MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

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New Zealand Fisheries Assessment Report 2004/48
September 2004

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Published by Ministry of Fisheries
Wellington
2004

ISSN 1175-1584

Citation:
Naylor, J.R.; Kim, S.W. (2004).
Fishery-independent surveys of the relative abundance and size-structure of paua (*Haliotis iris*) in PAU 5D.
New Zealand Fisheries Assessment Report 2004/48. 12 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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Timed-swim surveys were done in the Catlins area of PAU 5D in 2003–04 to estimate the relative abundance and length frequency distribution of paua. These surveys form part of a time series dating back to 1993–94, which along with growth information and fishery-derived data will be used in future assessments of PAU 5D. The target number of surveys for the area, and the target c.v. of 20% were both met. Estimates of relative abundance for PAU 5D did not show any significant change over time.

1. INTRODUCTION

The paua (*Haliotis iris*) fishery was summarised by Annala et al. (2004). Before 1995–96, PAU 5 was the most important paua QMA by number of quota holders and TACC. The TACC peaked in PAU 5 in 1991–92 at 492 t, having grown steadily from a provisional TACC of 390 t in 1985–86 (Annala et al. 2004). This TACC increase resulted from the allocation of additional quota by the Ministry of Fisheries as a result of the quota appeal process. Concerns about the status of the PAU 5 fishery led to a voluntary 10% reduction in the TACC in 1994–95 (Elvy et al. 1997). On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see Figure 1) and the TACC subdivided equally among them (Annala et al. 2004). It is widely considered that this led to a large redistribution of catch from Stewart Island to Fiordland and the Catlins/Otago coast (Elvey et al. 1997). Before 1 October 1997, catch and effort were recorded by Fisheries Management Area (Figure 1). Between 1997–98 and 2000–01 catch and effort were reported by 11 smaller areas in PAU 5D. Since 1 October 2001, catch and effort are reported by 47 zones in PAU 5D.

The 2002 stock assessment for PAU 5D concluded that the current level of catch was not sustainable, and that stocks had little chance of reaching the arbitrary biomass reference level for the period between 1985 and 1987 of 869 t (Breen et al. 2002). Because of this projection, the Minister reduced the TACC from 148.9 t to 114.0 t from 1 October 2002, and to 89 t from 1 October 2003 to "enable the stock to rebuild to optimal levels".

This document presents estimates of the relative abundance and population length-structure of paua in PAU 5D since 1993. Surveys done in 2003–04 extend the time series of estimates reported previously (McShane 1995, McShane et al. 1996, Andrew et al. 2000b, 2002). The estimates of relative abundance and length frequency reported here, along with catch and effort data, length frequency distributions from the commercial catch, growth estimates, and information from previous biological studies are incorporated into a length-based stock assessment model to determine the status of paua stocks in PAU 5D (e.g., Breen et al. 2000a, 2002). Previous estimates of biomass and yield were summarised by Annala et al. (2004).

2. OBJECTIVES

The objectives of the surveys were to estimate the relative abundance and size frequency distribution of paua in commercial areas of PAU 5D using fishery-independent surveys. The target c.v. for relative abundance estimates was 20% of the mean.

3. METHODS

3.1 Survey design

The relative abundance of paua was estimated using a timed-swim method developed by McShane (1995), modified by Andrew et al. (2000a), and previously applied to PAU 5B and PAU 5D by Andrew et al. (2000b). The method has been used in PAU 5D since 1993–94, and is briefly summarised below.

The coastline in the Catlins area of PAU 5D was divided into two strata (Figure 2). The strata consisted of areas of coastline containing paua habitat from which more than 90% of the commercial catch was historically taken (McShane et al. 1995, Elvey et al. 1997). Each stratum was subdivided into 250 m wide strips, each of which was considered a potential sampling site. Each year, sites were randomly selected within strata. If a randomly chosen site contained unsuitable habitat, it was permanently discarded from the list of potential sites and another chosen. Sites were selected with replacement among years, but not within. Fifteen sites were sampled within each stratum, which, based on the variance estimated from previous surveys, was sufficient to provide estimates of the mean relative abundance with c.v.s that are less than 20% of the mean.

