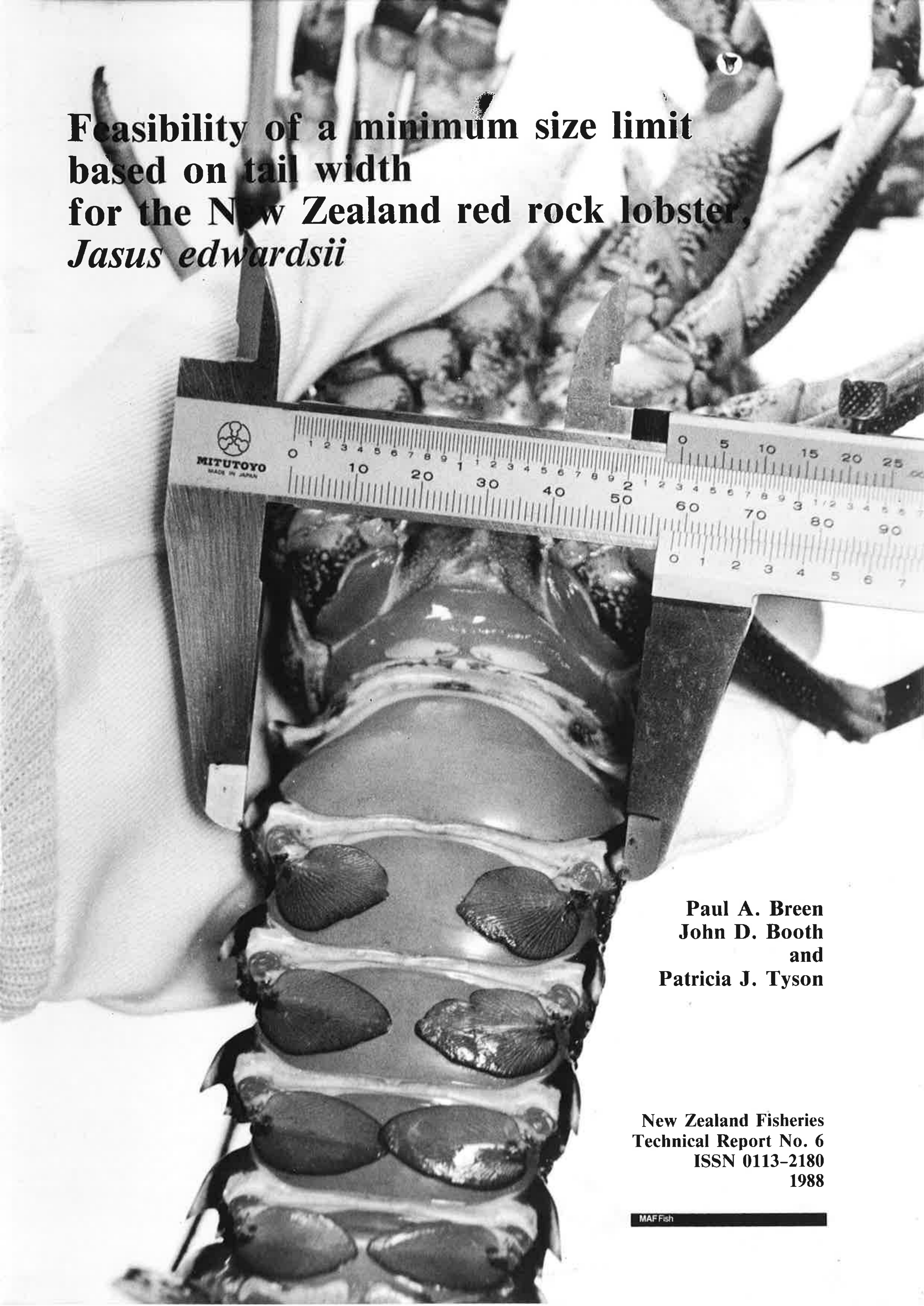
Feasibility of a minimum size limit based on tail width for the New Zealand red rock lobster, *Jasus edwardsii*



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Contents

Abstract

Breen, P. A., Booth, J. D., and Tyson, P. J. 1988: Feasibility of a minimum size limit based on tail width for the New Zealand red rock lobster, *Jasus edwardsii*. *New Zealand Fisheries Technical Report No. 6*. 16 p.

This report examines whether tail width, measured across the primary spines on the second abdominal segment, would be a feasible size limit measure for red rock lobsters (*Jasus edwardsii*) in New Zealand. The precision of the present size limit (tail length), two tail width measures, and carapace length was examined. Carapace length could be measured with greatest precision, tail length and one tail width were least precise, and the other tail width was intermediate in precision.

The effect of various processing operations on carapace length and the two tail width measures was examined. Some operations caused significant, but small, changes. All three measures were usually affected in the same way and by about the same amount on average. Tail width appears to be feasible for a size limit if enforcement difficulties can be overcome.

Morphometric measurements were made to determine the tail widths and carapace lengths equivalent to the existent tail length size limit (152 mm). Rock lobsters from various locations around New Zealand displayed sexual dimorphism and regional allomorphism. Equivalent measures were calculated for males and females separately. Data from each of seven controlled fishery areas were weighted according to 1986 landings, and equivalent tail width and carapace length measures were then determined by use of geometric mean functional regression. The tail width and carapace length estimates for males were 54 and 100 mm, those for females were 58 and 93 mm.

Introduction

The method of measuring minimum legal size (MLS) of red rock lobsters (*Jasus edwardsii*) (Decapoda: Palinuridae) in New Zealand has often been re-examined (e.g., Bain 1967, Sorensen 1970, 1971, Anon. 1981). The present MLS is based on tail length (TL), measured from the posterior edge of the calcified bar on the ventral surface of the first abdominal segment to the posterior edge of the telson. The present MLS is 152 mm TL, except for an area corresponding nearly exactly with the Otago controlled fishery area, where it is 127 mm TL (Annala 1983).

The present regulations (Fisheries (Commercial Fishing) Regulations 1986) state that when measuring rock lobsters one may use "no more pressure applied to the rock lobster tail or measuring device than will hold the pin of the measuring device against the posterior side of the first calcified bar and will cause the ventral surface of the tail to just touch the measuring device". This regulation causes problems. There is wide variation in the interpretation of the pressure required. The tail is a complex articulated series of skeletal segments, not a rigid structure; so the repeatability of TL measurements between observers is low (*see* Anon. 1978). There is concern that heavy measurement of sublegal lobsters is a source of mortality, particularly in areas where much of the catch is just below the legal size (McKoy 1981). In some areas, broken calcified bars on the first abdominal segment are common, and this injury is probably caused by heavy measuring. Thus, TL is an imprecise measure, subject to abuse.

