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Paua (*Haliotis iris*) length at maturity in PAU 2, PAU 5B, PAU 5D, and PAU 7

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EXECUTIVE SUMMARY

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Length at maturity data are used in paua stock assessments to estimate spawning stock biomass. Collecting this data from a range of sites within a Quota Management Area (QMA) will improve these estimates. Length at maturity was estimated at five sites in PAU 7, and four sites in each of PAU 2, PAU 5B, and PAU 5D. Length at maturity varied between sites within all QMAs, but the lengths at which 50% and 95% of samples were mature were generally about 90 mm and 100 mm respectively. The relationship between shell length, width, and height was also examined to determine whether the shell length to height ratios may be a useful predictor of length at maturity or the likely maximum size within a population. Shell length/height ratios varied between sites and ranged between 3.40 and 3.87. There was a strong linear relationship between length at maturity and length/height ratio. Shell weight was a slightly better predictor of maturity than shell length, but shell length is much easier to determine in the field.

1. INTRODUCTION

Length at maturity data are used as an input into the length-based Bayesian stock assessment model to help in the estimation of spawning stock biomass. To date, the proportion mature estimates within the model have been based on data collected from only a few sites around New Zealand and concerns have been raised about whether or not this limited pool of data accurately represents the variation in length at maturity throughout the paua fishery. The purpose of this project was to estimate the length at maturity at a number of sites within specific QMAs and estimate the level of variation in length at maturity both within and between QMAs. It is envisaged that the more extensive pool of data will help reduce uncertainty with the model and will help inform decisions on finer spatial scale assessments and management.

The relationship between shell length, width, and height was also examined to determine whether the shell length to height ratio may be a useful predictor of length at maturity or the likely maximum size within a population.

2. METHODS

Specific Objective One:
To determine length at maturity in PAU 2, PAU 5B, PAU 5D, and PAU 7.

Within each of PAU 2, PAU 5B, PAU 5D, and PAU 7 four sites were chosen for sampling after discussion with the relevant Paua Management Action Committees (PauaMacs). Sites were chosen to be geographically representative of the QMAs, but took into account the availability of previous estimates of length at maturity. The location of sites is shown in Figure 1 and their coordinates are listed in Table 1.

Size-at-maturity was estimated for 16 sites over the four QMAs. At each site sampled, a minimum of 100 paua between 50 mm and 125 mm shell length were collected and assigned to 2 mm sizes classes. As far as possible, these paua were evenly spread over this size range. All shells were tagged through their outer respiratory pores with numbered Hallprint cable tie tags (T2175A tags) so that maturity data could be easily cross referenced with the morphometric variables assessed in objective 2. Sexual maturation was determined by visual inspection of the testis or ovary. Paua in each size class were scored as: 0, immature (no visible signs of gametes); 1/2, just mature (some gametes visible but gut tissue visible through the gonad); and 1, mature (no gut tissue visible through the gonad). For estimating size-at-maturity, gonads scored as 'just mature' were considered immature because they are unlikely to make a significant contribution to gamete production (Poore 1973; Sainsbury 1982; Wilson & Schiel 1995, Naylor et al. 2006). Rates of maturity-at-length were determined by fitting these data to the logistic equation:

$$p = \frac{e^{a+bl}}{l + e^{a+bl}}$$

where p is the proportion mature, l is shell length, and a and b are parameters of the logistic function. The 95% confidence intervals of the ogive fit were estimated as 1.96 times the calculated standard error of the mean for each value.

