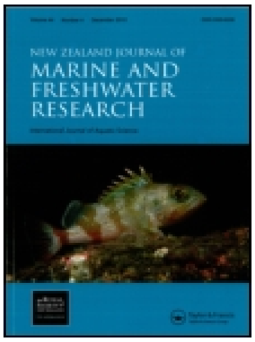

New Zealand Journal of Marine and Freshwater Research

ISSN: 0028-8330 (Print) 1175-8805 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzm20

Growth of rock lobsters (Jasus edwardsii) in the Gisborne region, New Zealand

J. L. McKoy & D. B. Esterman

To cite this article: J. L. McKoy & D. B. Esterman (1981) Growth of rock lobsters (Jasus edwardsii) in the Gisborne region, New Zealand, New Zealand Journal of Marine and Freshwater Research, 15:2, 121-136, DOI: 10.1080/00288330.1981.9515905

To link to this article: http://dx.doi.org/10.1080/00288330.1981.9515905

Published online: 22 Sep 2010.

Growth of rock lobsters (*Jasus edwardsii*) in the Gisborne region, New Zealand

J. L. McKOY
D. B. ESTERMAN
Fisheries Research Division
Ministry of Agriculture and Fisheries
P.O. Box 19062
Wellington, New Zealand

Abstract Juvenile rock lobsters, *Jasus edwardsii*, sampled at Gisborne, grew to about 38 mm carapace length (CL) within 1 year of settlement and to about 58 mm CL within 2 years. Annual growth, growth per moult, and moult frequency in the CL range 80–99 mm were determined by tagging for males in 4 areas and for females in 2 areas near Gisborne. There were significant differences in these characteristics between sexes and, for annual growth and growth per moult, between areas for each sex. Growth per moult did not vary significantly between years. Males between 80 and 99 mm CL moulted between September and November, with some further moulting between February and August. Females in the same size range moulted once per year between December and July. Von Bertalanffy growth parameters calculated for males from 3 areas showed that growth on the eastern side of Mahia Peninsula was significantly faster than that in the other areas examined.

Keywords Decapoda; *Jasus edwardsii*; growth; moulting; tagging; Gisborne.

INTRODUCTION

An understanding of the population dynamics of an exploited species is usually highly dependent on a knowledge of growth rates and processes. The estimation of growth rates in crustaceans is limited by the absence of any known annual or seasonal structural marks, and further constraints are provided by the discontinuous nature of growth. This factor becomes particularly important in species which moult only once or twice per year, for much of their lives, such as the New Zealand rock lobster, *Jasus edwardsii.*

Received 31 October 1980; revised 4 March 1981
Fisheries Research Division Publication 436

This paper presents the results of a study aimed at determining growth rates of *J. edwardsii* in 4 areas on the east coast of the North Island near Gisborne using size-frequency distribution and tagging data. These areas support a substantial rock lobster fishery, based mainly on the port of Gisborne, which has been the subject of investigations since 1974. Estimates of yield per recruit in this fishery were made by Saila et al. (1979) using preliminary growth and mortality data, and mortality estimates for the area, based on tagging and size-frequency distribution data, were made by Annala (1979, 1980).

The present study includes much of the growth data used by Saila et al. (1979), plus a considerable amount of new data which has allowed some useful comparisons of growth rates between areas. Growth rate data are also being used to predict the time of recruitment into the fishery of rock lobsters less than the legal size (J. D. Booth, unpubl. results) and estimates of moulting seasons are important, in conjunction with other biological data, in explaining seasonal changes in catchability (e.g., Street 1969).

METHODS

Growth of juveniles

The growth rate of juveniles was estimated from the progression of size-frequency modes of animals collected from under the main wharf at Gisborne. A similar technique was used to estimate growth rates in small *Jasus lalandii* (Pollock 1973) and *J. novaehollandiae* (Lewis 1977). The Gisborne wharf shelters large numbers of juveniles which were relatively easy to capture. Divers sampled the population between February 1976 and October 1979 and caught every rock lobster they could. Sample sizes varied as a result of the highly variable diving conditions under the wharf. The mean size and standard deviation of animals in each modal group were estimated using the method of Cassie (1954).

Since March 1978 the seasonal settlement of *J. edwardsii* puerulus larvae has been monitored as part of a study of larval recruitment to the area (J. D. Booth, unpubl. results). Data on seasons of peak settlement at this site were used as a basis for estimating the time of settlement of rock lobsters in each size frequency mode.