In most homarid and palinurid fisheries a cephalothoracic or carapace length (CL) (the distance from some feature on the anterior carapace to the posterior carapace margin) is used as the MLS (Cobb and Wang 1985). Because of the rigidity of the carapace the repeatability of a carapace measurement should be high, and measuring the carapace with reasonable care should not damage lobsters. Biologists and industry associations in New Zealand have long requested that the legal size measure be changed from TL to CL (e.g., Anon. 1981). Much effort has been expended in obtaining morphometric relationships to support the change to CL (e.g., Bain 1967, Street 1969, Sorensen 1970, Annala 1976, McKoy 1982, Annala *et al.* 1986). A CL measure has also been proposed for the packhorse rock lobster, *Jasus verreauxi* (Booth 1984). One problem with using CL in New Zealand is that in part of the country tails are permitted to be removed at sea. In New Zealand, rock lobsters must be landed alive, except in a "tailing-at-sea area" (TASA) (Annala 1983). The TASA was established so that vessels operating at long distances from processing plants could freeze tails on board. Previous proposals to phase out the TASA have met with strong opposition (Thompson 1963, Anon. 1963, 1971a).

An alternative measure is tail width (TW), which is used in the fishery for *Panulirus marginatus* in Hawaii, where tailing at sea is also allowed. Tail width size limits in Hawaii have evolved through a series of different measures (Skillman and Thomason 1986, Ralston pers. comm.).

In April 1986, industry representatives at the New Zealand Fishing Industry Board's National Rock Lobster Advisory Committee meeting voted to replace the TL measure as soon as possible. The concensus was to explore the feasibility of a TW measure, such as that used in Hawaii, and then to implement either a TW or CL measure.

Tail width, measured across one abdominal segment, should be less variable than TL. An important advantage TW has over CL is that it could be measured after the tail has been removed from the carapace. If a TW measure were introduced, the TASA could be expanded if other considerations (such as enforcement and quality assurance) could be met. With TW, sublegal lobsters could be detected at most processing stages.

This report describes the examination of tail width as a possible size limit measure. Preliminary results of part of the study were described by Breen and Booth (1986) and Breen *et al.* (1987). Initial criteria for a TW measure were that it be legally definable; precise; easily taken by industry members, Fishery Officers, and biologists; and stable during processing. Selection of a measure, precision, and stability are addressed here. Morphometric relations between TL, TW, and CL are described and the equivalent TW values for the present MLS for New Zealand as a whole are recommended.

Data archiving is described.

Methods and results

Selection of a possible tail width measure

Several possible TW measures were examined near the second abdominal segment, the widest part of the abdomen. A Fishery Officer and three fisheries scientists examined four possible measures. Each was discussed as to its potential legal definition, ease of measurement, and precision. Of the four measures discussed, the first two were based on the Hawaiian measures:

1. The distance between the widest part of the articulating process (called the "ginglymus" by Parker (1889)) between the first and second abdominal segments. This measure was rejected because the surfaces involved are small and rounded, so the measure was difficult to take and it would be impractical for use at sea.
2. The distance across the abdomen measured at the notch just posterior to the widest part of the articulation between the first and second abdominal segments. This was rejected because it was difficult to measure (chisel-edged calipers and a specific angle of approach were required) and because it distorted when the abdomen was flexed.
3. The greatest width of the second abdominal segment (TW1). Because of variation in individual segment shape, the widest part of the segment is sometimes at the tips of the primary spines (especially in mature females) and sometimes high on the dorsal side. Occasionally the shape is such that the greatest width is between perpendiculars touching different points on the two sides. The measure is tedious to obtain with calipers, but a suitable gauge could be made for the commercial fishery, and legality of a lobster would be easy to determine.
4. The distance across the primary spine tips of the second abdominal segment (TW2). The spines may curve inward, splay out, or have a compound curve. This measure requires great care when calipers are used. However, with several prototype gauges the measure could be taken quickly and easily. The potential problem of broken spines was initially addressed by examining landed catches; this showed that the incidence of broken spines was low.

After this initial examination it was decided to further investigate measures TW1 and TW2.

Precision of carapace length, tail widths, and tail length

"Precision" was defined as the immediate repeatability of a measurement determined by different measurers. Precision was determined by three Fishery Officers and two research technicians familiar with rock lobsters; each measured the same animals.

Measurements were made on 18 July 1986 on 60 live rock lobsters obtained from a commercial fisherman. All except three were male, and all were close to the present legal size, some sublegal and some legal. They were caught near Wellington and held in running sea water for up to 2 weeks before being measured. All were tagged by wiring a numbered plastic disc to an antenna.

This trial began with a series of measurements and comparisons among observers and discussion to arrive at consistent measuring procedures. Each of the five observers then took four different measurements on all 60 rock lobsters. Observers determined the carapace length (CL) (distance from the antennal platform to the posterior margin of the carapace along the dorsal midline), greatest width of the second abdominal segment (TW1), width of the second abdominal segment measured across the tips of the primary spines (TW2), and tail length (TL) as defined above. Vernier calipers were used to measure CL, TW1, and TW2 to the nearest 0.1 mm; a commercial fishery tail measuring device was used to take TL to within 1 mm rounded down. Tail length was measured in accordance with the regulations. A recording assistant was provided for each observer. Any observed damage to rock lobsters that might have caused measurement errors was noted.

Outlier analysis was performed by regressing one observer's data on another's and inspecting the standardised residuals. Possible errors were then investigated by inspecting all five instances of the same measurement. Four obvious errors were either corrected or deleted from the data set. From the recorded observations of damage, and inspection of all possibly affected measurements, TW1 and TW2 measurements were discarded from one rock lobster.

Means of each measure for each observer over all individuals measured are given in Table 1. Data from observer 4 (a research technician) were arbitrarily chosen as the "standard" data for CL, TW1, and TW2; data from observer 1 (a Fishery Officer) were chosen as the standard for TL. Coefficients of determination between the standard and each observer for each measure are given in Table 2. There was good agreement on CL measurements (97.2–99.8%). Consistency in TW2 measurements was not as high (93.4–98.8%), and that for TW1 and TL was even lower (93.1–98.0%).

Deviations between the standard measurement and those made by the other observers were calculated. Table 3 shows the 95% confidence intervals for the distribution of these deviations. The width of this distribution was greatest by far for TL. However, there was no clear pattern in the other measures. Table 4 gives the means and extreme values observed of the absolute deviations for each measure for each observer. Again, TL showed the greatest variation, but there was no clear pattern among the others. As a percentage of the measure being taken, variation was least in CL and greatest in TW1.