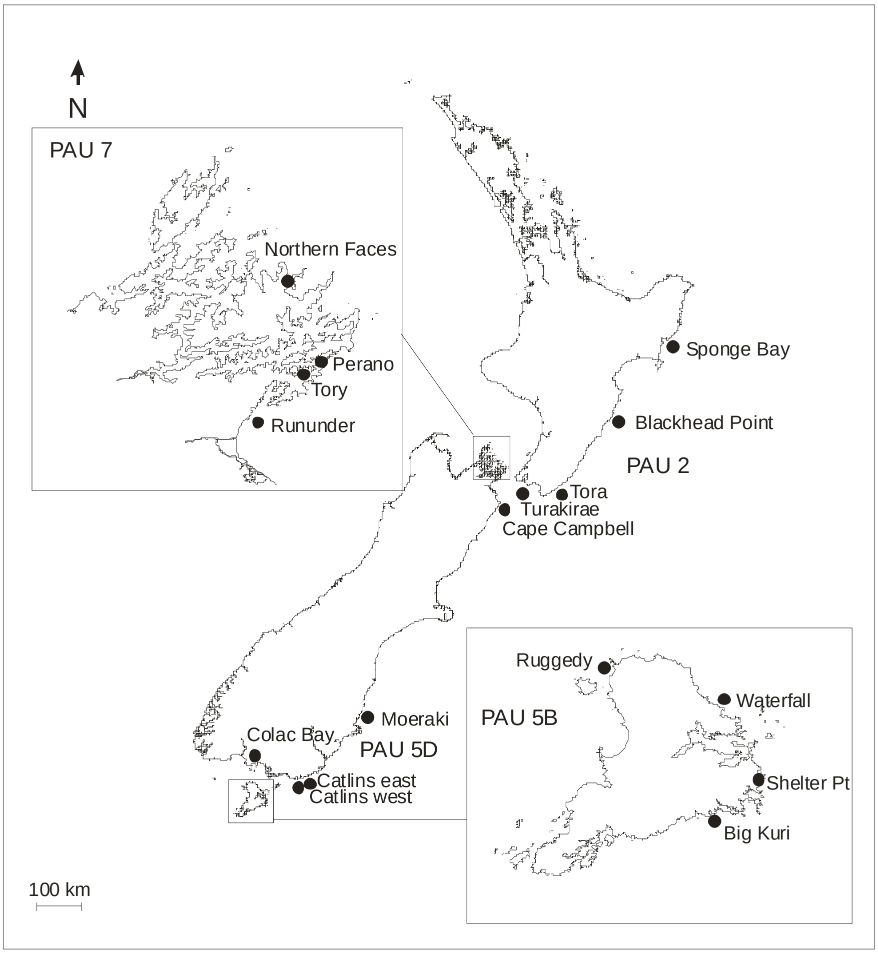

Figure 1: Location of sampling sites (black dots).

Most sampling was done between December and March to ensure that the paua sampled are at similar stages of their reproductive cycles. This is also the period over which weather conditions are generally more favourable and when longer days provide a larger sampling opportunity.

At each of the sites sampled for objective 1, about 100 shells were measured to determine their height, length and width. The length and width of each shell was measured to the nearest millimetre with vernier calipers. Shell height was measured to the nearest millimetre with modified vernier calipers, similar to the device described by Newman (1968), which measures the distance between the ventral plane and the highest point of the shell. Shells were also weighed to the nearest 0.1 gram and ratios of weight to length were calculated. For each site, a length at maturity relationship was fitted, and the length at 50% maturity (L50%) and 95% maturity (L95%) was calculated.

Specific Objective Two:

Determine the correlation between various shell morphometric markers (e.g. height, length, width) and length at maturity.

Regressions of these 10 maturity estimates with the shell height, width, length, and their ratios were used to determine if any relationships exist. Measures of shell length, width, weight, and height and their ratios are all likely to be correlated with each other, so individual multiple logistic regressions of each variable as a covariate in the length at maturity model were used to compare which measures of size have the strongest relationship with maturity. Data regressed also included those from sites sampled in PAU 3 and PAU 5A as part of MPI project PAU 2011-01.

3. RESULTS

Specific Objective One:

Length at maturity in PAU 2, PAU 5B, PAU 5D, and PAU 7.