Growth of tagged rock lobsters

Size-frequency distributions cannot be analysed to estimate growth rates of rock lobsters larger than about 70 mm carapace length (CL) because the variability in individual growth rates results in a large amount of overlap between year classes. Therefore, growth rates of such rock lobsters were estimated from tagging studies conducted in 4 areas within the fishery (Fig. 1) — Gable End Foreland to Young Nicks Head (Gisborne Local), Young Nicks Head to Pukenui Beach (South of Young Nicks Head), Pukenui Beach to the south end of Portland Island (Mahia East), south end of Portland Island to Wairoa River (Mahia West).

Rock lobsters were captured between October 1975 and July 1978 by pots or by diving and tagged with western rock lobster tags (Chittleborough 1974). These tags were not used in the field on animals smaller than about 70 mm CL because preliminary laboratory experiments indicated that these did not retain the tags well or died. The tags were inserted into the dorsal thoraco-abdominal musculature between the anterior edge of the first abdominal segment and the posterior edge of the carapace, 5–10 mm to the left or right of the mid-line. Tagged animals were normally returned to the water within 10–20 min of being removed, and all were released as close as possible to the site of capture.

Data recorded for each tagged animal included sex, carapace length, stage of sexual maturity (for females only, see Annala et al. (1980)), damage, and the location and date of capture. Carapace length, from the antennal platform to the dorsal posterior margin of the carapace along the mid-line, was measured with vernier calipers. Variability in CL as measured by different people was low (< 0.5 mm).

When possible, only undamaged rock lobsters were tagged and any which had lost more than 2 walking legs or an antenna were not included in the study. Minimally damaged animals were included on the basis of Chittleborough's (1975) study which showed that loss of 2 limbs did not affect mean growth increment per moult in *Panulirus longipes*.

Most recaptures of rock lobsters were made by local commercial fishermen who were asked to return the whole animal with information on the date, location, and depth of capture.

The effects of the tag on growth per moult were estimated by comparing the first moult increment after capture of tagged and untagged rock lobsters maintained in aquaria in Wellington between October 1974 and May 1975. About half the animals in each tank were tagged, and all were identified with numbered plastic discs attached to one antenna with stainless steel wire. Each animal was measured before moulting and subsequently after the shell had hardened following each moult.

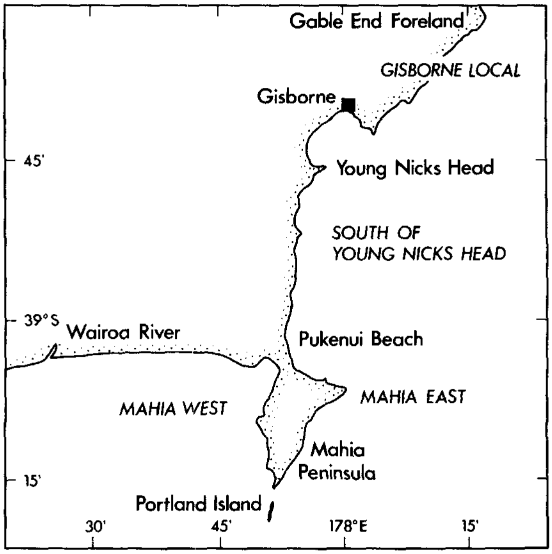

Fig. 1 Location of study area showing boundaries for grouping of growth data, and localities mentioned in the text.

RESULTS AND DISCUSSION

Growth of juveniles

The size-frequency distributions for samples of juvenile rock lobsters (males and females combined) collected under the Gisborne wharf are shown in Fig. 2. Modal size groups can be clearly identified for most samples. The modal means for males and females were separated for samples of adequate size (Table 1).

Generalised growth curves based on the progression of the size-frequency modes for males and females combined are shown in Fig. 3. The small number of animals larger than 65–69 mm CL in the samples may be the result of movement of these animals out of the wharf area.

There was very light settlement of puerulus larvae under the wharf throughout the year, except for a marked peak between early May and mid August. The mean size of recently settled puerulus at Gisborne was 11.2 mm CL (J. D. Booth, pers. comm.), and the size-frequency modes in Fig. 2 thus appear to represent settlement groups. The smaller group in the February 1976 sample probably settled in May–August 1975, the smaller group in the March 1977 sample in May–August 1976, and the smaller group in May 1979 sample in May–August 1978.

