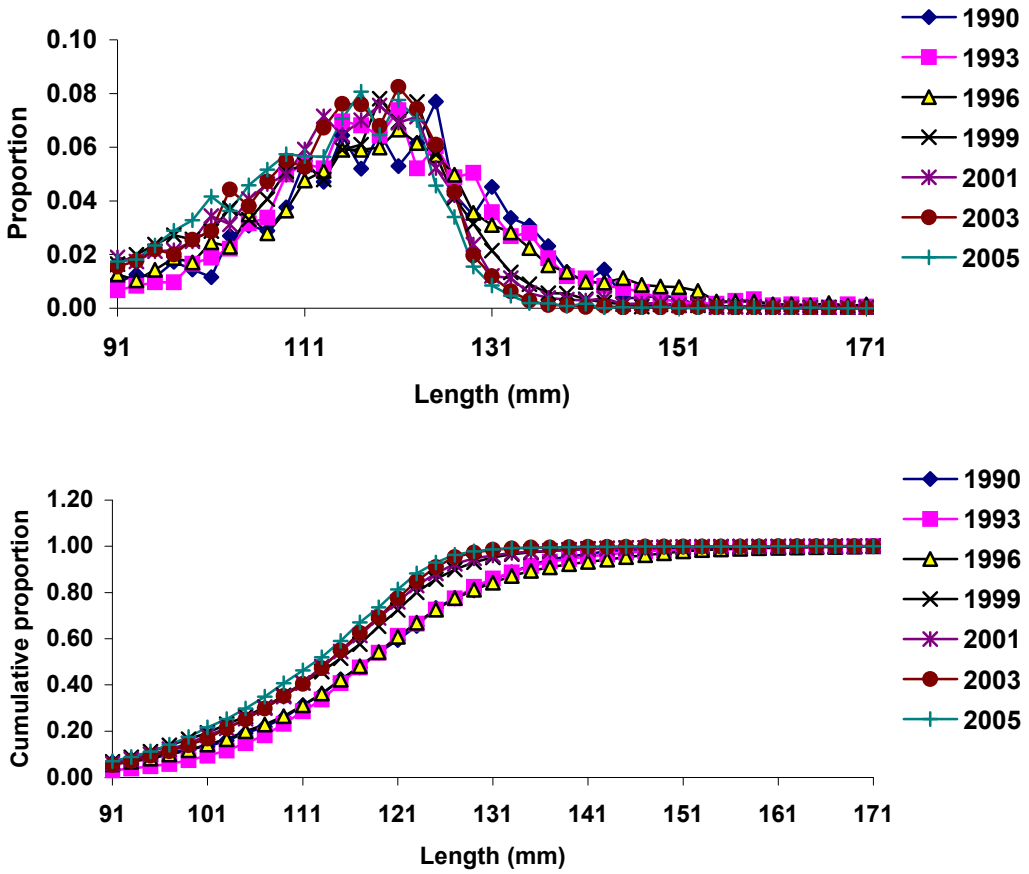


Figure 23: RDLFs from all survey strata within areas 17 and 38 aggregated for each year and plotted as proportion-at-length (top) and cumulative proportion-at-length (bottom) for each year. Extracted from Breen & Kim (2005).

7. MATURITY DATA

Data had been collected from one site at Staircase and six sites at D'Urville in March and May 1994. More data were collected during January 2005 during research diver surveys at Perano and Rununder. Paua were checked for maturity and for sex if mature. In all, 414 paua were examined. Data were aggregated for the assessment across all areas and dates. They were collated as the number examined and the number mature in 2-mm length bins (Table 17). There are no new maturity data for PAU 7 since January 2005, so the same data set as the 2005 assessment is used. Data and fits from the 2005 assessment are shown in Figure 24.

Table 17: Numbers of paua examined and number mature-at-length in the maturity-at-size study in PAU 7.