Site coordinates, dates of sampling, sample size and lengths at maturity are shown in Table 1. Shell lengths at 50% and 95% maturity for sites are shown in Figures 2, 3, 4 and 5 for PAU 2, PAU 5B, PAU 5D, and PAU 7 respectively, and for all sites in Figure 6. The Catlins east sample was collected too late to be included in the analyses done for objective 2. This sample was taken about 20 km east of the Catlins west sample, but was just west of the Catlins east research stratum. The sample was collected in mid-August because poor diving conditions over the summer months had prevented sampling over that period. Samples from Colac Bay were not included in the analyses because all paua in the sample were mature. The industry diver has agreed to return and collect another sample encompassing the size range representing the transition to maturity. Once collected, the data from the Colac Bay site will be added to MPI's *dive* database and will be available for any future analyses. A total of 1842 paua were assessed for maturity over all sites. The seasonal timing of sampling was most often between December and March, but all sites in PAU 7 were sampled in September, and the Catlins west site was sampled in early May (Table 1).

In PAU 2, length at 50% maturity was about 92 mm for Tora and Turakirae, and about 95 mm at Blackhead Point (Table 1, Figure 2). At the more northern Sponge Bay site, L_{50} was slightly lower at about 85 mm. Length at 95% maturity was about 100 mm at Tora and Sponge Bay, about 105 mm at Turakirae, and about 109 mm at Blackhead Point. Lengths at 50% maturity do not appear to be significantly different between sites sampled within PAU 2 (Figure 6).

In PAU 5B, L_{50} was about 10 mm higher, ranging between about 99 mm and about 104 mm (Table 1, Figure 3). L_{95} at sites in PAU 5B was also much higher, with three sites ranging from about 108 mm to about 114 mm, and the Ruggedy site at 132 mm. Lengths at 50% maturity do not appear to be significantly different between sites sampled within PAU 5B and appear to be significantly higher than sites sampled in all other QMAs with the exception of the Northern Faces and Perano sites in PAU 7 (Figure 6).

In PAU 5D, L_{50} and L_{95} were about 93 mm and 102 mm respectively at the Catlins west site, about 84 mm and 92 mm respectively at the Catlins east site, and about 77 mm and 84 mm respectively at the Moeraki site (Table 1, Figure 4). Lengths at 50% maturity at the Moeraki and Catlins East sites appear to be significantly lower than at the Catlins West site, and significantly lower than all other sites in all QMAs with the exception of the Sponge Bay site in PAU 2 and the Campbell site in PAU 7 (Figure 6).

In PAU 7 L_{50} ranged between about 87 mm and about 99 mm and L_{95} ranged between about 97 mm and 106 mm (Table 1, Figure 5). Length at 50% maturity at the Northern Faces site appears to be significantly higher than most other sites in PAU 7, and significantly higher that sites in all other QMAs except PAU 5B.

Table 1: Date of sampling, lengths at maturity, and coordinates of sites sampled in PAU 2, PAU 5B, PAU 5D, and PAU 7.

QMA	Date	Site	L_{50} (mm)	L_{95} (mm)	n	Latitude	Longitude
PAU 2	28/2/2013	Tora	91.7	99.1	115	-41.487	175.574
PAU 2	1/3/2013	Turakirae	91.6	104.3	101	-41.435	174.912
PAU 2	26/3/2013	Sponge Bay	84.6	102.0	104	-38.707	178.049
PAU 2	27/3/2013	Blackhead Point	94.9	108.8	95	-40.221	176.789
PAU 5B	13/12/2014	Shelter Point	103.6	113.8	94	-47.070	168.174
PAU 5B	11/12/2014	Ruggedy	103.3	132.0	123	-46.704	167.745
PAU 5B	12/12/2014	Big Kuri	99.5	108.3	120	-47.118	168.042
PAU 5B	12/12/2014	Waterfall	98.9	110.5	131	-46.823	168.061
PAU 5D	27/03/2013	Moeraki	76.9	83.9	115	-45.367	170.866
PAU 5D	5/5/2016	Catlins west	92.8	102.2	103	-46.666	168.991
PAU 5D	14/8/16	Catlins east	83.5	91.8	142	-46.652	169.223
PAU 7	2/9/2013	Perano	94.5	106.3	112	-41.199	174.366
PAU 7	2/9/2013	Tory Channel	92.6	100.5	127	-41.215	174.309
PAU 7	2/9/2013	Rununder	91.8	104.2	126	-41.335	174.179
PAU 7	3/9/2013	Cape Campbell	87.1	96.9	86	-41.726	174.278
PAU 7	14/9/2013	Northern faces	98.9	109.2	123	-41.030	174.270