The precision of TW2 during flexion of the tail was measured. Two measurers each determined TW2 twice from each of 22 lobsters; when the abdomen was extended, and when the tail was curled under the lobster's body. The mean difference was an increase of 0.05 mm when the tail was curled. This was not significant ($t = 1.16$, $n = 44$, $P > 0.5$).

TABLE 1: Mean values (mm) of each measure* obtained by each observer in the precision trials

Observer	CL	TW1	TW2	TL
1	101.17	56.32	56.20	153.07
2	101.11	56.60	56.28	152.30
3	100.94	56.19	56.23	152.45
4	101.05	56.55	56.23	153.55
5	101.29	56.25	55.92	153.15

* $n = 60$ for CL and TL; $n = 59$ for TW1 and TW2.

TABLE 2: Coefficients of determination ($100r^2$) between measurements of each observer and those of the arbitrarily chosen standard observer

Observer	CL	TW1	TW2	TL
1	99.6	93.1	98.8	–
2	99.8	98.0	96.6	95.5
3	98.7	93.7	93.4	94.3
4	–	–	–	96.0
5	97.2	95.0	97.6	94.2

TABLE 3: 95% confidence intervals (and interval width) on the distribution of deviations (mm) between measurements of each observer and those of the standard observer

Observer	CL	TW1	TW2	TL
1	−0.56 to 0.32 (0.88)	−0.65 to 1.13 (1.78)	−0.36 to 0.42 (0.78)	
2	−0.36 to 0.24 (0.60)	−0.54 to 0.46 (1.00)	−0.72 to 0.61 (1.33)	−1.2 to 2.7 (3.9)
3	−0.74 to 0.97 (1.71)	−0.49 to 1.21 (1.70)	−0.93 to 0.94 (1.87)	−1.6 to 2.8 (4.4)
4				−2.3 to 1.4 (3.7)
5	−1.49 to 1.02 (2.51)	−0.46 to 1.06 (1.52)	−0.28 to 0.46 (0.74)	−2.3 to 2.2 (4.5)

TABLE 4: Mean (and extreme) absolute deviations (mm) between measurements of each observer and those of the standard observer

Observer	CL	TW1	TW2	TL
1	0.1983 (0.5)	0.3627 (1.7)	0.1559 (0.5)	
2	0.1333 (0.4)	0.1898 (0.9)	0.1831 (1.9)	0.967 (4)
3	0.3083 (1.8)	0.4305 (1.6)	0.3797 (1.2)	0.950 (3)
4				0.817 (2)
5	0.4117 (3.1)	0.3678 (1.2)	0.0915 (1.0)	0.817 (4)
% of measure*	0.26	0.60	0.36	0.49

* Mean deviation expressed as a percentage of the mean measure.

Stability of carapace length and tail width

Changes in CL, TW1, and TW2 were measured during various processing operations, such as drowning, cooking, tailing, freezing, and thawing. Only those combinations commonly found during normal commercial processing were examined. Forty rock lobsters near legal size, obtained from a commercial fisherman, were assigned randomly to each of three groups. The lobsters included some of those which had been used for the precision study. Each group was subjected to one of the series of treatments described below. Each lobster was measured by one measurer before the study and again by the same measurer after each operation. In the group to be tailed, tails were tagged with a numbered plastic dart tag. In the other two groups, numbered plastic discs were wired to the antennae.

Group A was measured, drowned for 45 minutes in fresh water and measured, cooked for 5 minutes at 110 °C in an autoclave and measured, frozen overnight and measured, then thawed and measured. Group B was measured, tailed by hand in a commercial factory and measured, frozen overnight and measured, then thawed and measured. Group C was measured, frozen overnight and measured, and then thawed and measured. All operations were carried out as quickly in sequence as possible. The effects of treatments on measurements were examined by conducting two-tailed paired *t*-tests.

The effects of operations were examined by comparing measurements before and after each operation. Significant changes are shown in Table 5. Drowning had no significant effect on any measure. The effects of freezing and thawing (freezing increased measurements, thawing decreased them) were consistent between groups A and C; but freezing and thawing had no significant effect on group B. Tailing caused a significant decrease in TW2 only.

Mean differences between initial measurements and measurements after each operation are given in Table 6. In group A, measures were not significantly different after drowning; however, all decreased after cooking and remained significantly smaller through freezing and thawing. The change produced by cooking was the largest caused by any operation. In group B, tailing caused a significant decrease in TW2, but not in TW1; and TW2 remained smaller through freezing and thawing. In group C, freezing caused a significant increase in two measures, and all three measures were significantly decreased after thawing.

The changes were small. The largest mean difference was 0.505 mm (CL at the end of treatments in group A); most other differences were less than 0.2 mm. The largest percentage change was 0.69% (TW1 after thawing in group A).

Although the animals were handled carefully, some damage occurred. Cooked rock lobster exoskeletons were more fragile than uncooked ones, and abdominal spines were more vulnerable to damage while frozen. The number of animals from which CL, TW1, and TW2 could not be obtained at the end of all operations was:

group A (n = 40), CL 0, TW1 2, TW2 4;
group B (n = 40), TW1 2, TW2 4;
group C (n = 37), CL 1, TW1 3, TW2 7.

TABLE 5: The effects of processing operations on the three measures*

Group	Measure	Live	Drowned	Cooked	Frozen	Thawed
A	CL			–	+	–
	TW1			–	+	–
	TW2			–		–
		Live	Tailed	Frozen	Thawed	
B	TW1					
	TW2		–			
		Live	Frozen	Thawed		
C	CL		+	–		
	TW1		+	–		
	TW2			–		

* Changes are shown when a paired *t*-test on measurements made after adjacent operations was significant at the 95% level.

TABLE 6: Mean differences (mm) (and percentage of the base mean measure) between the initial measurements and those made after each operation

Group	Measure	Drowning	Cooking	Freezing	Thawing
A	CL	−0.029 (−0.03)	−0.479* (−0.47)	−0.400* (−0.40)	−0.505* (−0.50)
	TW1	−0.098 (−0.18)	−0.369* (−0.67)	−0.177* (−0.32)	−0.382* (−0.69)
	TW2	+0.015 (+0.03)	−0.292* (−0.53)	−0.236* (−0.43)	−0.344* (−0.63)
		Tailing	Freezing	Thawing	
B	TW1	+0.011 (+0.02)	−0.087 (−0.16)	+0.003 (+0.01)	
	TW2	−0.116* (−0.21)	−0.169* (−0.31)	−0.141* (−0.26)	
		Freezing	Thawing		
C	CL	+0.157* (+0.16)	−0.129* (−0.13)		
	TW1	+0.078* (+0.14)	−0.167* (−0.30)		
	TW2	+0.040 (+0.07)	−0.086* −0.15)		

* Significant at the 95% level.

