ISSN 1175-1584

MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

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New Zealand Fisheries Assessment Report 2005/23
April 2005

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Trophia
P O Box 63
Kaikoura

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Published by Ministry of Fisheries
Wellington
2005

ISSN 1175-1584

Citation:
Hart, A.M. (2005).
Surveys of pre-recruits of *Jasus edwardsii* in CRA 8
using modified commercial pots – a pilot study.
New Zealand Fisheries Assessment Report 2005/23. 24 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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A pilot study was undertaken in the CRA 8 *Jasus edwardsii* fishery to investigate the feasibility of measuring pre-recruit abundance and size using modified commercial pots. Five rock lobster vessels set experimental pots from August to November 2001 at 14 sites between mid Fiordland and eastern Stewart Island. At each site, pots were set in pairs of one normal commercial pot (N) and one without escape gap (WE) pot, and lifted between 5 (Site 10) and 29 (Site 3) times. All lobsters were counted; their tail width was measured and sex status identified, and the data were recorded on data sheets adapted from the logbook programme. The catches of WE and N pots were compared statistically using 10 abundance and 10 size indicators, which included total number caught, overall average size, number of pre-recruits (under 54 mm tail width [TW]), average size of pre-recruits and average size of large lobsters (over 60 mm TW).

A total of 6592 lobsters between 28 and 90 mm TW were sampled, measured, and sexed. Of these, 4528 (69%) were caught in WE pots, and 2064 (31%) were caught in N pots. The difference in numbers caught between the two pot types was due to the pre-recruit portion of the population, which were caught in far greater numbers by WE pots. WE pots sampled animals as small as 28 mm TW and clear differences in size-frequency between sites were evident.

There was no statistical difference between pot types in estimating parameters of the post-recruited population; the WE pots caught similar numbers and sizes of post-recruits, berried females, and large lobsters (over 60mm TW). The difference in average size of large lobsters measured by the two pot types was 0.4 mm. Post-hoc power analysis revealed that all tests were sufficiently powerful to detect small differences. For example, minimal detectable difference (between WE and N pots) in numbers of post-recruit (above 54 mm TW) lobsters was 1.1 lobsters per pot (19% of a mean of 5.7); the minimal detectable difference for average size of post-recruits was 1 mm (2% of a mean of 57.9 mm).

Commercial pots with closed escape gaps provide substantial potential for monitoring the abundance and size of pre-recruit *Jasus edwardsii* in CRA 8. Optimal design is achieved by sampling 50 sites at 5 potlifts per site. A site allocation regime is necessary to ensure these sites are representative of the population. If a pre-recruit index of abundance is required for management of the CRA 8 fishery, a monitoring programme using WE pots could be implemented, with due consideration to quality control issues as discussed within this report. Further tests of the sampling efficiency of WE pots would be advantageous, and detailed recommendations are made.

1. INTRODUCTION

Knowledge of the recruitment strength in lobster fisheries is a valuable management tool. A measure of the strength of upcoming year classes presents options for management not available when only the relative abundance of the fished stock is known. An index of pre-recruit abundance can be used to forecast changes in the abundance of the recruited population, and consequently the appropriate annual catch. The relative strength of settlement can be used as a predictor of subsequent recruitment in lobster fisheries (Booth & Phillips 1994), and the relative abundance of the first settlement stage, pueruli, has been used successfully in the West Australian lobster fisheries to predict catch (Caputi et al. 1995). However, in the CRA 8 fishery there is a large time lag (6 to 8 years) between settlement and recruitment, and there are logistical difficulties in obtaining settlement data. Dive surveys of pre-recruits at Stewart Island have detected 2 and 3 year olds (Breen & Booth 1989); however the surveys were discontinued in 2000 because of the prohibitive cost of running the programme alongside puerulus collectors.

Surveys to measure the relative abundance of organisms over time should be optimised by the use of pilot studies to collect information about the efficiency of the sampling gear and the spatial and temporal variability inherent in the population under consideration (Snedecor & Cochran 1989). This information can be used in cost-benefit analyses to determine optimal levels of replication in long-term monitoring programme's and allow *a priori* decisions to be made about what level of precision is required and what level of precision is possible from any proposed sampling designs (Horppila & Peltonen 1992; Montgomery 2000).

This pilot study examined the feasibility of obtaining a pre-recruit abundance index with a modified pot design in CRA 8. It complemented objective 8 of the 2000-01 Ministry of Fisheries rock lobster research project, which was to examine the relationship between recruitment indices derived from puerulus collectors, juvenile dive surveys, and the observer and logbook catch sampling programmes and make recommendations on the most appropriate way of predicting recruitment to the fishery.

Information gained from this study was used to design a long-term monitoring program for pre-recruits in CRA 8. The objectives of the study were:

Objective 1: to identify appropriate sites for monitoring pre-recruit abundance.

Objective 2: to identify a pot design suitable for pre-recruit surveys at each site.

Objective 3: to carry out a pilot survey of pre-recruit rock lobsters in CRA 8.

Objective 4: to design a long-term pre-recruit monitoring programme.

2. METHODS AND RESULTS

2.1 Study sites

The participating fishers (Jerry Excell, Brett Hamilton, Colin Hopkins, Mark Peychers, Peter Young) selected 14 sites for the pilot study (Table 1, Figure 1) based on their fishing experience and knowledge of distribution of pre-recruits of *Jasus edwardsii* in this area.

2.2 Pot types

Following initial discussions, the consensus was that pot design be kept simple and logistically feasible (i.e., be able to be incorporated into normal fishing activity). Two types of pot were compared in this study: normal commercial pots (N) and pots with escape gaps closed up (WE). Pots varied slightly in size between sites (Stewart Island pots are generally larger than those used in Fiordland). However within sites, WE pots were exactly the same as the N pots. Special permits were obtained from the Ministry of Fisheries to allow escape gaps to be closed during the experiment.

2.3 Experimental design

Pots were baited in the normal manner at each site, set in pairs (WE/N), and lifted between 5 (Site 10) and 29 times (Site 3). The experiment was carried out between 9 August and 1 November 2001, and each participant used their local knowledge of the 'biting phase' to determine time of sampling. At each potlift, all lobsters were counted and sexed, their tail width (TW) was measured, and data were recorded on data sheets modified from those used in the logbook programme (Starr & Vignaux 1997). Participants were given appropriate codes for recording their information.

2.4 Data analysis

Twenty abundance and size variables were statistically compared between the pot types. These were: 1) total number caught; 2) number of pre-recruits (under 54 mm TW); 3) number of post-recruited lobsters (over 54 mm TW); 4) number of large lobsters (greater than 60 mm TW); 5) total number of males; 6) total number of females; 7) number of male pre-recruits; 8) number of male recruits; 9) number of female pre-recruits; 10) number female recruits (greater than 57 mm TW); 11) average size caught; 12) average size of pre-recruits; 13) average size of recruited lobsters (over 54 mm TW); 14) average size of large lobsters (over 60 mm TW); 15) average size of males; 16) average size of females; 17) average size of male pre-recruits; 18) average size of males recruits; 19) average size of female pre-recruits; 20) average size of female recruits (over 57 mm TW).

Data were analysed by a paired *t*-test to determine the effect of pot design on abundance and size (Table 2). Post-hoc power analyses following the procedures of Zar (1984) were carried out where appropriate. Evidence for 'biting phase' was examined by Pearson correlation analysis of catches of pre- and post-recruits.