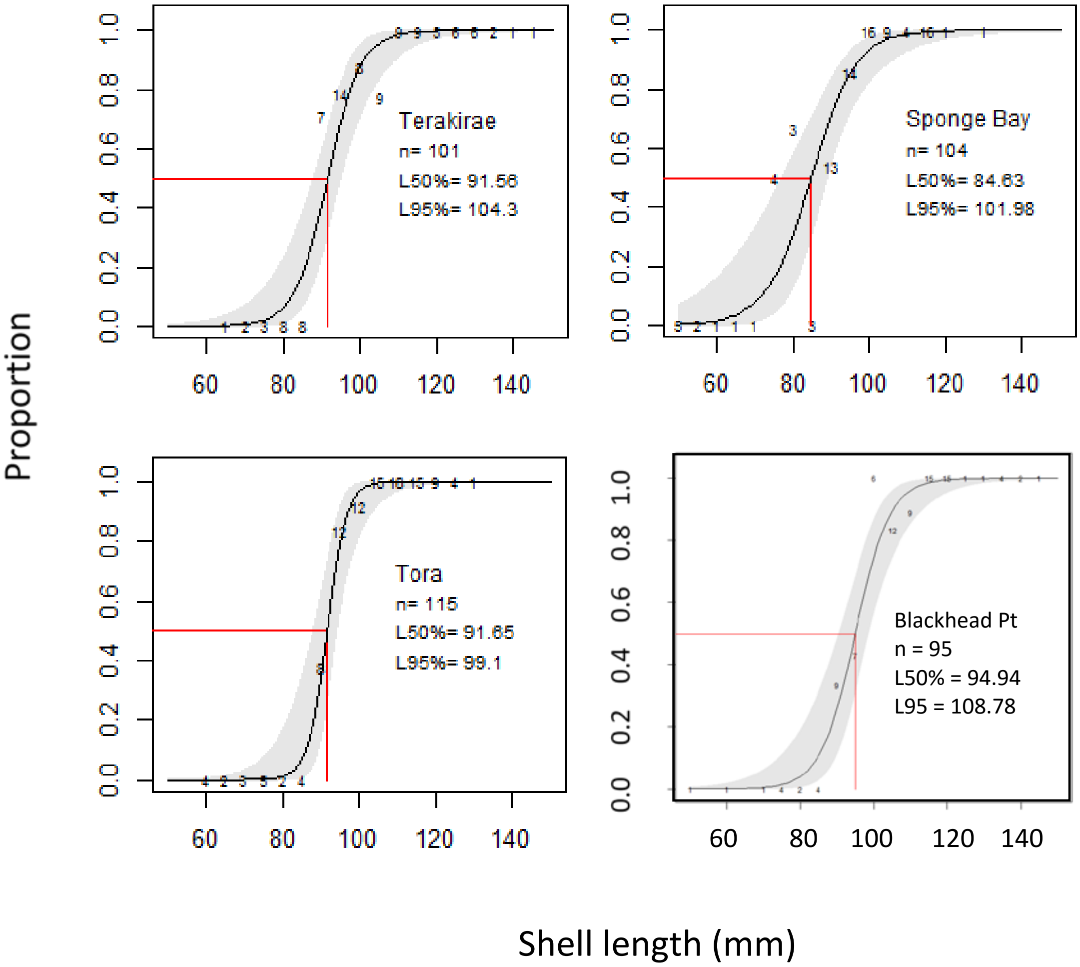

Figure 2: Proportion mature at length and fitted logistic curves for sites sampled in PAU 2. Numbers adjacent to ogives are the number of samples at that length.