Table 7 gives 95% confidence intervals for measurements taken after each operation. The scale of measurement changes caused by processing operations is similar to the precision error among different observers (*see* Table 3).

TABLE 7: 95% confidence limits on the difference (mm) between initial measurements and those made after each processing operation

		CL		TW1		TW2	
Group	Operation	−	+	−	+	−	+
A	Drowning	0.54	0.49	1.25	1.05	0.53	0.56
	Cooking	1.06	0.10	1.60	0.87	0.66	0.07
	Freezing	0.99	0.19	1.09	0.74	0.69	0.21
	Thawing	1.05	0.04	1.51	0.75	0.61	0.08
B	Tailing			0.45	0.47	0.67	0.44
	Freezing			0.66	0.49	0.76	0.42
	Thawing			0.45	0.45	0.52	0.23
C	Freezing	0.48	0.79	0.39	0.54	0.54	0.62
	Thawing	0.48	0.23	0.83	0.50	0.35	0.17

Tail width and carapace length analogous to the present tail lengths

Morphometric measurements of rock lobsters were made around New Zealand between July 1986 and September 1987 (Fig. 1). Three observer-recorder teams collected 42 sets of measurements, each set collected on one vessel during 1 day's fishing. Observers measured as many rock lobsters as possible during each day's fishing. They recorded sex, female maturity, CL, TW2, and TL, and they noted broken first and second abdominal segment calcified bars, broken spines on the second segment, damaged telsons, and damaged carapaces. When females were ovigerous, TL could not be taken.

Raw data from each sample were checked for range errors, member-of-set errors, and gross errors in the correlations among CL, TW2, and TL. Errors found were corrected where possible or the data were discarded. Data were then examined in a second outlier analysis by regressing one set of measurements against another to detect outliers.

Geometric mean functional regression (GMFR) (Ricker 1973) was used to obtain the TW2 equivalent to the present MLS of 152 mm TL. This regression was chosen because it gives symmetrical estimates and the estimates are not influenced by the location of the sample mean with respect to 152 mm TL. Data were considered to have been drawn from a type B situation (Ricker 1973), and most variability was assumed to be natural rather than measurement error. Not all authors agree that Ricker's method is correct (*see* Schnute 1984), but the choice of method makes little difference to the final outcome in this instance.

In addition, the analysis was done on untransformed data. Skillman and Thomason (1986) compared results from untransformed and log-transformed data and concluded that using log-transformed data might give a better fit, but that no practical effect was seen in the final result. Log transformations are not thought to be appropriate here.

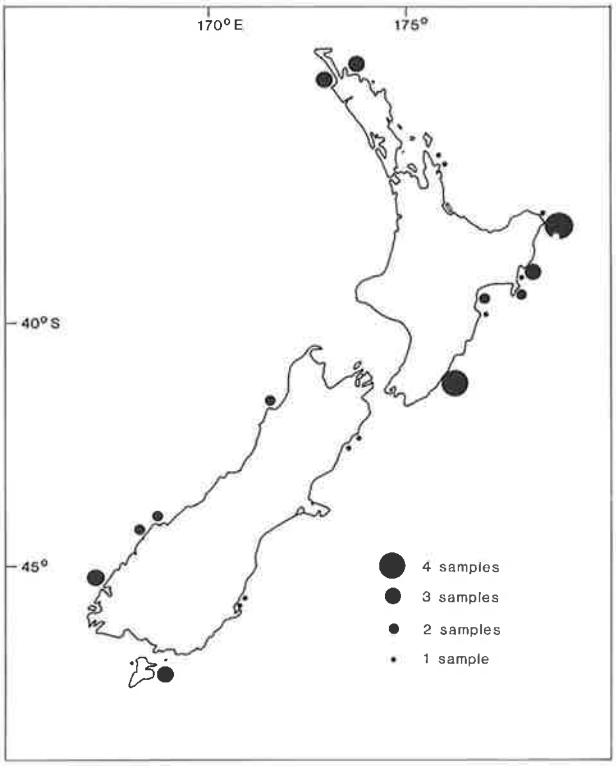

Fig. 1: Locations around New Zealand sampled for morphometric measurements of rock lobsters.

Because of morphometric differences, males and females were treated separately in all analyses. Sexual dimorphism means that separate CL and TW2 estimates must be determined for males and females.

There were differences in morphology among different areas. Figure 2 shows for males the TW2 and its confidence limits predicted from CL 99.5 mm for each sample taken during the study. The predictions are based on simple predictive regressions of TW2 on CL for each sample. No seasonal trends are apparent. Because of regional morphometric differences, data were grouped by controlled fishery area (CFA) (Fig. 3) for analysis. Table 8 shows the number of individual lobsters measured in each CFA, the 1986 provisional landings from each CFA, and the weighting factors required to make samples from each area consistent with fishery landings. A weighted estimate was made by weighting the sums of squares in regression analysis.

Weights were determined from:

$$W_j = \frac{(C_j/C_{tot})N_{tot}}{N_j}$$

where W_j is the weighting factor for area j, C_j is the catch in area j, C_{tot} is total catch, N_{tot} is total number sampled, and N_j is number sampled in area j.

For each data set, three comparisons were made for each sex: CL v. TL, TW2 v. TL, and TW2 v. CL. The predictive regression of y on x (simple regression), the predictive regression of x on y (reverse regression), and