2.5 Optimal monitoring design

The optimal monitoring design for pre-recruit surveys of *Jasus edwardsii* requires a two stage sampling survey (Snedecor & Cochran 1989). The primary sampling unit is site, with the secondary sampling unit being pot lifts (within sites). In the absence of cost constraints, optimal design is achieved by minimising variance (maximising precision) obtained by sampling different replicate samples of sites and potlift.

The formulas for estimating variance components are from Snedecor & Cochran (1989). Variance for the mean number of lobsters per site per potlift ($V_{\bar{x}}$) is:

$$V_{\bar{x}} = V_s/n_s + V_p/(n_s n_p) \quad (1)$$

where $V_{\bar{x}}$ is the variance of the mean number of lobsters per site, and is calculated as:

$$V_s = (MSS - MSP)/n_p \quad (2)$$

where *MSS* and *MSP* are the mean square estimates for the site and potlift (error) factors respectively, obtained from an ANOVA. The ANOVA that generated *MSS* and *MSP* used data from 11 sites with 13 potlifts per site. Appendix 1 shows the ANOVA results for each variable.

V_p is the variance of the mean number of lobsters per potlift, and is same as *MSP*, n_s is the number of sites, and n_p is the number of potlifts per site. Simulations assessed the effect of number of sites (5 to 40), and number of potlifts per site (3 to 30) on $V_{\bar{x}}$.

3. RESULTS

A total of 6592 lobsters were caught, measured, and sexed (Table 1). Of these, 4568 (69%) were caught in WE pots, and 2064 (31%) in N pots.

3.1 Analysis of lobster abundance

3.1.1 Differences between pot types

Pots with closed escape gaps caught significantly more lobsters overall, pre-recruits, males, females, male pre-recruits, and female pre-recruits (Table 2).

3.1.2 Similarities between pot types

There was no significant difference between pot types in numbers of post-recruited lobsters (over 54 mm TW), numbers of large lobsters (over 60 mm TW), number of post-recruited males (over 54 mm TW), number of post-recruited females (over 57mm TW), or number of berried females (Table 2). The average difference between WE and N pots for total number of post-recruits was 0.02 (Table 2); for total number of post-recruit males, the average difference was –0.13 lobsters; for total number of post-recruited females, the average difference was –0.05 lobsters; for number of berried females, the average difference was 0.19 lobsters.

Power analysis revealed that for the non-significant results, all tests had sufficient power to detect biologically relevant differences (Table 3). For example, the minimum detectable difference in numbers between pot types for total numbers of post recruit lobsters (over 54mm TW) was 1.1 lobsters at a power of 0.8; for post-recruited males it was 0.4 lobsters; for large lobsters and berried females it was 0.4 and 0.5 lobsters respectively (Table 3).

3.1.3 Temporal variation in catches

The daily catches (number per pot) during sampling at Sites 2, 3, 6, 11 and 13, are shown in Figures 2 and 3. These figures are representative of all sites and include a site with a small number of WE/N potlifts (Site 11 – 8 potlifts) and the site with the greatest number (Site 3 – 29 potlifts). At each site there appears to be a cyclical pattern over 10 to 14 days. The pattern is of sharp increases in catches followed by declining catches, then sharp increases, and is similar for pre-recruits and recruits. At most sites, catch rates of pre-recruits were significantly positively correlated with catches of post-recruits (Table 4).

3.2 Analysis of lobster sizes

3.2.1 Differences between pot types

Compared to N pots, WE pots caught lobsters with significantly lower overall average size, lower average size of pre-recruits, lower average size of males, lower average size of females, lower average size of male pre-recruits, and lower average size of female pre-recruits (see Table 2).

3.2.2 Similarities between pot types

There was no significant difference in average size of post-recruited lobsters, post-recruited males, post-recruited females, berried females, or large lobsters between pot types (see Table 2). The average difference in lobster tail width between WE and N pots was 0.02 mm for all post-recruited lobsters, 0.4 mm for post-recruit males, 0.3 mm for commercial sized females, 1.9 mm for berried females, and 0.08mm for large lobsters (Table 2).

Power analysis revealed that for the non-significant results, all tests had adequate power to detect biologically relevant differences (Table 3). For example, the minimum detectable difference for size of post-recruit males was 0.9 mm at a power of 0.8. For post-recruit females, the minimal detectable difference was 1.5 mm at a power of 0.8; for berried females the MDD was 3.3 mm.

3.2.3 Size-frequencies of lobsters caught

Size-frequency comparisons for different combinations of pot design, sex, and sites, are shown in Figures 4 to 7. Distinct pre-recruit size-classes are evident at some sites (Figure 7e).

3.3 Optimal sample design

Sampling more than 40 sites at a maximum of 5 potlifts per site achieved minimal decrease in variance (increase in precision) for either total numbers per potlift (Figure 8) or any variable describing various sub-components of the population (Figure 9). Between-site variation is the main contributor to variance in estimates of mean numbers per site per potlift, and maximising the sites visited and minimising the potlifts per site will generally decrease variance (Figure 8 and 9).

Optimal design is achieved by sampling 50 sites at 5 potlifts per site. Using estimates of average effort (26 minutes travel to the site, lift pot, measure lobsters, bait, and re-set) and catch rate (22 lobsters per WE pot) by participating fishers, the optimal design will be achieved at approximately 60 to 70% of the effort required to obtain data for this pilot study, and result in 5500 lobsters for size-fequency and catch rate analysis.

4. DISCUSSION

The closing of escape gaps on commercial pots resulted in successful sampling of pre-recruits (under 54mm TW) of *Jasus edwardsii.* The WE pots appear to be sampling a number of pre-recruit size classes, although this figure varies between sites and sometimes four size classes are evident in the data (West Stewart Island – Sites 11 and 12). Whether these correspond to age classes is undetermined. These results confirm the hypothesis that WE pots can be a useful sampling tool for monitoring the abundance and size of pre-recruit *Jasus edwardsii* in CRA 8.

There are a number of issues to be considered in designing a long-term pre-recruit monitoring programme. The discussion below makes the assumption that commercial vessels would be available to undertake pre-recruit sampling in a manner similar to that achieved during the pilot study.

First, the objective(s) of the programme need to be clearly specified, as it (they) will influence the sampling design and data analysis. In CRA 8, the objective is likely to be something like: 'To obtain an index of pre-recruit abundance of rock lobster for input into a decision rule process for TACC setting.'

Second, what is to be the index of pre-recruit abundance? Consideration of the likely index (e.g., should it be a specific size range, or all lobsters below 54 mm TW) has important implications for the placement of sampling sites – some sites may be more representative of certain year classes.

Third, how will the index be measured? In most monitoring programme's the objective is to measure temporal variation, and not to confound spatial variation with this measure. Consequently, fixed sites are usually recommended, but they need to be representative of the population distribution. Changes in lobster habitat and distribution over time will also affect site allocation and the program may need to adapt to these changes. In CRA 8, there is also a biological imperative to ensure sampling coincides with the biting phase of pre-recruit lobsters, which is known to vary between areas. This can be controlled to some extent by fishers using local knowledge on which to base their decisions to begin sampling. It would be prudent to formalise a site allocation process that deals explicitly with these considerations.