3.2 Sampling procedure

Two 10 minute searches were done at each site by divers using surface-supplied air. The areas searched were not overlapping and were constrained to be within 100 m of the vessel. In each search, the relative abundance of paua found in the open on the reef (typically over 70 mm) was estimated using the frequency of patches corresponding to various aggregation categories (Table 1). Because paua usually occur in shallow habitat, divers search reef in the depth range from low water to 10 m and seek to maximise the number of paua found. Paua were considered to be in the same patch if they were separated by less than two body lengths. At each site, visibility was also estimated by both divers, and their consensus recorded on a 5 point scale, where category 1 represented very clear water, and category 5 murky water (Table 2).

Before 1997, only the patch category was recorded and estimates of mean number per timed-swim were calculated using the mid-point of the patch category (McShane et al. 1996) (Table 1). Since 1997, the actual number of paua in patches was recorded, and for patches of more than 20 paua, the clock is stopped while they are counted (Andrew et al. 2000a). Until 2004, however, abundance was still estimated as the product of patch mid-points and the number of patch categories recorded.

The size composition of paua at each site was estimated by collecting the first four paua from each patch. This protocol meant that relatively more paua from small patches were measured than from larger patches; we assume there are no differences in the length composition of paua in patches of different size. Shells were measured to the nearest millimetre with vernier callipers at their longest basal length. Basal length does not include any overhang of the shell spire and in this respect differs from total length (longest measurement along the anterior-posterior axis) which is used in the commercial fishery to define minimum legal size (125 mm). All length-frequency data were grouped into 2 mm size classes for presentation, with paua longer than 170 mm being pooled into a single size class.

3.3 Analysis

Since 2004, relative abundance estimates for timed swims use the actual number counted in each swim. Before 1997, when only patch category was recorded, relative abundance is calculated using the mean patch size for each patch type, estimated from recent data when actual counts were recorded. In PAU 5D, 30 counts done in December 2001 were pooled with those done during the 2001–01 fishing year.

The estimates of the mean number of paua per timed-swim were scaled to account for differences in searching time. Searching time is influenced by the time required to process each patch (collect paua and record data). Although divers count patches now, this does not increase patch handling time as before 1997 paua in small patches had to be counted to be categorised, and divers also stop their stopwatch when the patch size looks larger than 20. McShane et al. (1996) estimated that it took 7.8 seconds to process each patch. Based on this estimate, the time spent searching is calculated as :

$$\text{time searching} = 600 - 7.8 \times (\text{number of patches found})$$

The timed-swim estimate is then modified by rescaling so the

$$\text{scaled abundance estimate} = 600 \times (\text{relative abundance/time searching})$$

The c.v.s of relative abundance estimates for each year were estimated by bootstrapping 1000 samples with replacement. The bootstrapped samples were treated as the population, and sampled n_z times, where n_z was the number of counts in each year. The process was repeated 1000 times to derive 1000 sample means. The c.v. was calculated by dividing the standard deviation of the sample means by the mean.

3.4 Standardisation

To minimise the effects of visibility and differences between divers on estimates of relative abundance, the timed-swim counts were standardised using the method of Vignaux (1993) as described by Kendrick & Andrew (2000).

4. RESULTS

4.1 Standardisation

The variables offered to the model were fishing year, diver, stratum, and visibility. Fishing year was forced to be an explanatory variable in the model. The order in which variables were selected into the model and their effect on the model r^2 are shown in Table 3. All variables except for the stratum were important for the relative abundance index for PAU 5D, and the model explained 11.5% of the variation in abundance estimates. Less than 7% of the variation in estimates was explained by the effect of fishing year (Table 3).

The standardised estimates are adjusted to negate the effects of differences in visibility and differences between divers. Generally, more paua were counted when the visibility was better, except for one count where a very large number of paua were counted when the visibility was lowest (Figure 3). Over all surveys, however, only two sites were surveyed when the lowest visibility category was recorded (Table 4). The effect of differences between divers on abundance estimates is shown in Table 3, and the standardised index is shown in Figure 4. Diver 4 had a very high index, divers 1 and 7 had low indexes, and divers 2, 3, 5, 6 and 8 were broadly similar.