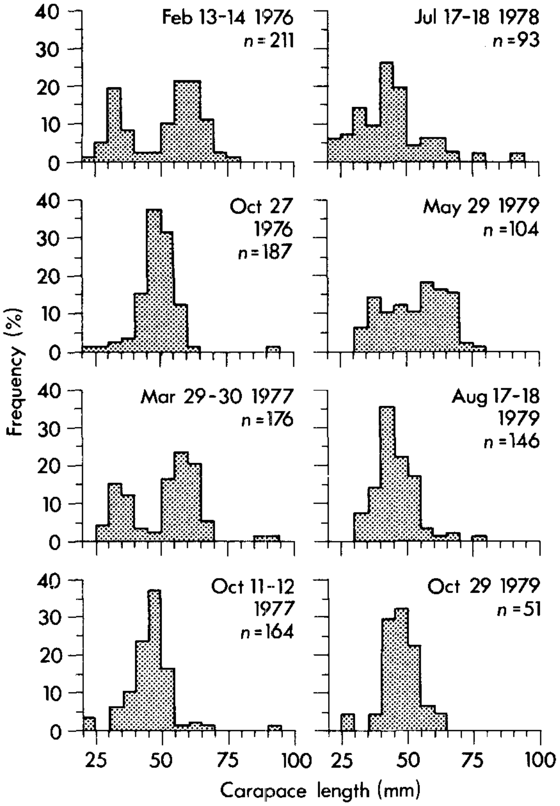

Fig.2 Size–frequency distributions of juvenile rock lobsters (*Jasus edwardsii*) collected from Gisborne wharf, males and females combined.

Assuming 30 June to be the mid-point of the settlement period, then the size–frequency data indicate that the mean size of juveniles 1 year after settlement is about 38 mm CL and at 2 years about 58 mm.

There is some possibility of bias, because of differential migration out of the area of animals in the larger year class, which would result in underestimation of growth rates. In addition, lower growth rates than in other areas might result from crowding effects if the wharf is an area of particularly high recruitment.

The association of the size–frequency modes with particular settlement groups (Fig. 3) is supported by laboratory growth data. Groups of rock lobsters collected as puerulus and raised in aquaria in Wellington in 1965–67 grew from a mean CL at collection of 12 mm to a mean CL of 35 mm in the first year (C. B. Kensler, pers. comm.).

Data on the growth of juveniles of other *Jasus* species are similar to those presented here. Lewis (1977) reported that juvenile *J. novaehollandiae* reached a mean size of 36.5 mm CL 1 year after settlement (puerulus 10.3 mm). Pollock (1973) reported slower growth in *J. lalandii*, which reached 22–24 cm CL 1 year after settlement (puerulus about 10 mm).

Growth of tagged rock lobsters

EFFECTS OF THE TAG ON MOULT INCREMENT

Increases in carapace length of tagged and untagged rock lobsters at the first moult after capture are compared in Fig. 4. There was no significant difference in moult increment of tagged and untagged rock lobsters within each sex (Mann-Whitney *U*-test). Cooper (1970) and Chittleborough (1974) respectively reported similar results for *Homarus americanus* and *Panulirus longipes cygnus* tagged with the same or similar tags. Moult frequencies of tagged and untagged *H. americanus* were not significantly different (Cooper 1970), but no data are available on the effects of the western rock lobster tag on moult frequency of palinurids.

TAGGING IN THE FIELD

The number of rock lobsters of each sex tagged and recaptured, and for which growth data were available in each area up to 31 October 1979, are shown in Table 2. Size–frequency distributions of the tagged rock lobsters for the combined tagging periods within each area are shown in Fig. 5. The size range of tagged rock lobsters was narrow; generally, those under 70 mm CL were difficult to catch in pots and, as mentioned above, were unsuitable for tagging. In the Gisborne Local area few rock lobsters over the minimum legal size (152 mm tail length or about 98 mm CL for males and 93 mm CL for females) were caught. In other areas, where larger animals had to be purchased from fishermen, numbers tagged were limited by finance.