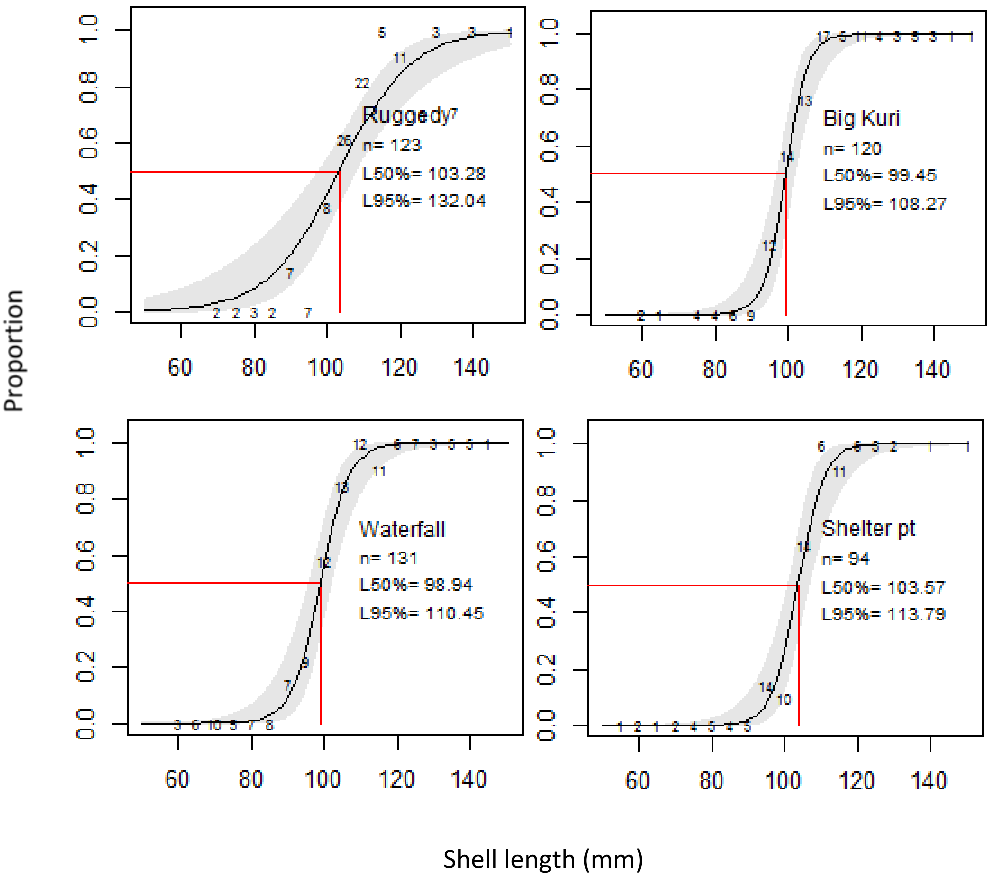

Figure 3: Proportion mature at length and fitted logistic curves for sites sampled in PAU 5B.