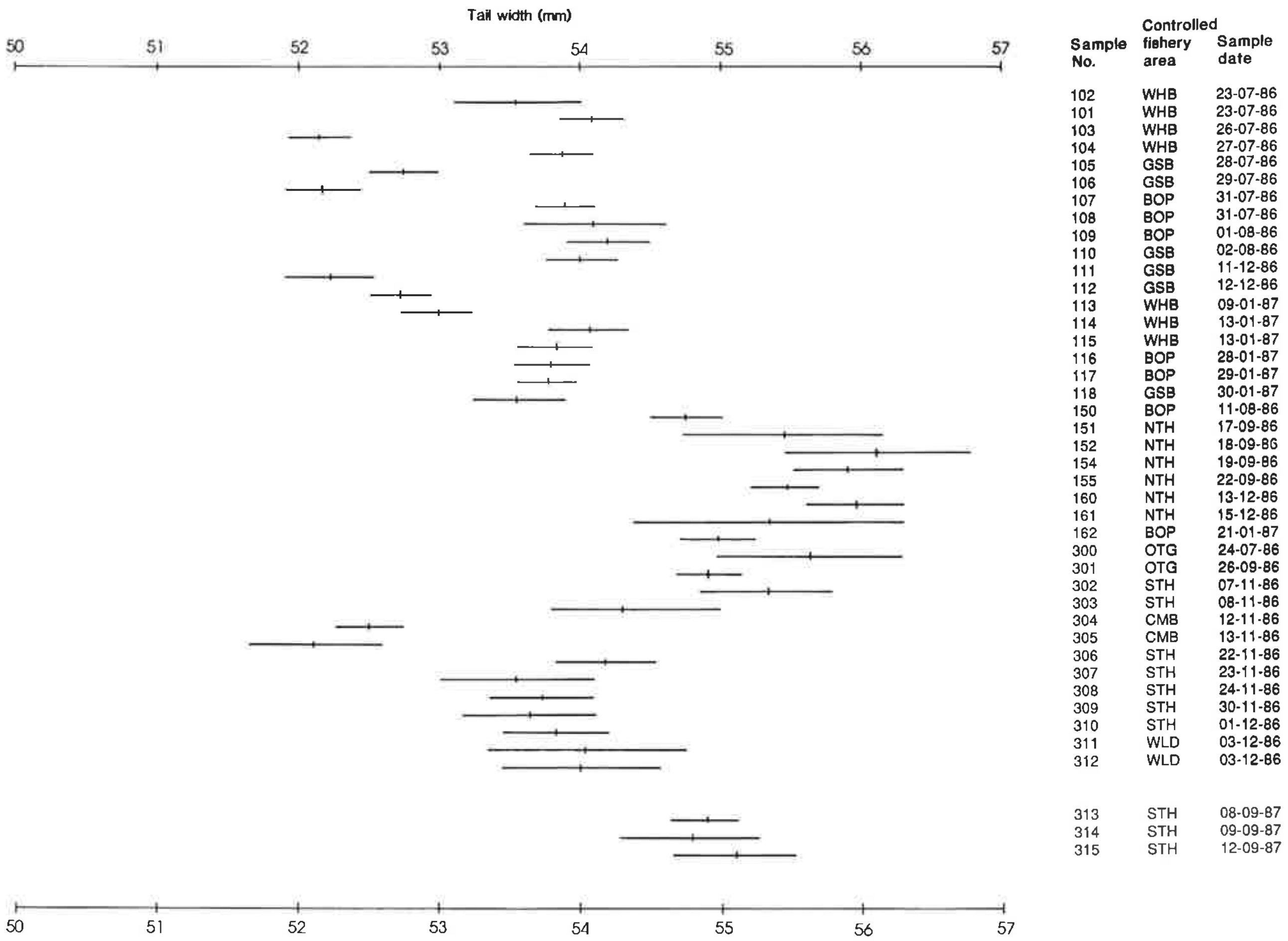

Fig. 2: Predicted TW2 for males for CL 99.5 mm, based on the predictive regression of TW2 on CL for each sample. (Horizontal bars show the 95% confidence limits.)

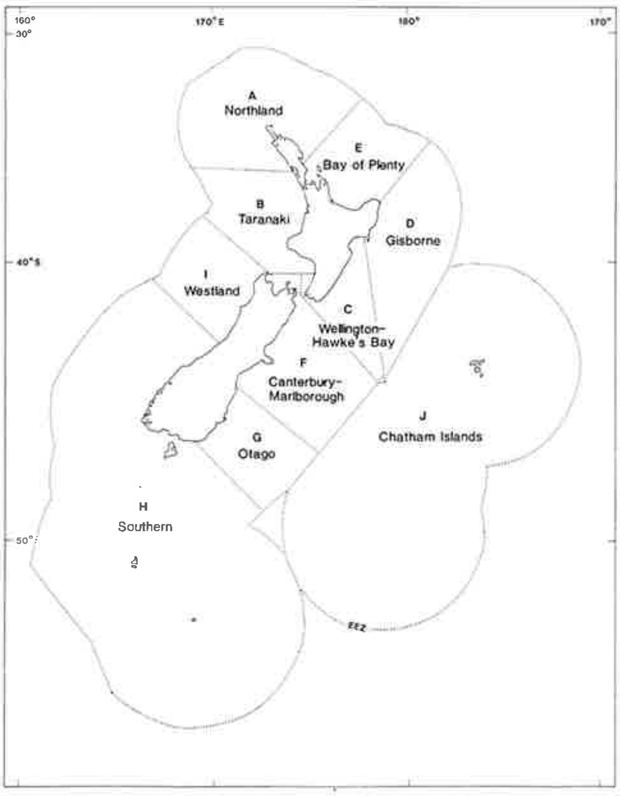

Fig. 3: Rock lobster controlled fishery areas.

the GMFR were calculated for each comparison. Both CL and TW2 were then predicted from a TL of 152 mm (127 mm TL for Otago). Full output from the regression program for one sample is given in Table 9. The prediction from the TW2 v. TL comparison is of primary interest.

The predicted TW2 for each sample, CFA, the whole data set, and weighted analysis for both sexes is given in Table 10. Predicted TW2 for the 42 samples ranged from 51.7 to 57.2 mm for males and from 54.5 to 60.8 mm for females. Predictions from data grouped by CFA ranged from 51.7 to 56.8 mm for males and from 55.5 to 59.9 mm for females. Tails appear to be wider in the north of New Zealand and decrease towards the south. Part of this pattern may result from differences between measurers' techniques for determining TL, though attempts were made to minimise these differences from the outset. From the weighted analysis, TW2 estimates were 53.55 mm for males and 57.89 mm for females.

The GMFR coefficients for samples grouped into CFAs and for the whole data set are given in Table 11, and full results from the whole data set (unweighted analysis) are given in Table 12. For both sexes, all three regression procedures gave nearly the same predicted TW2 values. The weighted mean TL was 152.5 mm for males and 151.3 mm for females.

TABLE 8: Number of rock lobsters measured in each controlled fishery area (CFA), 1986 provisional landings for each CFA, and weighting factors used in regression analysis

CFA*	Males	Females	1986 landings (t)	Weighting factor Males	Weighting factor Females
NTH	456	187	224	0.49	0.79
BOP	933	458	297	0.32	0.43
GSB	870	316	580	0.67	1.21
WHB	865	227	879	1.02	2.55
CBM	271	346	693	2.58	1.32
STH	739	1 102	1 446	1.97	0.86
WLD	52	99	34	0.66	0.23
Total	4 186	2 735	4 153		
OTG	316	364	299	-	-

* NTH, Northland; BOP, Bay of Plenty; GSB, Gisborne; WHB, Wellington-Hawke's Bay; CBM, Canterbury-Marlborough; OTG, Otago; STH, Southern; WLD, Westland.