Length (mm)	No. sampled	No. mature
71	2	0
73	6	0
75	8	0
77	8	0
79	10	0
81	11	1
83	13	3
85	14	4
87	28	8
89	29	13
91	27	12
93	22	11
95	40	27
97	33	30
99	28	27
101	15	15
103	27	27
105	21	19
107	32	32
109	30	29
111	5	5
113	2	2
115	2	2
117	0	0
119	0	0
121	0	0
123	1	1
125	0	0

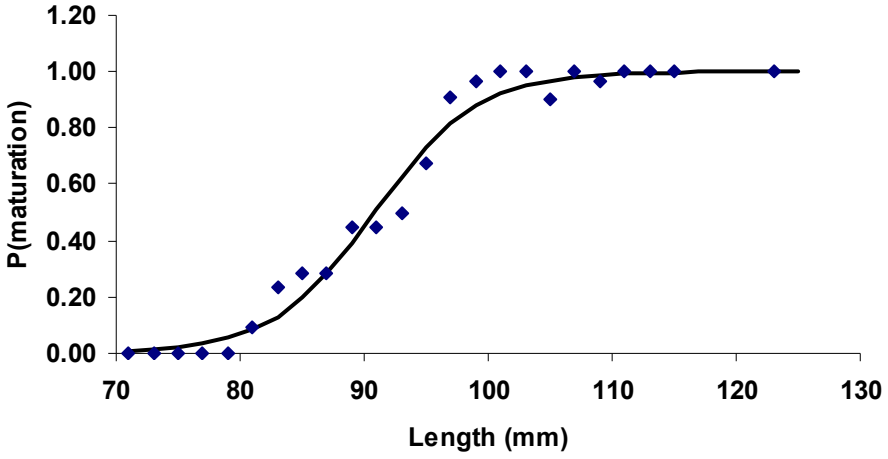


Figure 24: Observed (dots) and predicted (line) proportions of maturity-at-length from the 2005 assessment.

8. TAG RECAPTURE LENGTH INCREMENT DATA

No new tag recapture data for PAU 7 have been collected, so the same data set as the 2005 assessment is used (illustrated in Figure 25).

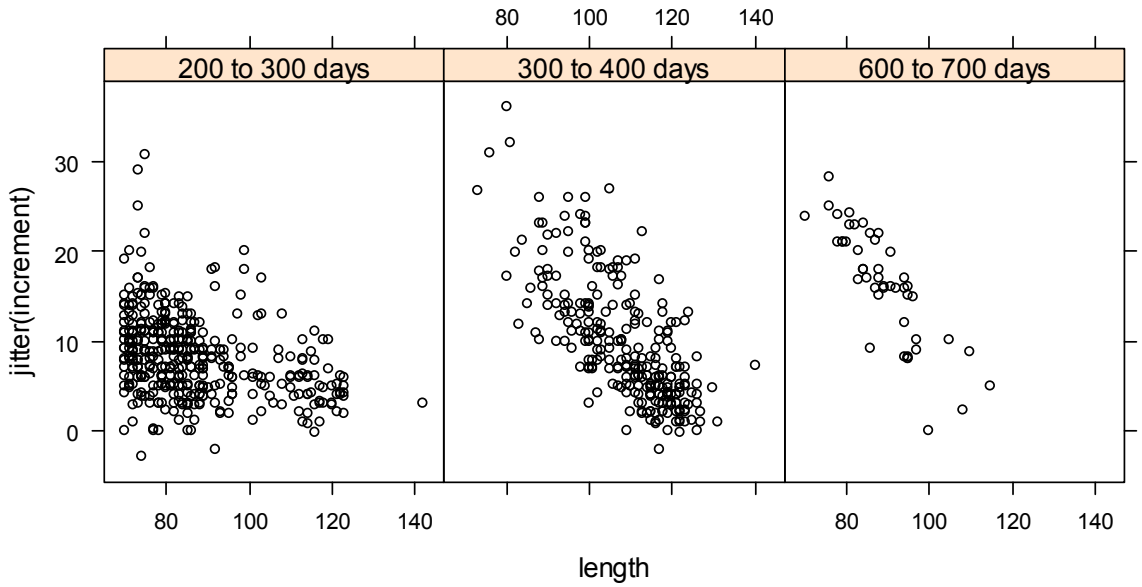


Figure 25: The tag recapture data, shown as the increment over the length (both in mm), grouped by the number of days at liberty. A small amount of jitter (random error) was added to the increment to reveal overlying points.

9. ACKNOWLEDGMENTS

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