Fourth, what level of between-site and within-site replication is appropriate? The results showed that, regardless of cost constraints, sampling 50 sites and 5 potlifts per site is the optimal design. This would require less sampling effort than that put into this pilot study and is therefore easily achievable and recommended. The main point to note is that the general conclusions of this pilot study (many sites, minimal replication per site) are supported by theoretical studies on optimal designs of monitoring programmes for fisheries and the marine environment (Warren 1994; Van der Meer 1997).

Long-term monitoring programmes require quality control of the logistical variables influencing the integrity of the data. These include: 1) site location and integrity, for example, ensuring that GPS locations are adequately protected; 2) standardisation of pot design - the ideal is to have the monitoring pots all one design, which is not feasible in CRA 8 because the optimal pot design for catching lobsters differs between locations. However, pot design can be standardised for individual sites, as was the case in this study. 3) Recapture of lobsters previously measured. If the sampling strategy at sites is sequential (i.e., 1 x WE pot set 5 times, rather than 5 x WE pots set simultaneously), a potential bias in the data arises if lobsters are recaptured. Sampling at sites should be simultaneous.

For each site, or groups of sites, a data sampling protocol that details the requirements for that particular site must be developed, so that as participants change over the long term, the data is still being collected accurately and with sampling gear that is comparable. A technician is likely to be necessary to oversee the programme.

4.1 Other implications

The paired pot comparison yielded some interesting results not forecast by the design, but of relevance to planning a monitoring program.

WE pots proved equally as effective as normal commercial pots in estimating abundance and measuring the size of the recruited portion (over 54 mm TW) of the lobster population. This was true for all lobsters over 54 mm TW, and for subsections of the recruited population, such as males only, females only, berried females, or large lobsters. Thus, WE pots could be used to monitor the overall *Jasus edwardsii* population and not just the pre-recruits, although sampling would need to account for differences in spatial distribution between pre- and post-recruits.

The WE/N comparison presented a good test of the effectiveness of the escape gaps in allowing the escape of undersized lobsters; the N pots could be made more effective at reducing under-size catch by building of more escape gaps within them. This observation was made by one of the participants in the pilot study and further tests would be advantageous.

The 'paired pots' experimental design demonstrated itself as a useful experimental tool that can be used to improve sampling efficiency. A question to be resolved is, what is the selectivity of the WE pots at the smaller size classes (under 4 5mm TW)? This could be addressed by comparing WE pots with a pot design that has closed escape gaps and a modified entrance funnel that allows only lobsters under, say 48 mm TW, to be caught. Such an experiment may yield even more data on pre-recruit abundance and hence improve the possibility of gaining a predictive index.

5. ACKNOWLEDGMENTS

This study was funded by the CRA 8 Management Committee Inc. John Steffens organised the project and read the draft reports. Many thanks to the lobster fishers who volunteered to collect the data and subject their fishing activities to the constraints of experimental design. They were Jerry Excell, Brett Hamilton, Colin Hopkins, Mark Peychers, and Peter Young. Christine Vissier collated the data and entered it into the database. Helen Reagan and Daryl Sykes ensured that permits were issued for closing the escape gaps and extra logbook data forms were sent to the participants. The study benefited significantly from the existing logbook programme, which meant a ready supply of trained hands and eyes for measuring, and sexing the lobsters. Terese Kendrick, Nathan Walker, Kevin Sullivan, and Paul Breen read various drafts of the report.

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Table 1: Site names, location, depth, and number of *Jasus edwardsii* caught. WE, commercial pots with escape gaps; N, normal commercial pots; *n*, sample size (number of paired potlifts)

Site	Site name	General Location	Depth (m)	WE	N	*n*
1	South Point	Mid-Fiordland (Charles/George)	46	304	97	15
2	House Roof Rock		46	563	155	24
3	Yogi Hut	South Fiordland (Chalky/Dusky)	55	866	357	29
4	Weather Station		46	105	42	12
5	Steveys		73	622	264	19
6	West Point Coal Island	South Shore (Foveaux Strait)	30	337	120	16
7	South – East Chalky		40	287	216	25
8			65	86	54	8
9			50	70	84	9
10			75	33	13	5
11	Jackson's River	Stewart Island (West)	64	150	89	8
12	Little Patch		46	166	106	8
13	Breaksea Islands	Stewart Island (South-East)	64	511	238	15
14	Lords River		73	428	229	15
		TOTALS		4568	2064	206

Table 2: Results of paired *t*-test comparison between WE and N pots for estimating number (A), and size (B) of *Jasus edwardsii*. H_0, mean of the difference (WE – N) was not significantly different from 0.

	df	Difference (WA-N)	*t*-statistic	*p*-value	#Result
(A)					
Total numbers	206	12.3	11.7	0.001	***
Number of post-recruit lobsters (≥ 54mm TW)	206	0.02	0.054	0.96	ns
Number of pre-recruits (< 54mm TW)	206	12.3	13.9	0.000	***
Number of large lobsters (≥ 60mm TW)	206	-0.04	-0.25	0.80	ns
Total number of males	206	4.97	10.1	0.002	**
Number of post-recruit males	206	-0.13	-0.89	0.37	ns
Number of pre-recruit males	206	5.10	11.7	0.002	**
Number of females	206	7.35	11.4	0.001	***
Number of post-recruit females (≥57mm TW)	206	-0.06	-0.21	0.83	ns
Number of pre-recruit females (< 54mm TW)	206	7.20	13.7	0.000	***
Number of berried females	206	0.19	1.08	0.28	ns
(B)					
Overall tail width	186	-4.3 mm	-12.8	0.000	***
Tail width of post-recruit lobsters (≥ 54mm TW)	169	-0.02 mm	-0.05	0.96	ns
Tail width of pre-recruits (< 54mm TW)	155	-2.9 mm	-12.0	0.000	***
Tail width of large lobsters (≥ 60mm TW)	70	0.08 mm	-0.08	0.93	ns
Tail width of males	155	-4.1 mm	--11.1	0.000	***
Tail width of post-recruit males (≥ 54mm TW)	83	-0.4 mm	-1.25	0.22	ns
Tail width of pre-recruit males (< 54mm TW)	129	-3.2 mm	-10.5	0.000	***
Tail width of females	178	-4.4 mm	-13.5	0.000	***
Tail width of post-recruit females (≥ 57mm TW)	108	0.3 mm	-0.5	0.62	ns
Tail width of pre-recruit females (< 54mm TW)	98	-2.8 mm	-11.3	0.000	***
Tail width of berried females	43	-1.9 mm	-1.63	0.11	ns

* for size variables, dfs are different because the comparison was possible only for potlifts where both WE and N pots caught the target size class, and this varies for each size class.

ns – non-significant result, * p<0.05; **p<0.01, ***p<0.001

Table 3: Minimum detectable differences (MDDs) for abundance and sizes of *Jasus edwardsii* for non-significant effects of pot design. MDDs are calculated at a power (1-β) level of 0. 8, and expressed as units (numbers or mm), and % of overall mean.