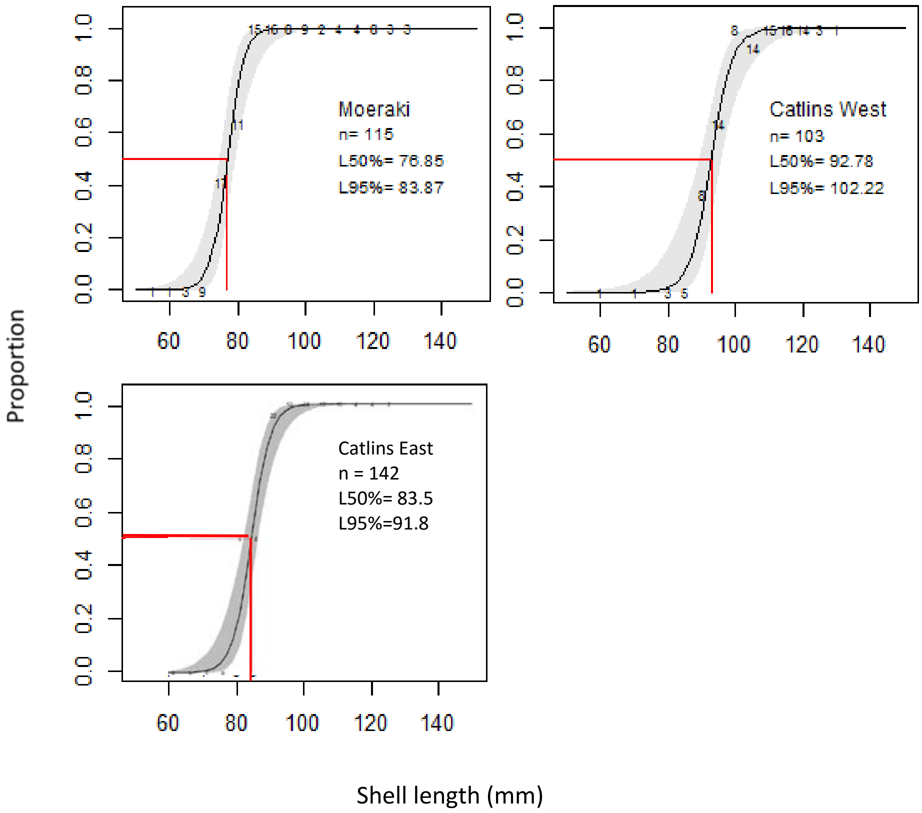

Figure 4: Proportion mature at length and fitted logistic curves for sites sampled in PAU 5D. Numbers adjacent to ogives are the number of samples at that length.