TABLE 9: Full output from the regression program for one sample

Females, CL v. TL, prediction from TL 152

	n	*a**	*b**	Predicted CL (mm)
Simple	113	7.98	0.56623	94.044
Reverse		−1.00	1.62848	93.952
GMFR†		4.37	0.58966	93.999

Females, TW2 v. TL, prediction from TL 152

	n	*a**	*b**	Predicted TW2 (mm)
Simple	113	−14.86	0.47270	56.988
Reverse		43.16	1.91318	56.888
GMFR		−18.62	0.49707	56.939

Females, TW2 v. CL, prediction from CL 93.5

	n	*a**	*b**	Predicted TW2 (mm)
Simple	323	−8.48	0.69023	56.052
Reverse		25.13	1.22880	55.637
GMFR		−14.22	0.74947	55.853

Males, CL v. TL, prediction from TL 152

	n	*a**	*b**	Predicted CL (mm)
Simple	178	−7.83	0.69849	98.338
Reverse		22.93	1.31524	98.131
GMFR		−12.53	0.72875	98.236

Males, TW2 v. TL, prediction from TL 152

	n	*a**	*b**	Predicted TW2 (mm)
Simple	176	1.25	0.34931	54.349
Reverse		15.92	2.51138	54.185
GMFR		−2.42	0.37295	54.270

Males, TW2 v. CL, prediction from CL 99.5

	n	*a**	*b**	Predicted TW2 (mm)
Simple	182	8.28	0.46845	54.889
Reverse		1.56	1.78802	54.774
GMFR		3.90	0.51185	54.834

* *a* and *b* are the constants in the regression equation $y = a + bx$.
† Geometric mean functional regression.

Because all three regressions pass through the mean x and mean y, and predictions were made from $x = 152$ mm, the three procedures should produce similar results. Differences in predicted TW2 would be expected if sampling were not centred on the point of interest.

During sampling it appeared that immature females (those without pleopodal setae) might have smaller TW2 measurements than mature females of the same carapace length. This was tested with a Student's *t*-test. Mean CL was the same for both immature and mature females ($t = 1.13$, d.f. = 669, N.S.), but the mean TW2 was significantly different ($t = 5.9$, d.f. = 645, $P < 0.01$). Mean TW2 was 54.38 mm for immature females and 56.50 mm for mature females.

If a CL or TW2 size limit were introduced, values in Tables 10 and 11 could be rounded to the nearest millimetre:

	CL	TW2
All areas except Otago		
Males	100	54
Females	93	58
Otago		
Males	82	46
Females	79	47

The incidence of damage to different body parts is given by fishing statistical area and for the whole data set in Table 13. In the whole sample of 7161 animals, 2.8% had one or both spines broken and could not be measured for TW2. A broken calcified bar on the second segment also precluded taking TW2, but this breakage was found in only 0.1% of the whole sample. Mahia and Gisborne showed the highest rates of spine breakages (7.0 and 6.3%), though 4.9% in the East Cape area had broken spines. Only one animal in the set had a broken carapace which prevented a measurement being made.

Broken bars on the first segment represented 0.7% of the set; Gisborne, East Cape, and Mahia again had the greatest incidence of damage. Together, incidences of broken first segment bars and tail damage reflect damage preventing TL being taken. Overall, these were 1.5% of the whole sample.

Impact of introducing a tail width measure

A program was written for the morphometric data described above to collate the number of lobsters in two groups: N_1 was the number with TL 152 mm or greater, N_3 was the number with TW2 equal to or greater than a specified value. The percentage impact (as instantaneous change in availability) of changing to a new MLS at the specified TW2 was calculated as:

$$\triangle A = 100(N_3 - N_1)/N_1$$

This analysis was carried out with TW2 equal to the estimates of 53.6 and 57.9 mm for males and females determined above and with specified TW2 of 52, 53, and 54 mm for males and 56, 57, and 58 mm for females. Overall national results are given in Table 14. The estimated impacts are very sensitive to small changes in MLS. This emphasises the need for a precise and enforceable size limit.

This analysis should be treated with caution and only as a guide to possible effects of changing MLS.

TABLE 10: Predicted TW2 (mm) corresponding to TL 152 mm from geometric mean functional regression analysis for each sample, controlled fishery area (CFA)*, the whole data set, and weighted analysis

Date	Sample	Location	CFA	Female *n*	Female TW2	Male *n*	Male TW2
23/07/86	101	Castle Point	WHB	–†		116	54.39
23/07/86	102	Mataikona	WHB	–		43	54.49
26/07/86	103	Cape Kidnappers	WHB	–		201	53.78
27/07/86	104	Napier	WHB	26	56.85	152	54.48
28/07/86	105	Gisborne	GSB	–		186	54.06
29/07/86	106	Gisborne	GSB	17	60.31	129	53.83
31/07/86	107	East Cape	BOP	–		128	54.53
31/07/86	108	East Cape	BOP	–		29	54.62
1/08/86	109	Te Araroa	BOP	32	60.30	88	54.27
2/08/86	110	Mahia	GSB	27	60.49	117	54.40
11/12/86	111	Gisborne	GSB	41	60.32	81	53.88
12/12/86	112	Young Nick's Head	GSB	75	60.80	235	53.71
9/01/87	113	Napier	WHB	114	58.88	114	53.73
13/01/87	114	Castle Point	WHB	35	58.59	123	53.50
13/01/87	115	Mataikona	WHB	49	58.89	116	54.04
28/01/87	116	East Cape	BOP	66	58.93	124	54.14
29/01/87	117	East Cape	BOP	124	59.25	198	53.97
30/01/87	118	Mahia	GSB	147	58.84	122	53.92
11/08/86	150	Whitianga	BOP	–		107	55.62
17/09/86	151	Mangonui	NTH	–		41	56.10
18/09/86	152	Mangonui	NTH	–		51	56.72
19/09/86	154	Ahipara	NTH	13	59.95	84	56.81
22/09/86	155	Ahipara	NTH	42	59.39	127	56.78
13/12/86	160	Ahipara	NTH	105	60.24	124	57.21
15/12/86	161	Mangonui	NTH	25	59.43	29	55.67
27/01/87	162	Red Mercury	BOP	224	59.58	259	56.17
24/07/86	300	Karitane	OTG	75		104	
26/09/86	301	Shag Point	OTG	289		212	
7/11/86	302	Stewart Island	STH	88	54.91	66	54.21
8/11/86	303	Stewart Island	STH	26	54.46	16	52.60
12/11/86	304	Kaikoura	CBM	187	58.92	209	51.68
13/11/86	305	Kaikoura	CBM	159	58.03	62	51.93
22/11/86	306	Doubtful Sound	STH	90	55.19	43	52.74
23/11/86	307	Doubtful Sound	STH	104	55.42	52	52.29
24/11/86	308	Doubtful Sound	STH	178	56.39	76	51.96
30/11/86	309	Cascade Point	STH	162	55.66	75	51.65
1/12/86	310	Cascade Point	STH	193	55.66	83	52.16
3/12/86	311	Cape Foulwind	WLD	69	55.95	18	52.33
3/12/86	312	Cape Foulwind	WLD	30	54.69	34	52.16
8/09/87	313	Big Bay	STH	113	56.94	176	54.27
9/09/87	314	Big Bay	STH	66	57.71	86	54.72
12/09/87	315	Stewart Island	STH	82	55.19	66	53.40
		NTH		187	59.89	456	56.82
		BOP		458	59.37	933	54.94
		GSB		316	59.66	870	53.95
		WHB		227	58.65	865	54.04
		CBM		346	58.44	271	51.73
		STH		1 102	55.98	739	53.32
		WLD		99	55.54	52	52.12
		Total (except Otago)		2 735	57.74	4 186	54.21
		Weighted (except Otago)		2 735	57.89	4 186	53.55