Variable	MDD
Abundance	
Number of post-recruit lobsters (≥ 54mm TW)	1.1 (19%)
Number of post-recruit males	0.4 (28%)
Number of post-recruit females (≥ 57mm TW)	0.6 (29%)
Number of berried females	0.5 (45%)
Number of large lobsters (≥ 60mm TW)	0.4 (35%)
Size	
Average tail width of post-recruit lobsters (≥ 54mm TW)	1 mm (2%)
Average tail width of post-recruit males (≥ 54mm TW)	0.9 mm (2%)
Average tail width of post-recruit females (≥ 57mm TW)	1.5 mm (3%)
Average tail width of berried females	3.3 mm (5%)
Average tail width of large lobsters (≥ 60mm TW)	2.6 mm (4%)

Table 4: Pearson's correlation coefficient (*r*) between catches of pre-recruits (<54 mm TW) and post-recruits (≥ 54 mm TW) in WE pots at each site. *n* – number of potlifts

Site	*r*	Result	*n*
1	0.75	**	15
2	0.47	*	24
3	0.46	*	29
4	0.78	**	12
5	0.75	***	19
6	0.44	ns	16
7	0.51	**	25
8	0.29	ns	8
9	0.86	**	9
10	0.98	**	5
11	0.7	ns	8
12	0.32	ns	8
13	0.53	*	15
14	0.54	*	15

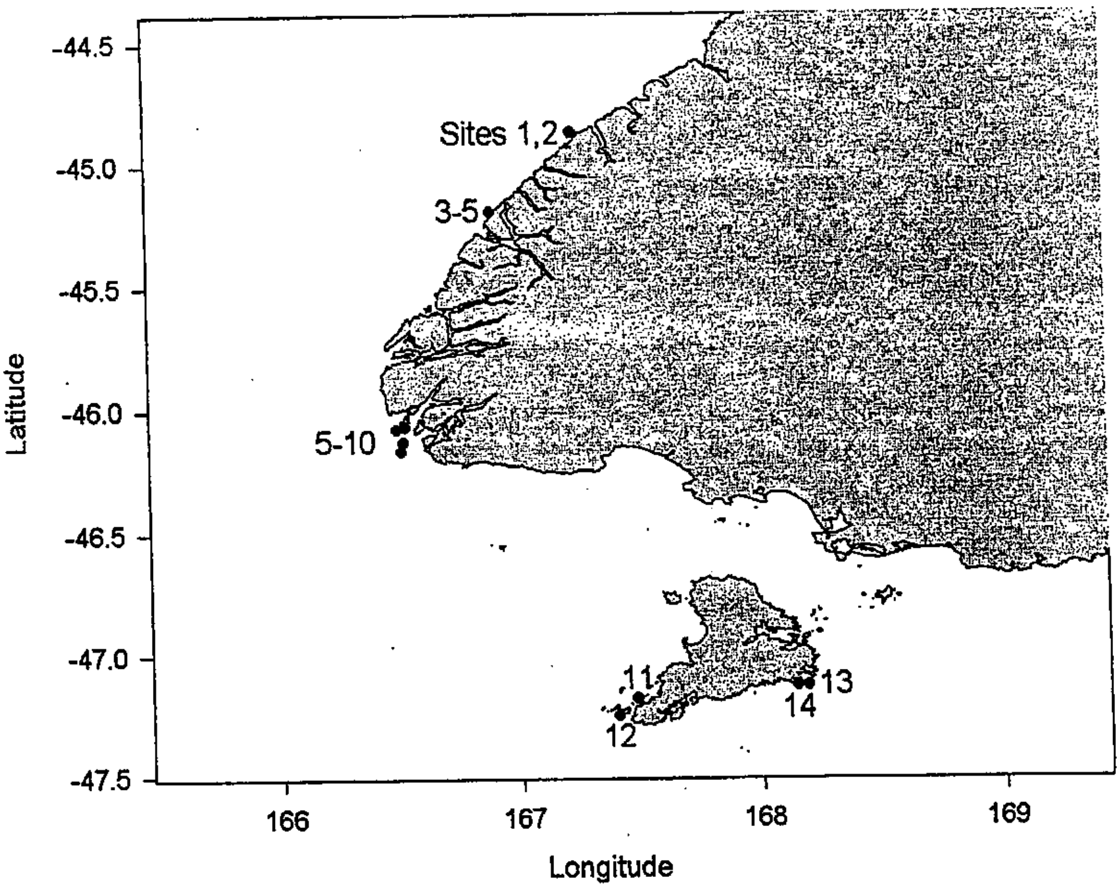

Figure 1: Map of Fiordland and Stewart Island showing approximate locations of study sites.

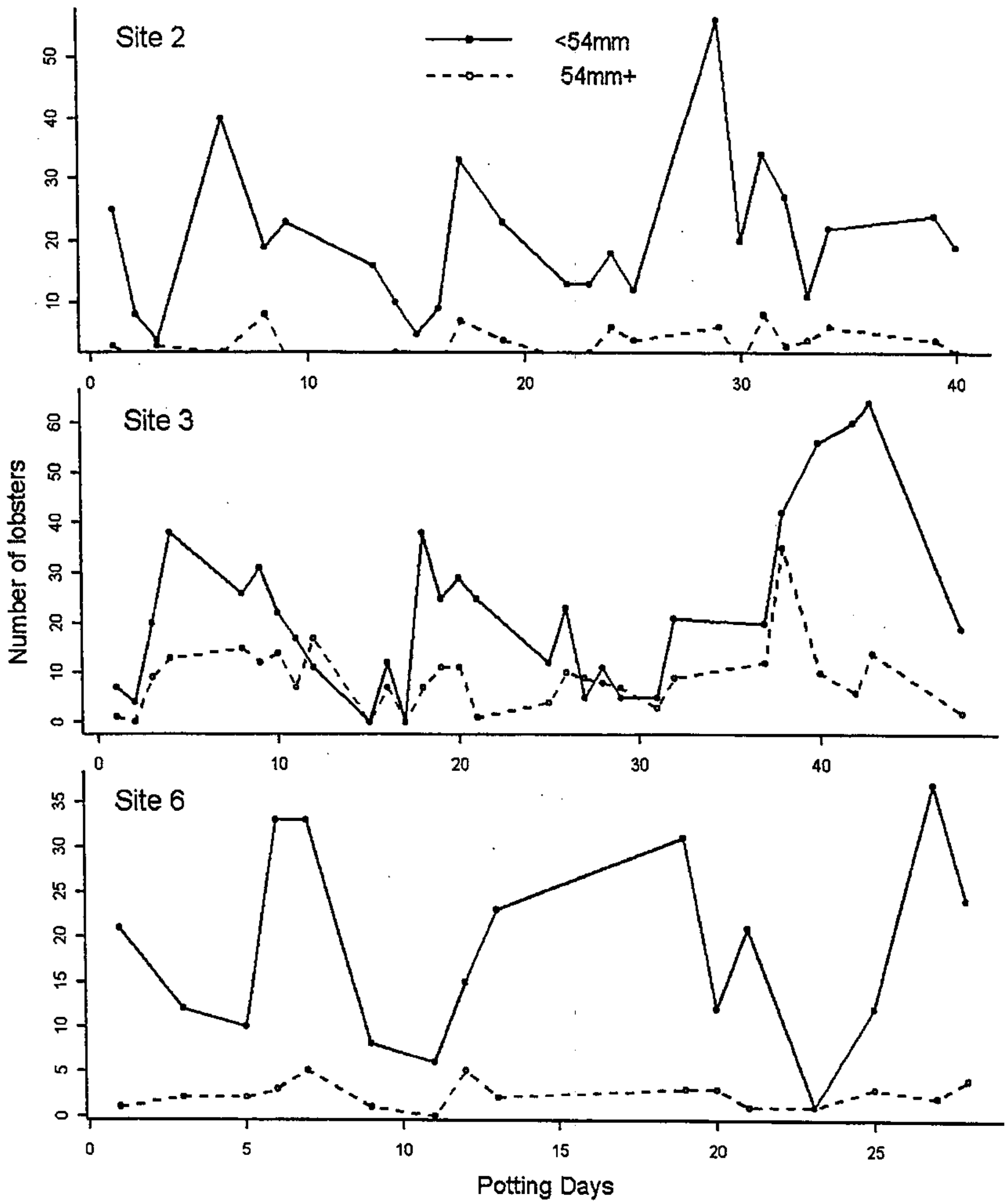

Figure 2: Potting behaviour (numbers caught over the sampling period) of pre-recruits (<54 mm TW) and post-recruit (54 mm+ TW) lobsters in the WE pots at Sites 2, 3, and 6. Individual points indicate a potlift; thus at Site 2, 24 potlifts were made over 40 potting days; at Site 6, 16 potlifts were made over 28 potting days.