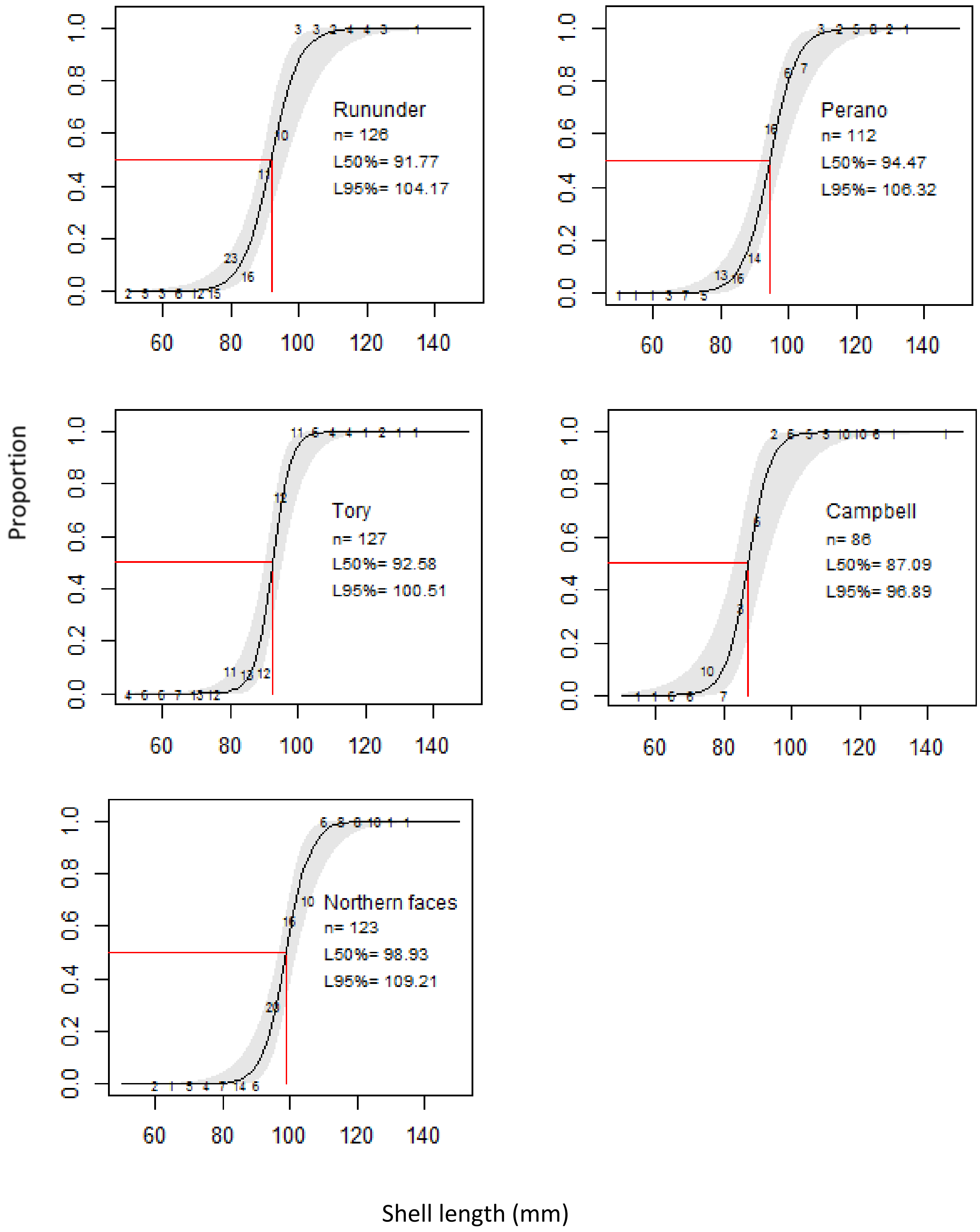

Figure 5: Proportion mature at length and fitted logistic curves for sites sampled in in PAU 7. Numbers adjacent to ogives are the number of samples at that length.

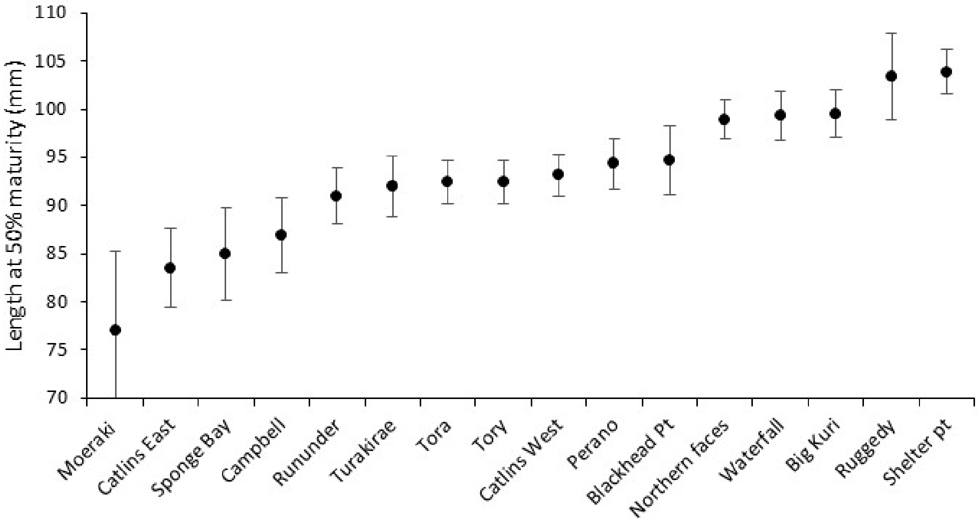

Figure 6: Lengths at 50% maturity and 95% confidence intervals for sites sampled in PAU 2, PAU 5B, PAU 5D, and PAU 7.

Specific Objective Two:

Relationship between various shell morphometric markers (e.g. height, length, width) and length at maturity.

Length to height ratios are shown in Table 2, and ranged between 3.4 at Sponge Bay to about 3.9 at Shelter Point. Length to height ratios and lengths at 50% maturity are shown in Figure 7. The two variables appear to follow similar trends and there is a strong linear relationship (corr = 0.81).

Table 2: Length to height ratios of paua sampled at sites in PAU 2, PAU 5B, PAU 7 and PAU 5D.