At a few sites (4.8% of the total) zero abundance was recorded, and there were also four sites where visibility was not recorded. Because the percentage of sites with zero abundance data was low, and because visibility is used as an explanatory variable, these sites were removed from the data set before analysis. In the 1997 fishing year, only the Catlins West stratum was surveyed, but these data were included in the analysis (Table 5).

4.2 Relative abundance

In all years the target c.v. of less than 20% was met (Table 6), and in 2003–04 the target number of sites was surveyed (see Table 5). Not all research strata were surveyed in all years, nor were the same number of timed swims done across strata or years (Table 5). There was no sampling in Catlins East in 1996–7.

Raw, scaled, and standardised abundance estimates, and their upper and lower 95% confidence intervals and are shown in Table 6, and raw and standardised estimates over time presented in Figure 5. The relative abundance of paua in the Catlins area of PAU 5D was poorly estimated in 1993–94 and, particularly, in 1996–97, and estimates were accompanied by wide confidence intervals (Figure 5). Raw, scaled, and standardised estimates were generally similar (Figure 5, Table 6). Scaled estimates take into account the amount of time spent collecting and recording during the search, and standardised estimates reduce sources of heterogeneity in the estimates.

The high variance associated with the 1996–97 estimate is because only the Catlins west stratum was sampled in that year. The general trend of abundance estimates appears to have decreased between 1996–97 and 1998–99 and abundance in 1998–99 was lower than in 1993–94 (Figure 5, Table 6).

Raw abundance estimates were similar between 1998–99 and 2000–01, and have since increased, and standardised estimates increased between 1998–99 and 2003–04 (Figure 5, Table 6). Raw abundance estimates are similar between 1993–94 and 2003–04, but the standardised index for 2003–04 is below the 1993–94 estimate. The overlap of 95% confidence intervals associated with both the raw and standardised estimates suggests, however, that differences between years are not significant. This is supported by the contribution to the variation of estimates associated with fishing year of only 6.7% (see Table 3).

The percentage of patches encountered with more than 20 paua is variable between 1993–94 and 2003–04 (Figure 6).

4.3 Population length-frequencies

Of the 4195 paua counted during surveys in PAU 5D in 2003–04, 45% were measured. The size structure of paua in PAU 5D is not consistent among years (Figure 7). Both the modes of the distributions and the relative frequency of smaller paua change considerably among years, especially in 1993–94 and 1996–97. Of particular concern are the large changes between 1993–94, 1996–97, and 1998–99 which are inconsistent with available estimates of growth rate in paua, and suggest that the sampling was not representative. The total sample size in 1996–97 was relatively small. The length frequency distributions since 1998–99 are relatively consistent apart from a decline in the mode of the distributions from about 125–145 in 1998–99 to about 115–140 in 2000–01 and 2003–04.

5. DISCUSSION

Estimates of relative abundance for PAU 5D show no significant change over time. Previous surveys in other QMAs (e.g. PAU 5B, Andrew et al. (2000b)) have shown significant changes in relative abundance over time, and the failure of the surveys to detect any significant change indicates that either there has been no change or the surveys are unable to detect change. The precision of estimates could be improved by increasing the number of sites surveyed within PAU 5D.

When surveys began in 1993–94, the areas surveyed accounted for more than 90% of the commercial catch in PAU 5D (McShane et al. 1996). These areas currently account for less than 55% of the commercial catch (Naylor & Andrew 2003). Redistribution of fishing effort since the inception of surveys may therefore reduce the power of surveys to detect change within the fishery. Industry surveys outside the areas normally surveyed were carried out in 2003 to address the imbalance between survey areas used in assessments and current commercial fishing areas, and also to assess the abundance of paua in water deeper than the current depth range of surveys. The results of the project were inconclusive because persistent poor weather and diving conditions prevented their completion (Naylor & Andrew 2003). It may be useful in future surveys, however, to extend the depth range of surveys to 15 m to ascertain the contribution of paua in that depth range to their overall abundance.