MOULTING SEASONS

Moulting seasons of rock lobsters between 80 and 99 mm CL were estimated from recaptured animals. Growth increments of recaptures from each tagging date and area for which sufficient data were available were plotted against the number of days between tagging and recapture (Fig. 6–18). A comparison of the numbers of recaptures with no growth (and which presumably had not moulted) with the number which had grown in any particular time interval after tagging shows a distinct seasonality in moulting. The first moulting period after tagging is usually quite distinct. For some recaptures after more than 6 months, a particularly

Table 1 Estimated means and standard deviations (s.d.) of size-frequency modes of juvenile rock lobster, *Jasus edwardsii*, collected under Gisborne wharf during each sampling period. Samples for 29 May and 29 Oct 1979 were inadequate to separate males and females. (Each horizontal line on the table represents 1 mode; sample sizes shown in Fig. 2.)

Dates of Collection	Males		Females		Males and Females Combined	
	Mean	s.d.	Mean	s.d.	Mean	s.d.
13-14 Feb 1976	30.5	3.2	30.5	4.4	30.5	3.8
	58.0	5.7	51.5	4.5	57.0	5.5
27 Oct 1976	46.2	5.1	45.5	5.7	46.0	5.1
29-30 Mar 1977	31.8	3.2	31.7	4.1	31.5	4.0
	56.8	5.2	53.2	4.3	54.5	4.1
11-12 Oct 1977	43.0	5.2	42.4	5.6	42.5	5.6
17-18 Jul 1978	37.2	9.3	34.0	7.0	37.0	8.5
	57.6	3.9	52.0	5.2	57.2	4.6
29 May 1979					39.2	6.6
					58.8	5.6
17-18 Aug 1979	41.2	6.5	42.4	5.9	41.6	6.5
29 Oct 1979					44.5	5.5

large growth increment indicated that 2 moults could have taken place.

The distribution of recaptures with time is influenced by seasonal changes in catchability (probably related to moulting cycles) and by associated seasonal changes in fishing effort (Annala 1979, 1980). Rock lobsters do not feed and are not catchable in pots for 1–2 weeks before and after a moult, and some bias in estimating moulting seasons may be introduced when tagging is carried out close to a moulting period, e.g., possibly only early or late moulters are captured in moulting seasons.

Gisborne Local males. The October 1975 tagging (Fig. 6) indicated that moulting began in late November and continued through to January. There is no clear evidence from this set of data for a second moult within the year after tagging. However, the proximity of the tagging period to a major moulting period may have biased this sample for early and late moulters.

The February 1976 tagging (Fig. 7) indicated a main moulting period around September–October 1976 and that some males moulted between March and August 1976.

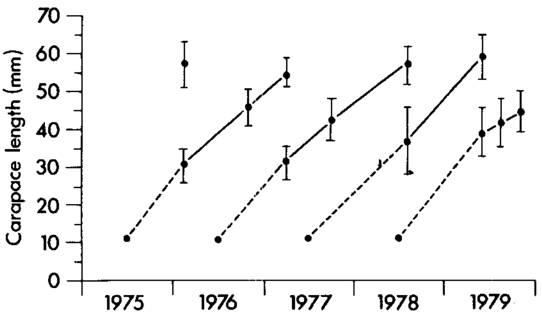

Fig.3 Growth curves (males and females combined) based on means of size-frequency modes (± 1 standard deviation) of juvenile rock lobsters from Gisborne wharf.

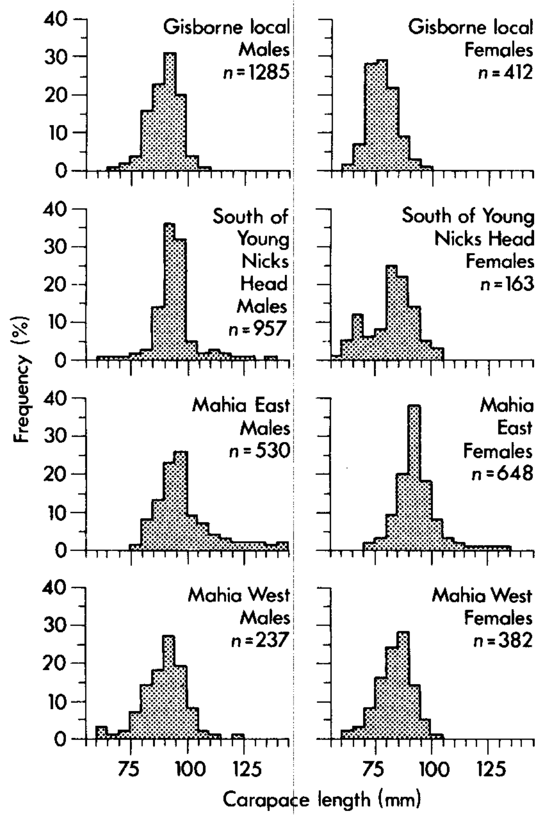

Fig.4 Growth at first moult after capture of tagged and untagged rock lobsters at Wellington.