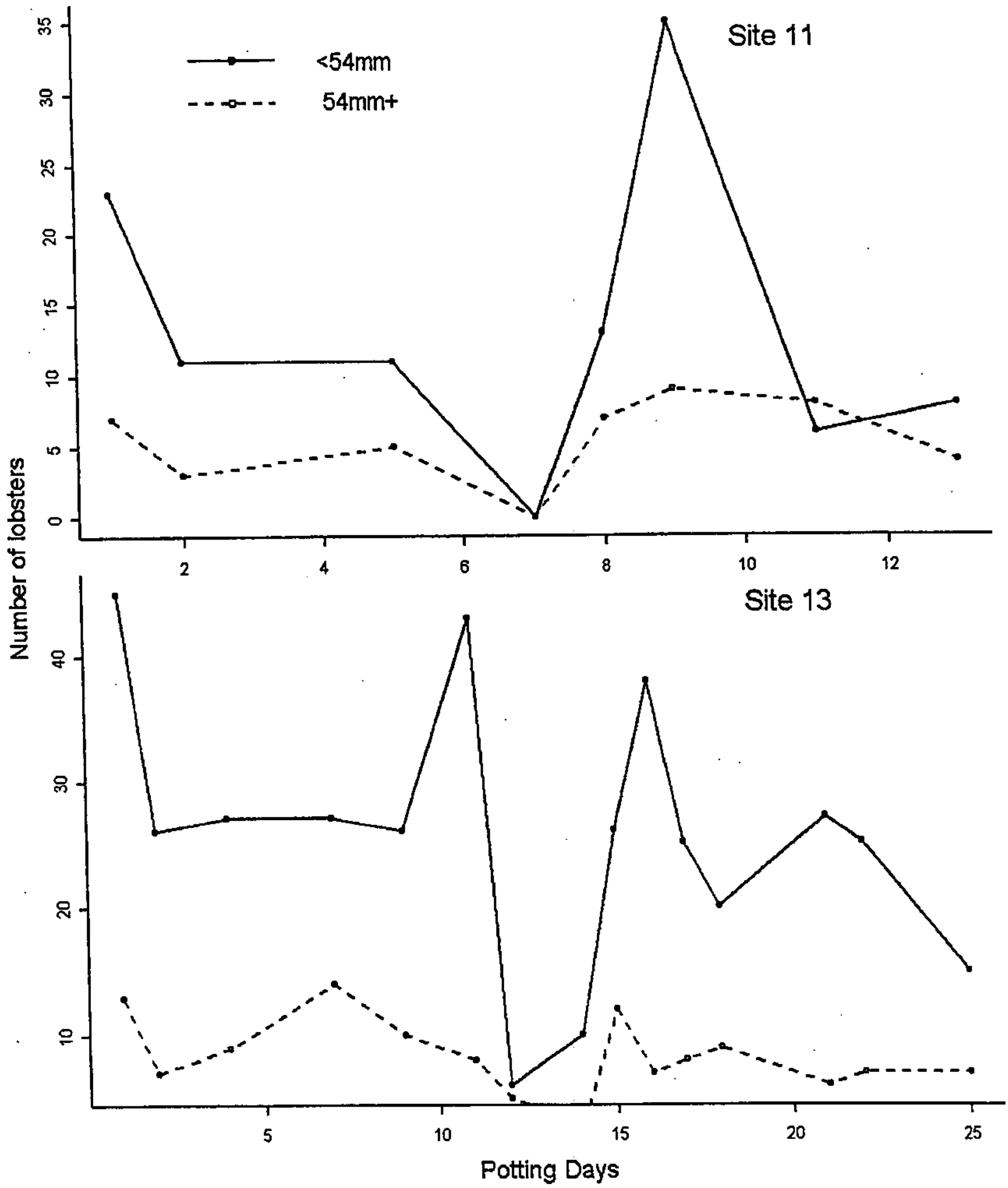

Figure 3: Potting behaviour (number of lobsters caught over the setting period) of pre-recruit (<54 mm TW) and post-recruit (54mm+ TW) lobsters in the WE pots at Sites 11 and 13.