The information summarised here, along with growth information and fishery-derived data, will be used as inputs into future stock assessments of PAU 5D.

6. ACKNOWLEDGMENTS

We are grateful to Pete Notman, Steve Mercer, Owen Anderson, and Chazz Marriott for assistance in the field, and to Keith Michael for constructive comments on the manuscript. This work was funded by the Ministry of Fisheries project PAU 200101.

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Table 1: Patch categories, old assumed mid-points, and actual mean numbers in caterories for PAU 5D.

Patch category	Number of paua	Old mid-point	Actual mean number
1	1 – 4	1.3	1.5
2	5 – 10	7.5	7.0
3	11 – 20	15.5	14.6
4	21 – 40	30.5	28.7
5	41 – 80	60.5	52.3
6	More than 80	120.5	105.0

Table 2: Definition of visibility code.

Visibility code	Definition
1	>10 m
2	6-10 m
3	3-6 m
4	1.5-3 m
5	<1.5 m

Table 3: Variables selected into the model with corresponding r^2.

	r^2
Fyear	6.7%
Visibility	8.9%
Diver	11.5%

Table 4: Number of data with each visibility code in each fishing year.

	Visibility			
Fishing year	2	3	4	5
1993–94	6	30	2	0
1996–97	2	13	3	0
1998–99	28	27	0	2
2000–01	23	19	4	0
2003–04	24	27	4	0

Table 5: Number of sites surveyed in each stratum in each fishing year.

Fishing year	Catlins East	Catlins West
1993–94	20	20
1996–97	0	20
1998–99	30	30
2000–01	20	30
2003–04	30	30

Table 6: Mean number of paua per 10 minute search for raw, scaled, and standardised (Std) abundance, lower (LB) and upper (UB) 95% confidence intervals, and c.v.s of raw abundance estimate. Upper and lower bounds for raw and scaled data estimated from bootstrapping.

	Raw				Scaled			Std		
	LB	Mean	UB	C.V.	LB	Mean	UB	LB	Mean	UB
1993–94	61.0	86.6	121.8	17.97	75.5	107.7	151.0	79.4	129.3	210.6
1996–97	65.7	92.1	123.2	*19.33*	*95.3*	*142.5*	*197.7*	*84.7*	*178.6*	*376.8*
1998–99	40.0	54.9	65.9	14.47	49.1	68.9	84.2	35.6	56.2	88.5
2000–01	38.5	49.2	62.2	14.88	50.2	67.5	89.3	44.2	70.0	110.7
2003–04	53.5	73.5	96.4	16.13	80.3	113.2	153.1	57.0	89.1	139.3

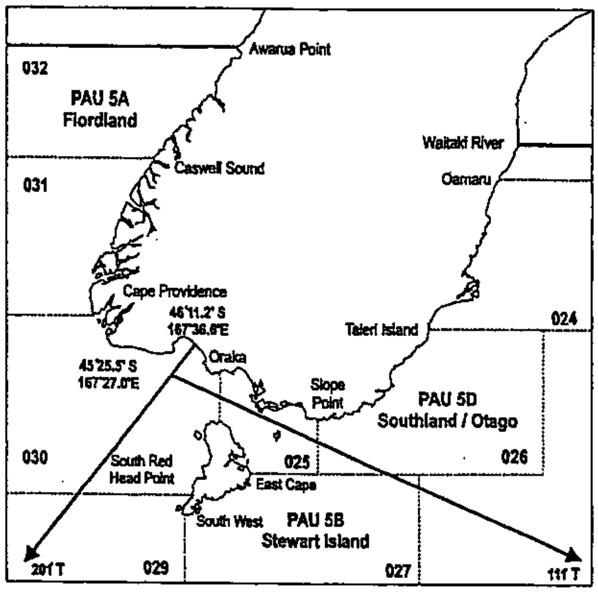

Figure 1: Map showing the boundaries of the new QMAs (solid lines) and Fisheries Management Areas used before 1 October 1997 (speckled lines).