The July 1976 tagging (Fig. 8) indicated that moulting began in September and that most recaptures after the end of November had moulted. Large growth increments suggest that some animals had moulted twice by February–March 1977 and that all had moulted at least twice by October–November 1977.

The July 1977 tagging (Fig. 9) showed that moulting began in October 1977 and that all recaptures after December had moulted. Most animals recaptured after July 1978 appeared to have moulted at least twice.

South of Young Nicks Head males. The March and July 1977 taggings (Fig. 10 & 11) indicated tht most males moulted between late September and November and that some may have moulted again by February and March.

Mahia East males. Most of the males tagged in July 1976, July 1977, and July 1978 had moulted by November of the year of tagging (Fig. 12 & 13) indicating a main moulting season for this area in October–November. The large growth increments in some later recaptures suggest a second moult for some animals between February and August.

The October 1976 tagging (Fig. 14) was close to the main moulting period and determination of the moulting season for this sample was difficult. However, the consistently large increments after September 1977 suggest that the main moult in that year took place in October–November.

Mahia West males. The main moulting period for this area was difficult to estimate from the October 1975 and 1976 taggings (Fig. 15), but most recaptured animals appeared to have moulted in December–January. The large growth increments of 2 recaptures in June and July suggest that some animals moulted twice in the year following tagging.

Mahia East females. There were few recaptures of females from this area, especially between February and September. However, the results from the October 1976 (Fig. 16) and July 1977 and 1978 (Fig. 17) taggings show that some females (both immature and mature) moulted between December and January and that the others moulted between February and July.

Mahia West females. The October 1976 tagging (Fig. 18) indicated that some females moulted in January–February, and the others between February and June.

Moulting periods were therefore similar in each area. Most males moulted between September and November and some moulted a second time between February and August. Fewer data were available for females, but it seems likely that most sexually mature females moult only once per year, sometime between December and July. Most

Table 2 Numbers of *Jasus edwardsii* tagged in each area and numbers recaptured for which growth data were available, to 31 Oct 1979.

	Males			Females		
	No. Tagged	No. Recaptured	Percent Recaptured	No. Tagged	No. Recaptured	Percent Recaptured
Gisborne Local						
Oct 1975	392	197	50.3	97	25	25.8
Feb 1976	179	97	53.6	75	17	22.7
Jul 1976	444	273	61.5	105	27	26.2
Jul 1977	270	157	58.4	134	26	18.5
South of Young Nicks Head						
Oct 1975	23	7	30.4	44	1	2.3
Mar 1977	560	318	56.8	28	6	23.0
Jul 1977	374	236	63.1	91	25	27.5
Mahia West						
Oct 1975	73	15	20.5	109	12	11.0
Oct 1976	164	79	48.2	273	103	37.9
Mahia East						
Jul 1976	51	30	58.8	32	14	43.7
Oct 1976	129	59	46.1	256	122	47.5
Jul 1977	136	73	53.4	208	100	48.3
Jul 1978	214	177	55.2	152	71	46.1

females in the Gisborne area between 80 and 99 mm CL are mature (Annala et al. 1980), and the moult in mature females is associated with mating and egg-laying (McKoy 1979). Egg-laying occurs within 6 weeks of the female moult; females carrying eggs usually begin appearing in fishermens' catches in April, and by early June most mature females are carrying eggs. This would indicate a main moult between February and June. Insufficient data were available to estimate moulting seasons for immature females.

The little data available for animals 100–120 mm CL indicate that males at Gisborne Local, South of Young Nicks Head, and Mahia East had a main moult in September–November and that females at Mahia East moulted between March and July.

Street (1969) found that in Otago and Southland "small and medium sized" males and immature females (between about 60 and 90 mm CL) usually moulted in June or July and again in December or January. The main moulting period for "large" males was from October to early December and for mature females from late February to early April. The moulting periods for "large" (> about 90 mm CL) or mature animals were therefore similar to those observed in the present study.