QMA	Site	Length/height ratio
PAU 2	Tora	3.49
PAU 2	Turakirae	3.49
PAU 2	Sponge Bay	3.40
PAU 2	Blackhead Point	3.72
PAU 5B	Shelter Point	3.87
PAU 5B	Ruggedy	3.72
PAU 5B	Big Kuri	3.75
PAU 5B	Waterfall	3.67
PAU 5D	Moeraki	3.42
PAU 5D	Catlins East	3.59
PAU 5D	Catlins West	3.53
PAU 7	Perano	3.75
PAU 7	Tory Channel	3.79
PAU 7	Rununder	3.57
PAU 7	Cape Campbell	3.52
PAU 7	Northern Faces	3.68

Width had the most explanatory power, but was not much better than length (Table 3). Given the relative ease of measuring length and the large database of length measurements, shell length is probably the most useful variable to associate with estimates of maturity.

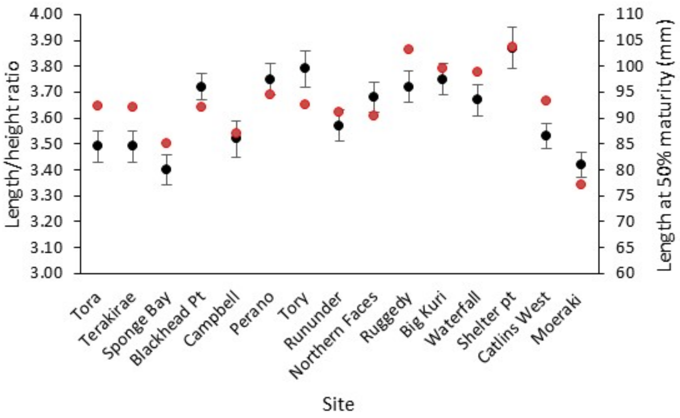

Figure 7: Lengths at 50% maturity (orange dots) and length to height ratios and 95% confidence intervals for sites sampled in PAU 2, PAU 5B, PAU 5D, and PAU 7.

Table 3: Regression fits to morphometric data.

Regression fits	**dF**	**AIC**
Length+Site	2 537	1 184.8
Height+Site	2 537	1 252.8
Weight+Site	2 537	1 693.4
Width+Site	2 537	1 154.0
HLR+Site	2 537	2 289.1
WidthLR+Site	2 537	2 699.0
HWeightR+Site	2 537	1 923.7

4. DISCUSSION

Most samples were collected over summer (December to April) in order to help reduce bias in the maturity estimates. The Catlins east site was sampled in August, and sites in PAU 7 were sampled in September. Paua usually spawn in late summer or early autumn (Poore 1973, Sainsbury 1982) but may spawn as late as August (McShane & Naylor 1996). It is possible that paua at the Catlins east site had already spawned at the time of collection. If enough paua had spawned to the extent that gonad tissue was not discernible even though they were mature, estimates could be biased upwards. It is very unusual; however, for paua to completely spawn so that no coloured gonad tissue is visible on the digestive gland (authors' unpublished information).

Length at 50% maturity varied within and between QMAs and ranged from about 77 mm at Moeraki in PAU 5D, to about 100 mm at sites in PAU 5B. Large variation in length at maturity for paua has sometimes been reported in the literature (e.g. Naylor et al. 2006), and much reduced lengths at maturity have usually been associated with 'stunted' populations, such as those around Taranaki or Banks Peninsula. Because the sites chosen for sampling in both QMAs in this work were chosen on the basis of their representing areas of the commercial fishery, it is not surprising that estimates of maturity are broadly similar.

Shell length to height ratios showed a strong relationship with estimated maturity at length. It is generally accepted that for paua, the shells of stunted or slow growing populations are relatively higher for their length, and this relationship was proposed by Saunders et al. (2008) as a possible method to identify 'stunted' populations. The range of values in their study was similar to those found here and they proposed that a shell height to length ratio of 3.25 or lower indicated that the local

population was ‘stunted’. A major difference in their work was that they deliberately sampled populations they knew to be ‘stunted’. If ‘stunted’ paua were sampled their shell length to height ratios may indicated that they were from areas of either slow growth or low maximum size.
The length at maturity information collected as part of this project should better inform the determination of spawning stock biomass in PAU 2, PAU 5B, PAU 5D, and PAU 7.

5. ACKNOWLEDGMENTS

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