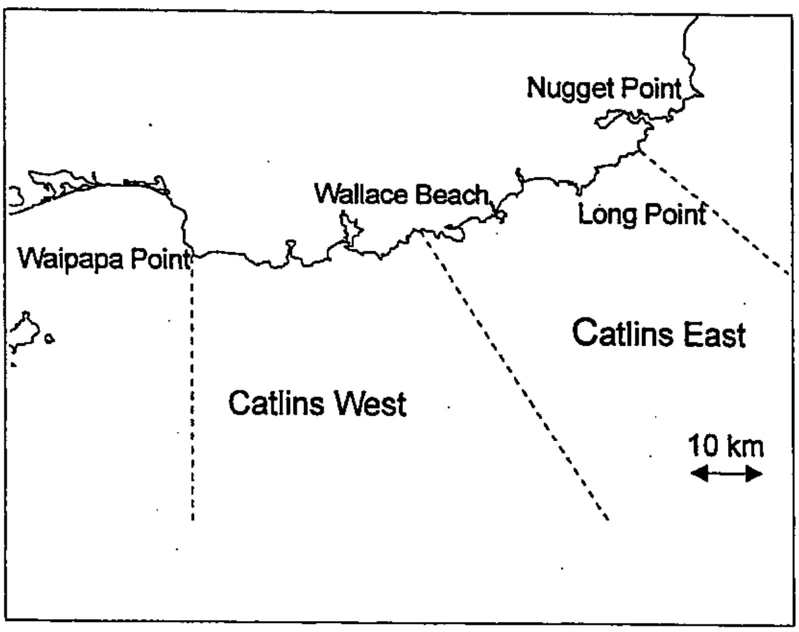

Figure 2: Research strata surveyed in PAU 5D.

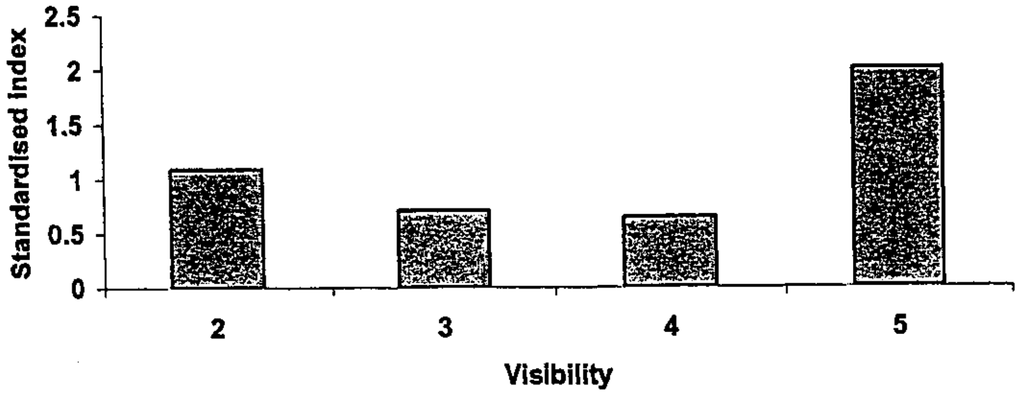

Figure 3: Standardised index by visibility (category 1 was not recorded).

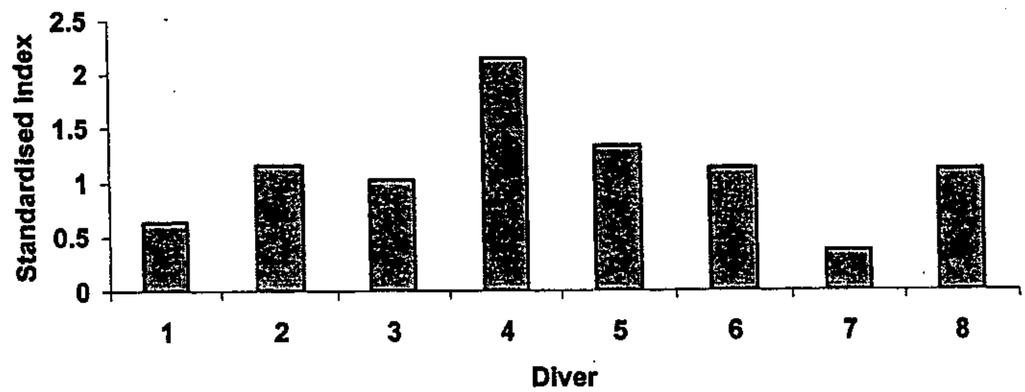

Figure 4: Standardised index by diver.