ANNUAL GROWTH

Annual growth was estimated from the growth increments of animals recaptured on or near the anniversary of tagging by a method similar to that of Hancock & Edwards (1967). Since there were few recaptures on exact anniversaries, recaptures for a selected period each side of the anniversary date were also used as estimates of annual growth. The choice of a satisfactory period depends on a reasonable knowledge of the times of the main moulting periods. For most of the tagging data, growth of animals recaptured between 330 and 400 days after tagging was assumed to represent annual growth. Release and recapture periods should not be close to the moulting seasons since estimates of annual growth and moult frequency could be biased by moulting immediately before or just after tagging (Hancock & Edwards 1967). For this reason no annual growth estimates were made for males tagged in October or for females tagged in February and March.

For individual recaptures there was no significant correlation between annual growth and CL at tagging for any of the areas where sufficient data were available. This probably results from the small size range for which annual growth data are available and the considerable individual variability in annual growth (Fig. 6–9).

Estimates of annual growth for each area by 10 mm size groups are summarised in Table 3.

For comparison between areas and sexes, data were combined for the 80–89 and 90–99 mm CL ranges. Annual growth of males in the areas Gisborne Local (7.1 mm), South of Young Nicks Head (8.3 mm), and Mahia East (12.4 mm) differed significantly at the 1% level (Kruskal-Wallis *H*-statistic; Dunn's approximation for unequal sample sizes was used for multiple comparisons). Annual growth of females between 80 and 99 mm CL at Mahia East (3.3 mm) and Mahia West (2.9 mm) was not significantly different (Mann-Whitney *U*-test). Within Mahia East, annual growth of males differed signficantly at the 1% level from that of females (Mann-Whitney *U*-test). Data were inadequate for comparisons between years.

The data on annual growth for males from Gisborne Local, South of Young Nicks Head, and Mahia East were used to calculate the parameters of the von Bertalanffy function for each area (Table 4) using Fabens's (1965) method. Juvenile growth data were available for Gisborne Local only. Variances for L_∞ (asymptotic length) and K (a parameter

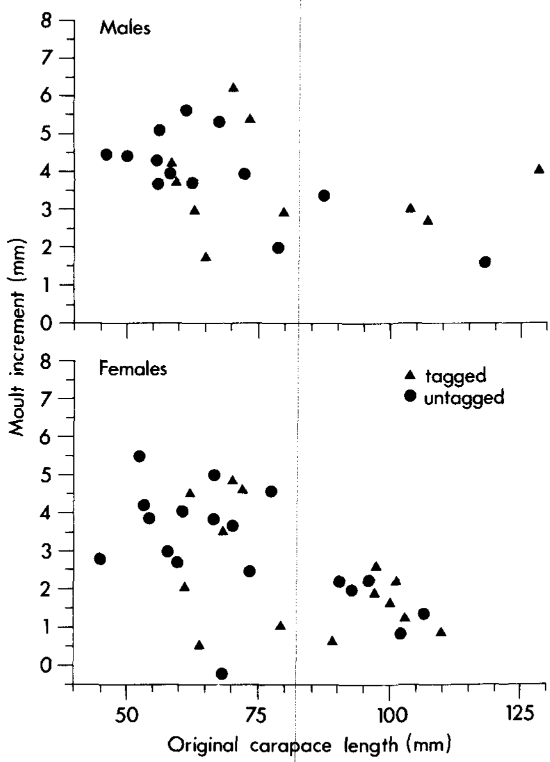

Fig.5 Size-frequency distributions of rock lobsters tagged in the Gisborne region between Oct 1975 and Jul 1978.

relating to the change in length increments) were calculated using a modification of the method of Allen (1966) applied to Fabens's (1965) equation. Regression analysis (Rao 1965) showed that the von Bertalanffy parameters for Mahia East were significantly different from those for the other 2 areas, but that the parameters for South of Young Nicks Head and Gisborne Local were not significantly different.

The considerable degree of allometric growth associated with the change in form from the phyllosoma to the puerulus stage means that the calculated t_0 (the hypothetical age at which the organism would have been at zero length) cannot be used to estimate the duration of larval life.

The age–length relationships and the growth of recaptures near the second anniversaries of tagging for these areas (originating at the appropriate point on the calculated line) are shown in Fig. 19. Variations about the line can be explained in terms of the stepwise growth of individual animals.