* WHB, Wellington-Hawke's Bay; GSB, Gisborne; BOP, Bay of Plenty; NTH, Northland; OTG, Otago; STH, Southern; CBM, Canterbury-Marlborough; WLD, Westland.
† Too few individuals to analyse.

First, the data base was the same as that used to estimate the appropriate TW2 for males and females, so this impact analysis suffers from circularity. Second, catches were not randomly sampled. Third, the size and sex composition of catches vary seasonally; two seasonal sets of samples were collected in most places (though not in Otago and Kaikoura), but the data do not reflect actual catch compositions during a season. Fourth, sampling was not proportional to landings in any area. In addition, it is not clear how instantaneous changes in availability will affect annual catches. For these reasons, impact data for specific areas cannot be estimated.

The effects on local catches in areas where the proposed TW2 measures of 54.0 and 58.0 mm do not match the current 152 mm TL are not likely to last for long on average. Mean moult increments of animals near MLS at selected areas around New Zealand are 6.6 mm CL for males and 3.2 mm CL for females (Table 15). Thus, the average increase in a single moult is about 3.5 mm TW2 for males and 2.0 mm TW2 for females. However, the precise length of time taken to reach the new MLS in any area will depend on local morphometrics, growth rates, and the time of year in which the new MLS is introduced. We do not have adequate data to make this prediction.

TABLE 11: Geometric mean functional regression coefficients for males and females

Males

Controlled fishery area	CL v. TL				TW2 v. TL			
	*a**	*b**	Predicted CL	*n*	*a*	*b*	Predicted TW2	*n*
Northland	-10.00	0.735	101.638	462	-1.36	0.383	56.819	456
Bay of Plenty	-14.35	0.757	101.683	986	-6.53	0.404	54.943	933
Gisborne	-13.42	0.752	100.844	967	-4.39	0.384	53.948	870
Wellington-Hawke's Bay	-12.88	0.747	100.720	893	-5.36	0.391	54.044	865
Canterbury-Marlborough	-17.07	0.754	97.569	270	-5.68	0.378	51.733	271
Southern	-18.70	0.763	97.274	738	-2.75	0.369	53.321	739
Westland	-16.26	0.735	95.402	52	-3.61	0.367	52.124	52
All areas (except Otago)	-13.22	0.745	99.978	4 368	-6.75	0.401	54.206	4 186
Otago	-7.11	0.698	81.569	322	-2.43	0.378	45.613	316

Females

Controlled fishery area	CL v. TL				TW2 v. TL			
	a	*b*	Predicted CL	*n*	*a*	*b*	Predicted TW2	*n*
Northland	-0.79	0.642	96.774	186	-10.64	0.464	59.892	187
Bay of Plenty	-7.71	0.677	95.271	471	-13.09	0.477	59.374	458
Gisborne	0.64	0.611	93.486	338	-15.83	0.497	59.656	316
Wellington-Hawke's Bay	6.66	0.570	93.324	235	-13.92	0.477	58.651	227
Canterbury-Marlborough	-4.25	0.629	91.323	351	-15.84	0.489	58.444	346
Southern	-2.69	0.622	91.907	1 114	-16.24	0.475	55.976	1 102
Westland	-10.52	0.662	90.081	103	-19.26	0.492	55.538	99
All areas (except Otago)	-1.10	0.619	92.970	2 798	-10.87	0.451	57.736	2 735
Otago	-1.74	0.632	78.548	367	-2.78	0.391	46.938	364

* *a* and *b* are the constants in the regression equation $y = a + bx$. Predicted values are given for TL of 152 mm (127 mm in Otago).

TABLE 12: Full results of unweighted analysis of the whole data set except Otago

	n	*a**	*b**	Predicted TW2 (mm)
Females, TW2 v. TL, prediction from 152 mm TL				
Simple	2 735	−5.92	0.4189	57.752
Reverse		33.31	2.0563	57.720
GMFR†		−10.87	0.4514	57.736
Males, TW2 v. TL, prediction from 152 mm TL				
Simple	4 186	−2.19	0.3708	54.179
Reverse		26.93	2.3060	54.236
GMFR		−6.75	0.4010	54.206

	n	*a*	*b*	Predicted CL (mm)
Females, CL v. TL, prediction from 152 mm TL				
Simple	2 798	3.72	0.5873	92.986
Reverse		9.47	1.5334	92.954
GMFR		−1.10	0.6189	92.970
Males, CL v. TL, prediction from 152 mm TL				
Simple	4 368	−7.99	0.7101	99.941
Reverse		23.94	1.2804	100.018
GMFR		−13.22	0.7447	99.978

* *a* and *b* are the constants in the regression equation $y = a + bx$.
† Geometric mean functional regression.

TABLE 13: Incidence (%) of breakage or injury which prevented measurement

Location	Statistical area	Spines	Bar 2	Bar 1	Tail*	Carapace	*n*
Ahipara	939	0.1			0.1		569
Mangonui	903	0.8			2.0	0.4	245
Mercury Bay	906	0.9			0.2		425
East Cape	908	4.9		1.2	0.6		918
Gisborne	910	6.3	0.2	2.8			915
Mahia	911	7.0		1.0	1.9		516
Napier	912	2.8		0.4	0.4		688
Castle Point	913	2.2		0.2	0.2		543
Kaikoura	917	0.2			0.2		673
Otago	920	0.4		0.1	0.6		717
Stewart Island	924		1.3				234
Fiordland	927						365
Cascade-Foulwind	928 + 930						353
Total number		192	9	50	57	1	7 161
% overall		2.8	0.1	0.7	0.8	0.0	

* Refers to damaged telsons and unspecified damage that prevented measurement of TL.