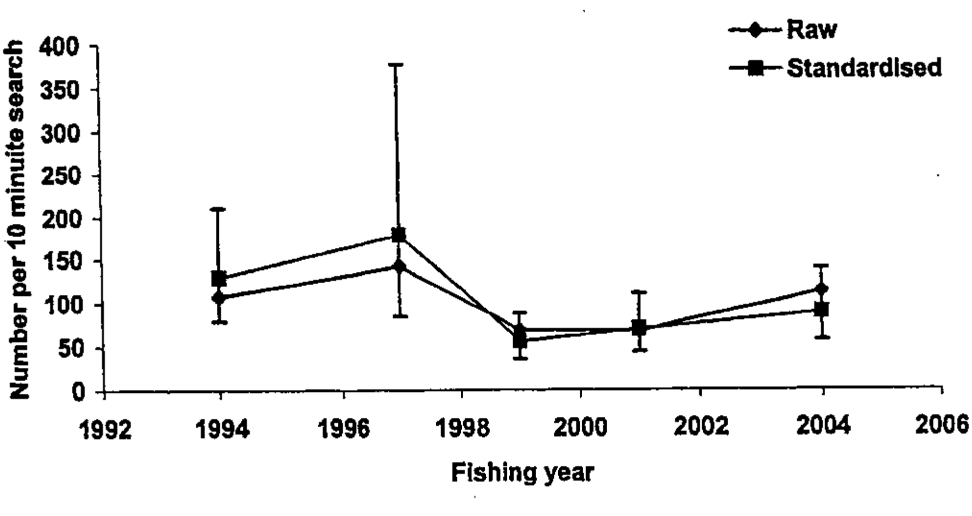

Figure 5: Number of paua per 10 minute search (Raw) and standardised abundance (number of paua per 10 minute search). The error bars indicates 2 standard error of the standardised abundance.

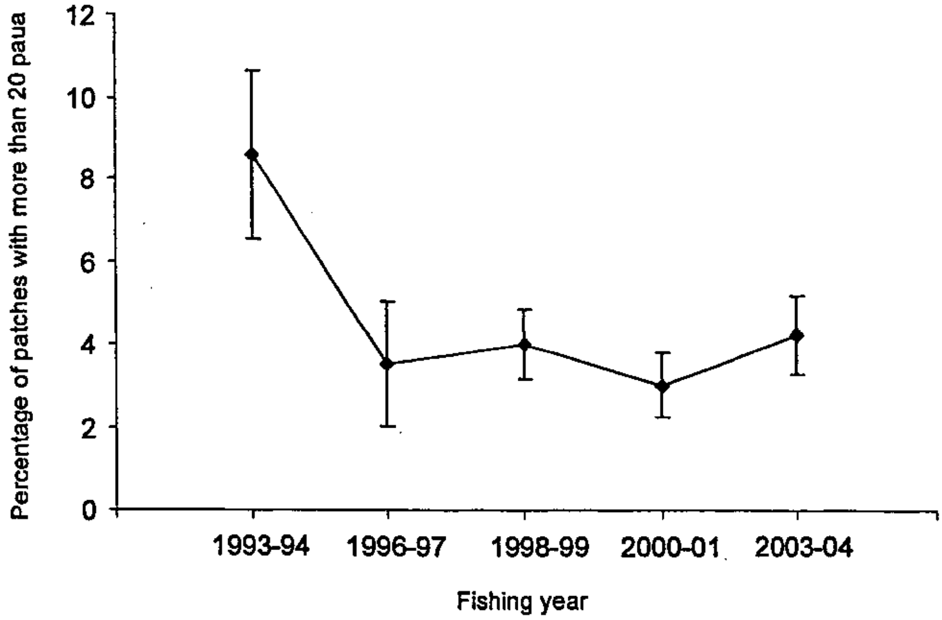

Figure 6: Percentage of patches with more than 20 paua (± SE).