The von Bertalanffy parameters calculated in this study differ from those calculated for males by Saila et al. (1979) who combined growth data for the areas Gisborne Local, Mahia East, and Mahia West;

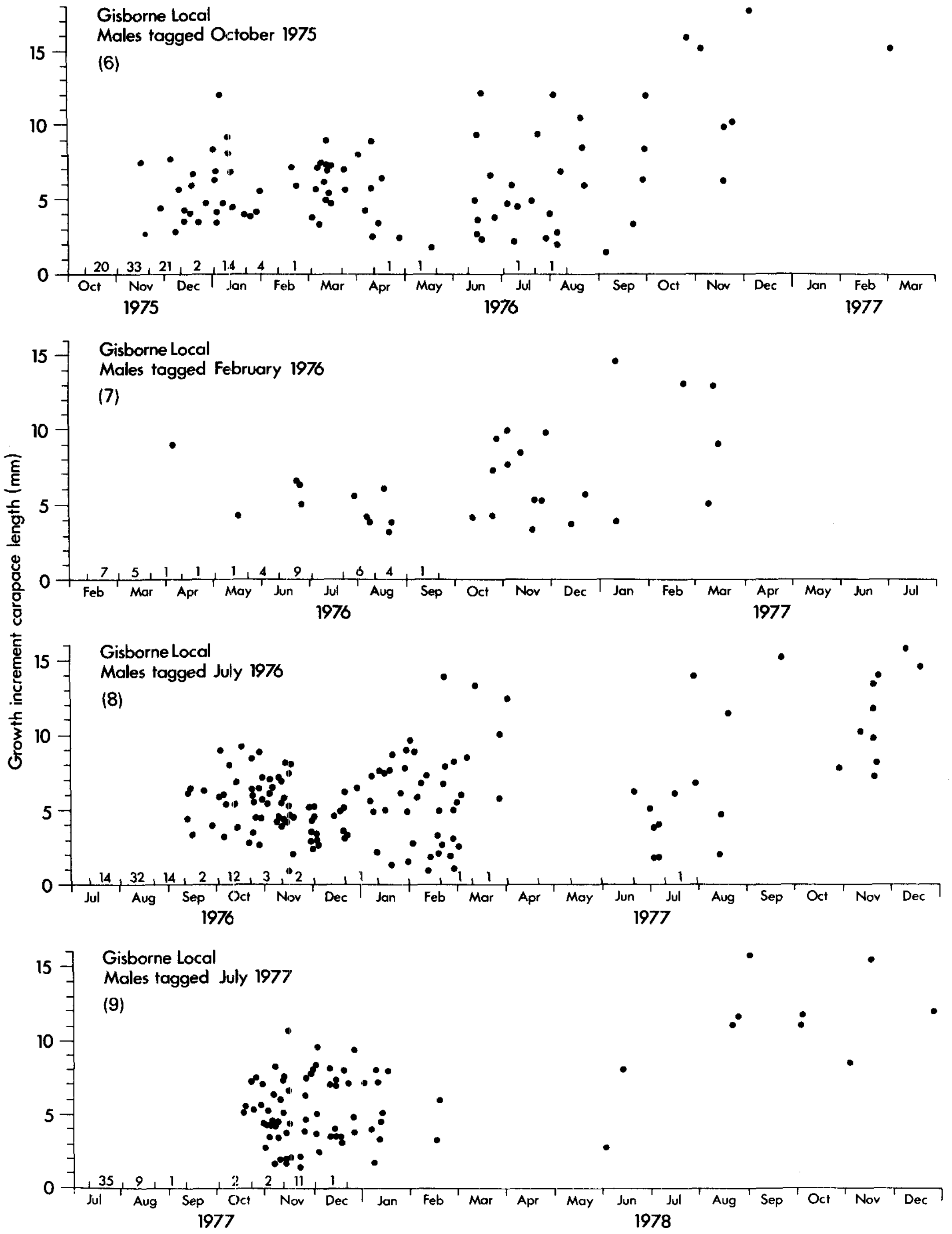

Fig.6–18 Growth increments of recaptured tagged rock lobsters 80–99 mm carapace length for each tagging period in each area. Numbers of animals which had not grown at recapture shown for 20-day periods along the abscissa. All females were mature at tagging and recapture except those marked (x) which were immature at tagging and recapture.