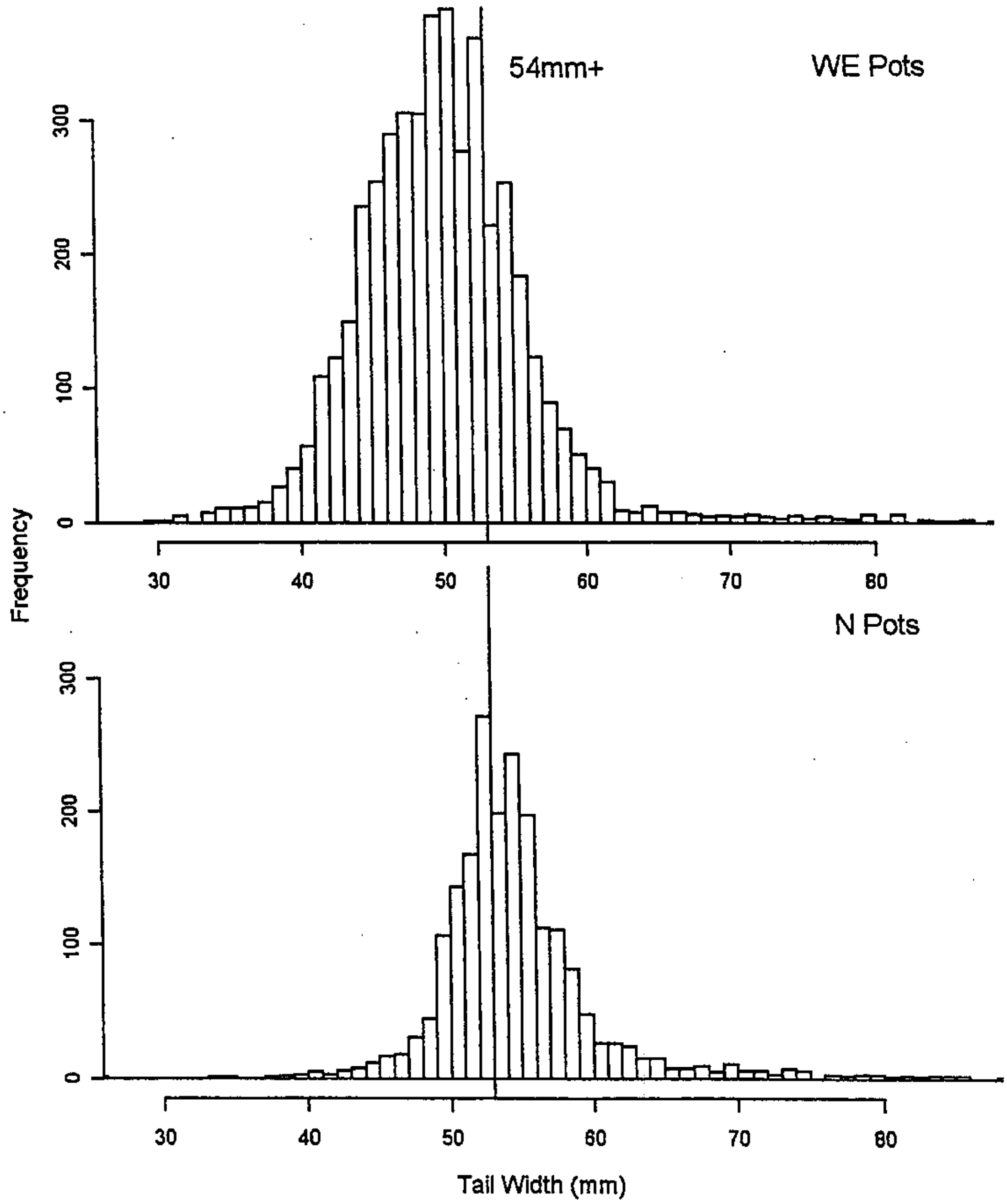

Figure 4: Size-frequency of all *Jasus edwardsii* caught during the pilot study in the two pot types; N, normal; WE, without escape gaps. The vertical line indicates minimum size which escape gaps are designed to retain.

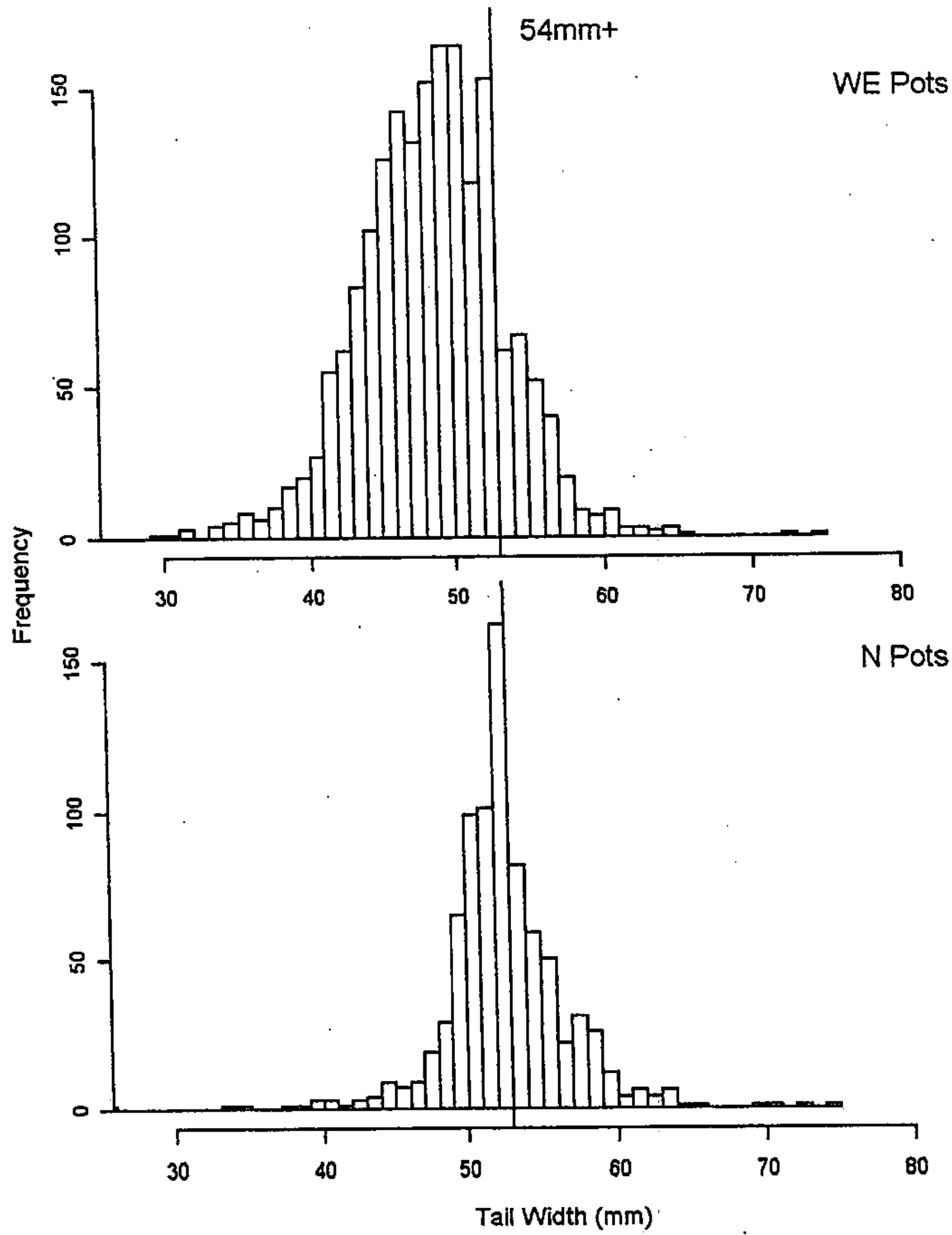

Figure 5: Size-frequency of male *Jasus edwardsii* caught during the pilot study in the two pot types; N, normal; WE, without escape gaps. The line at 54 mm+ indicates the minimum legal size for males.