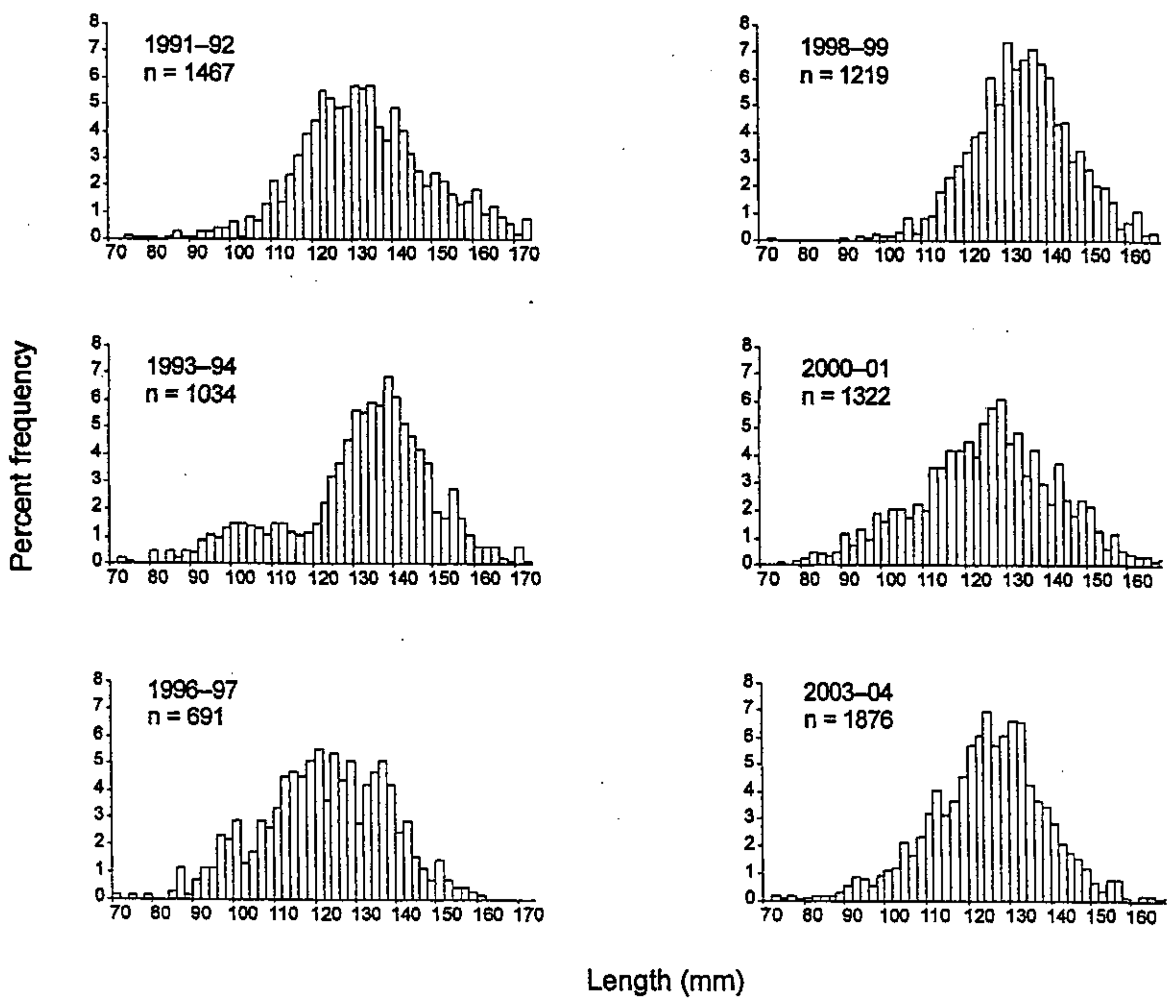

Figure 7: Length frequency Figudistributions of paua sampled from PAU 5D.