If the heavy measuring practices reported in some areas are widespread, the impact on national catches of moving to the TW2 measures of 54.0 and 58.0 mm would be greater than that shown in Table 14 and would be felt for longer than suggested above. The degree to which fishermen in each area conformed with the spirit of the tail length regulation would affect the impact of the new MLS. This effect is not possible to estimate, but it could far outweigh any impact caused by regional morphometric variations.

If the current MLS of 152 mm TL is generally being adhered to, a tail width of 58.0 mm would result in a small drop in the effective MLS of females in the north of New Zealand and a small increase in the south. Because size at the onset of breeding is well below the current MLS in the north, but well above it in the south, there would be some reduction in egg-per-recruit in the north, but only a small corresponding increase in the south. Females in the north will on average breed one time fewer before being recruited into the fishery. The implications of these changes are unknown, but are probably small.

TABLE 14: Instantaneous impact estimates on national availability of changing to a MLS at the TW2 values specified

	Males		Females
TW2 (mm)	Impact (%)	TW2 (mm)	Impact (%)*
53.6	8.5	57.9	−1.6
54.0	−0.5	58.0	−4.1
53.0	21.1	57.0	16.6
52.0	45.6	56.0	37.2

* Minus signs show legal rock lobster availability (based on numbers) would decrease.

The changes in effective MLS outlined above may also cause changes in the longer term in yield-per-recruit (YPR). These changes would probably not be large for females, but for males the YPR could be lower than that at present in the north of the country and slightly higher in the south. This could help to offset short-term loss in landings in the south.

Data archive structure

All programs and data were archived in IND.BREEN.ARC35.24SEP87.

Raw data from each sample are in TWFnnn.RAW (nnn is the sample number). These files were checked with a program called SCAN, which checked for range, member-of-set, and other errors, and it wrote error messages to TWFnnn.ERR. Data were examined a second time by regressing measurements against one another; data pairs with residuals greater than 3.0 were discarded. The MINITAB regression analyses were saved in TWFnnn.LIST. The edited data were then saved in TWFnnn.TWF. Combined data were saved in TWFxxx.TWF (xxx is the CFA). All data combined are in TWFALL.TWF.

The program used in regression analysis is called SIZE. It prompts for the three-byte sample code (nnn or xxx as described above) and opens the output file TWFnnn.OUT.

The TW2 measurement was recorded in uncorrected form, as read from calipers with a small hole drilled in the fixed leg as described below. The program SIZE adds the appropriate caliper adjustment factor. Any further analysis of the data must similarly handle this problem correctly. The data are available from the Fisheries Research Centre tape librarian.

TABLE 15: Moult increments and frequencies, average annual growth, and major moulting times of rock lobsters near MLS in various areas around New Zealand

	Males				Females				
	Moult increment (mm CL)	Moult frequency (No.yr^{-1})	Annual growth (mm CL)	Major moulting periods	Moult increment (mm CL)	Moult frequency (No.yr^{-1})	Annual growth (mm CL)	Major moulting periods	Source
Tauroa Point	7	1.8	12.6	Mar-Aug Oct-Dec	4	1.6	6.4	Mar-Aug Oct-Dec	Booth, J. D. (unpublished data)
Gisborne	6	1.5	9.0	Sep-Nov Feb-Aug	3	1.0	3.0	Dec-Jul	McKoy and Esterman (1981)
Kaikoura	7	1.0	7.0	Nov-Dec	3	1.0	3.0	Mar-Apr	Annala, J. H. (unpublished data)
Stewart Island	6	1.4	8.4	Jun-Jul Nov-Jan	3	1.5	4.5	Jun-Jul Nov-Jan	McKoy (1985)
Fiordland	7	1.5	10.5	Jun-Aug Dec-Feb	3	1.0	3.0	Feb-May	Annala and Bycroft (1988)

Discussion

Tail width, as measured across the tips of the primary spines on the second segment (TW2), appears to satisfy the criteria we examined. Fishery Officers think that a satisfactory legal definition of tail width can be developed. Gauges tested by fishermen received a favourable response.

Precision of the TW2 measure was less than precision of the carapace length when five observers made the same measurement, but was greater than precision of the present tail length. Several prototype gauges have been built by Ministry of Agriculture and Fisheries officers and tested by fishermen. Comments received have been largely favourable as far as they concern ease of measurement. The TW2 measurement is less easy to determine with vernier calipers, but can be taken if care is used. If calipers are modified by drilling a small hole on the back side near the bottom tip of the fixed leg, the measure is easy to obtain by placing one spine tip in this hole. The distance between the hole and the inside surface of the fixed leg (called the caliper adjustment) must then be added. This distance is best determined by repeated measurements on several lobsters with and without the use of the hole. If this procedure is used, the caliper adjustment should be engraved on the calipers.

Processing operations cause significant, but small, changes in the TW2 measurement. Changes are small enough that they probably would not prevent reliable detection of processed sublegal rock lobsters. The changes observed in this study were smaller than those reported by Anon. (1971b) for frozen tails. In that study, mean tail length increased by 1.6–1.9 mm after freezing; an increase of 1.00–1.25%. The largest mean change caused by freezing in this study was a shrinkage of 0.43%. Bradstock (1950) reported that cooking shrank the carapace length by "no more than 1 mm" and that after cooking "abdomen breadth decreases no more than 1 mm." A prosecution based on measurements made after processing would have to take such changes into account, and, for this purpose, more work would need to be done.

The study identified a potential problem in damage to the rock lobsters. In this respect, TW2 was the worst measure examined. Carapace length is extremely rarely affected by damage; damage affecting tail length occurs with a frequency of about 1–2%. Damage affecting TW2 affected nearly 3% of the total sample, and in some areas it averaged 7%. Casual observations made during the stability trials indicated that spines and second segment bars become more fragile after cooking or freezing. There might be a higher percentage of damage in a commercial sample. Because of the high incidence of breakage (at least in some areas), this is a potential problem for enforcement of the MLS.

The TW2 measurement can be increased by applying pressure to the second segment bar during measuring or by applying lateral pressure to the gauge during measurement. The legal definition of a tail width measurement must be clear in requiring that no pressure may be applied to the segment either directly or through the gauge.

In this study tail width was greater in females than in males. Increased tail width is probably associated with maturity. A plot of abdominal width against carapace length (whole data set) showed a great variability and no inflection such as that reported to take place at maturity in *Homarus americanus* (*see* Aiken and Waddy 1980). Sexual dimorphism in tail morphometry does not appear to have been previously reported in palinurids. Berry (1971) reported that increased abdominal width in female *Palinurus homarus* was in direct proportion with carapace length and appeared to be caused by outward projection of the pleural spines. This issue requires more analysis for *Jasus edwardsii*.

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