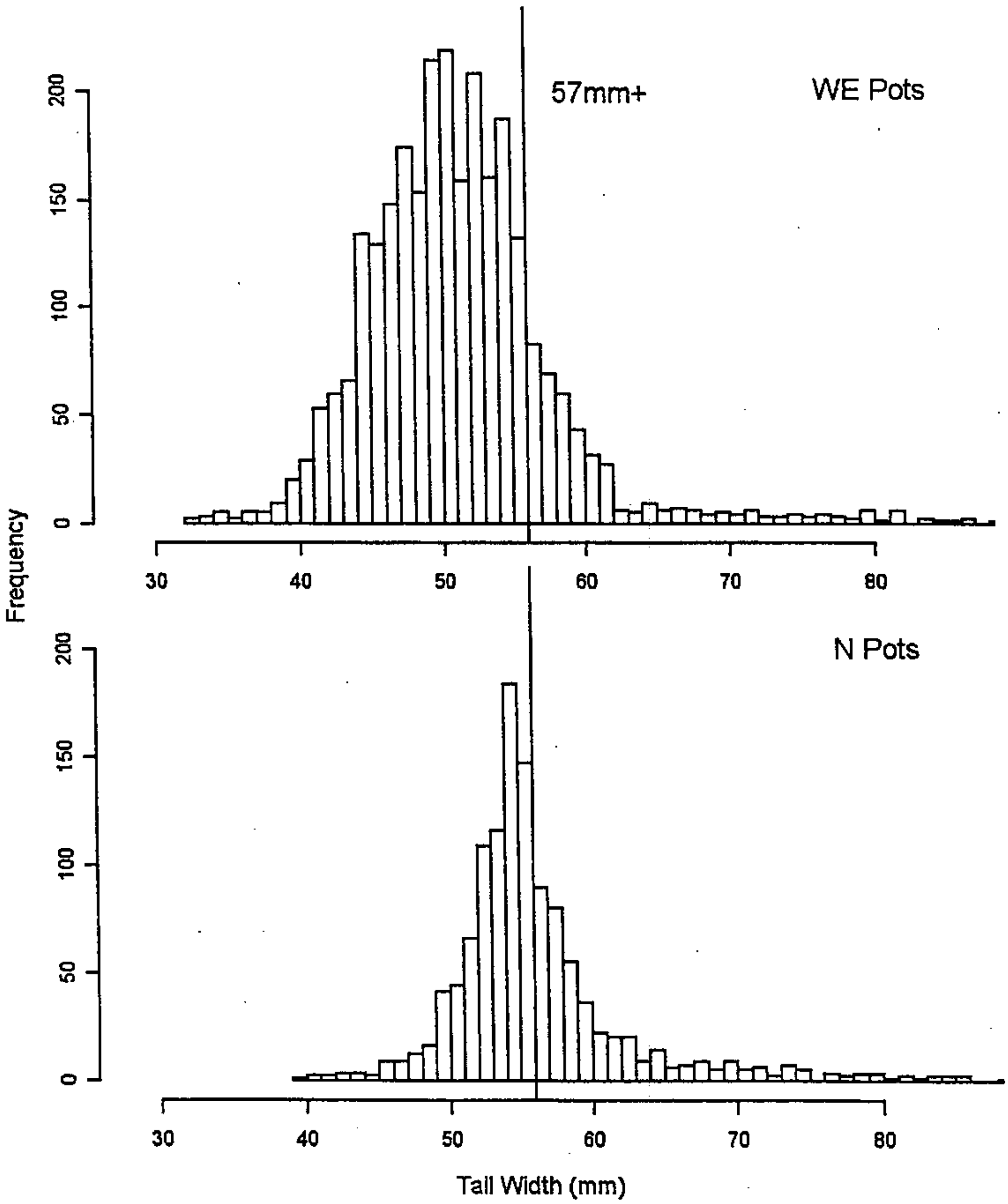

Figure 6: Size-frequency of female *Jasus edwardsii* caught during the pilot study in the two pot types; N, normal; WE, without escape gaps. The line at 57 mm+ is the minimum legal size for females.

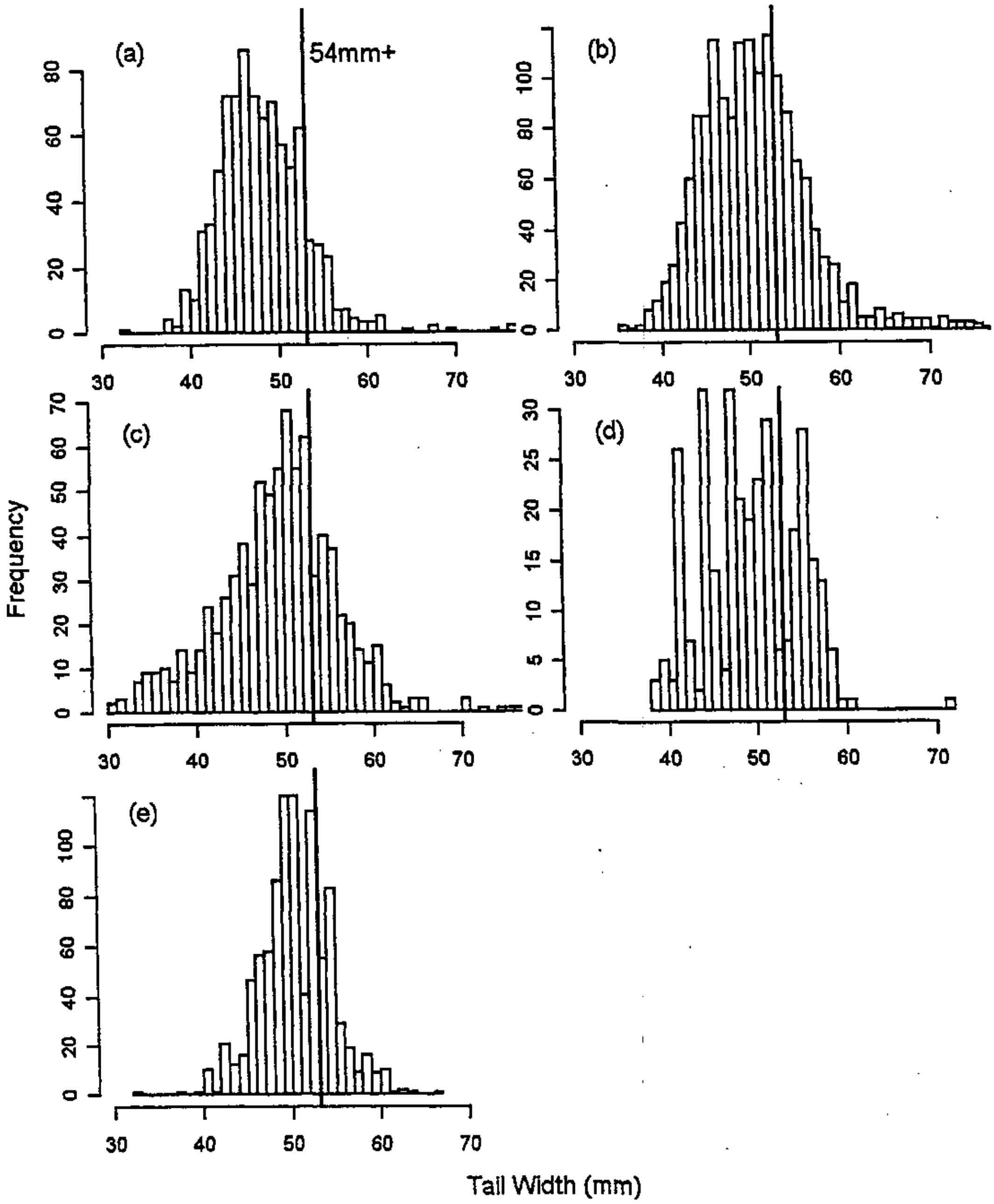

Figure 7: Size-frequency of *Jasus edwardsii* caught in WE pots (without escape gaps) at each of the main locations within CRA 8. (a) Mid-Fiordland (Sites 1 to 2), (b) South-Fiordland (Sites 3 to 5), (c) South Shore/ Foveaux Strait (Sites 5 to 10), (d) West Stewart Island (Sites 11 to 12); (e) East Stewart Island (Sites 13 to 14).

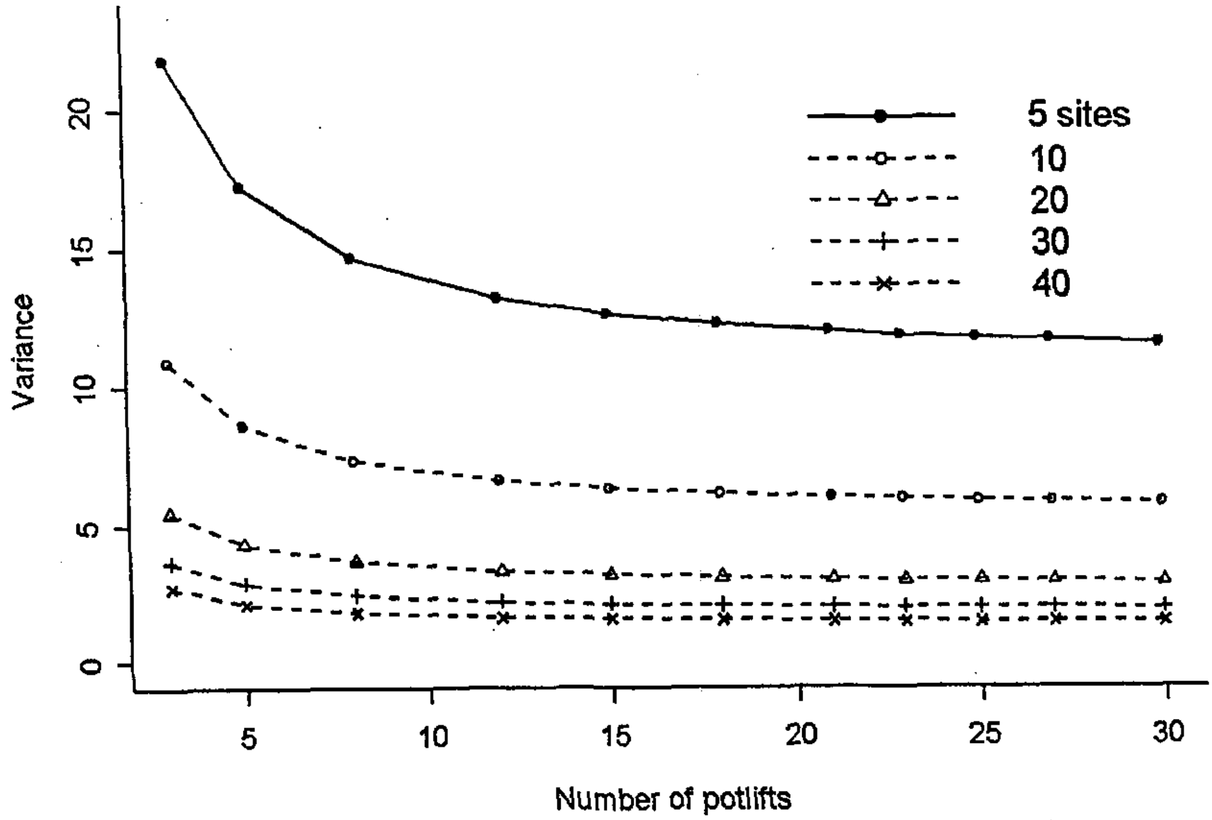

Figure 8: Variance of the estimate of the total number of lobsters per pot for a variety of combinations of sites and potlifts.

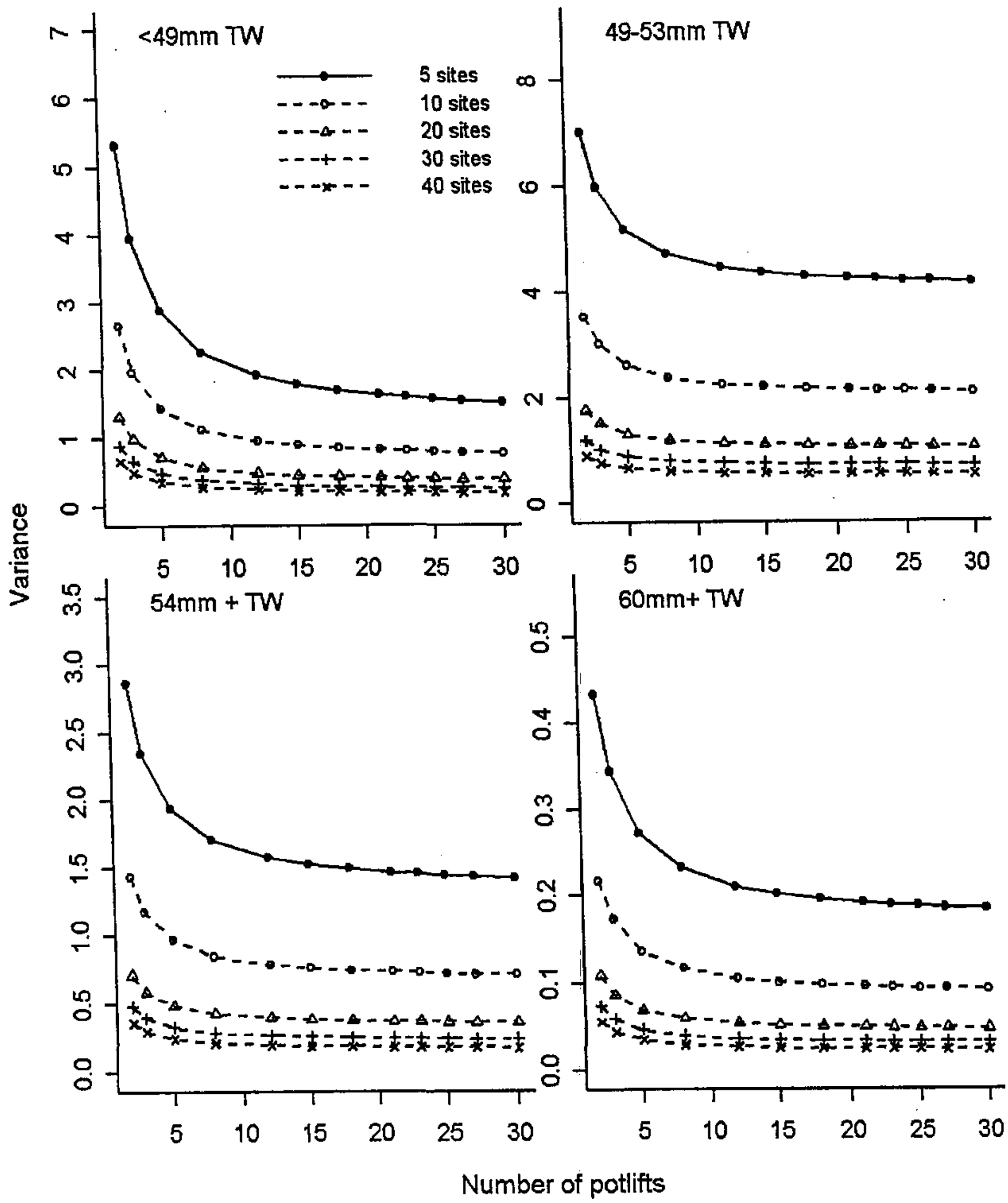

Figure 9: Variance of the estimate of the number of lobsters per pot for 2 pre-recruit size classes (animals <49 mm TW) and (animals from 49 to 53 mm TW), all commercial size animals (54 mm + TW) and large lobsters. Variance is calculated for a range of sampling designs (sites and potlifts).

Appendix 1. ANOVA results for total numpers per potlift and other variables.

Mean squares estimates used in equation 2 to simulate the effect of various combinations of site numbers and pot numbers on variance (precision), as reported in Figure 8 and 9.

Variable	Source of Variation	d.f	Mean square
Total numbers	Site	10	868.2
	Potlift	136	172.2
< 49 mm TW	Site	10	124.9
	Potlift	136	40.6
49 to 50 mm TW	Site	10	296.9
	Potlift	136	30.5
≥ 54 mm TW	Site	10	104
	Potlift	136	15.5
≥ 60mm TW	Site	10	13.8
	Potlift	136	2.7