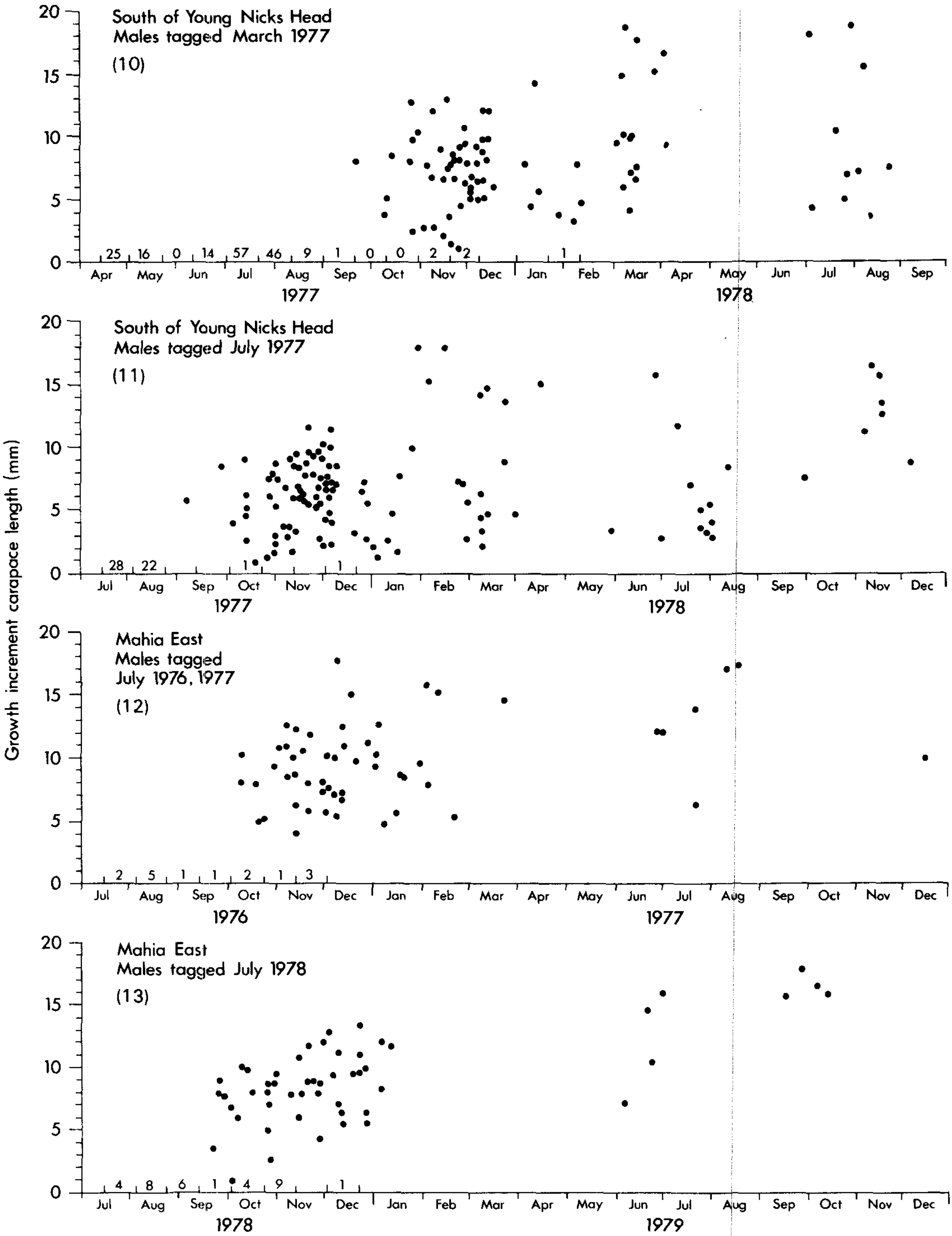
South of Young Nicks Head
Males tagged March 1977
(10)
25 16 0 14 57 46 9 1 0 0 2 2 1
Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
1977
1978
South of Young Nicks Head
Males tagged July 1977
(11)
28 22 1 1
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1977
1978
Mahia East
Males tagged
July 1976, 1977
(12)
2 5 1 1 2 1 3
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1976
1977
Mahia East
Males tagged July 1978
(13)
4 8 6 1 4 9 1
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1978
1979
Growth increment carapace length (mm)
0
5
10
15
20

Fig.10–13

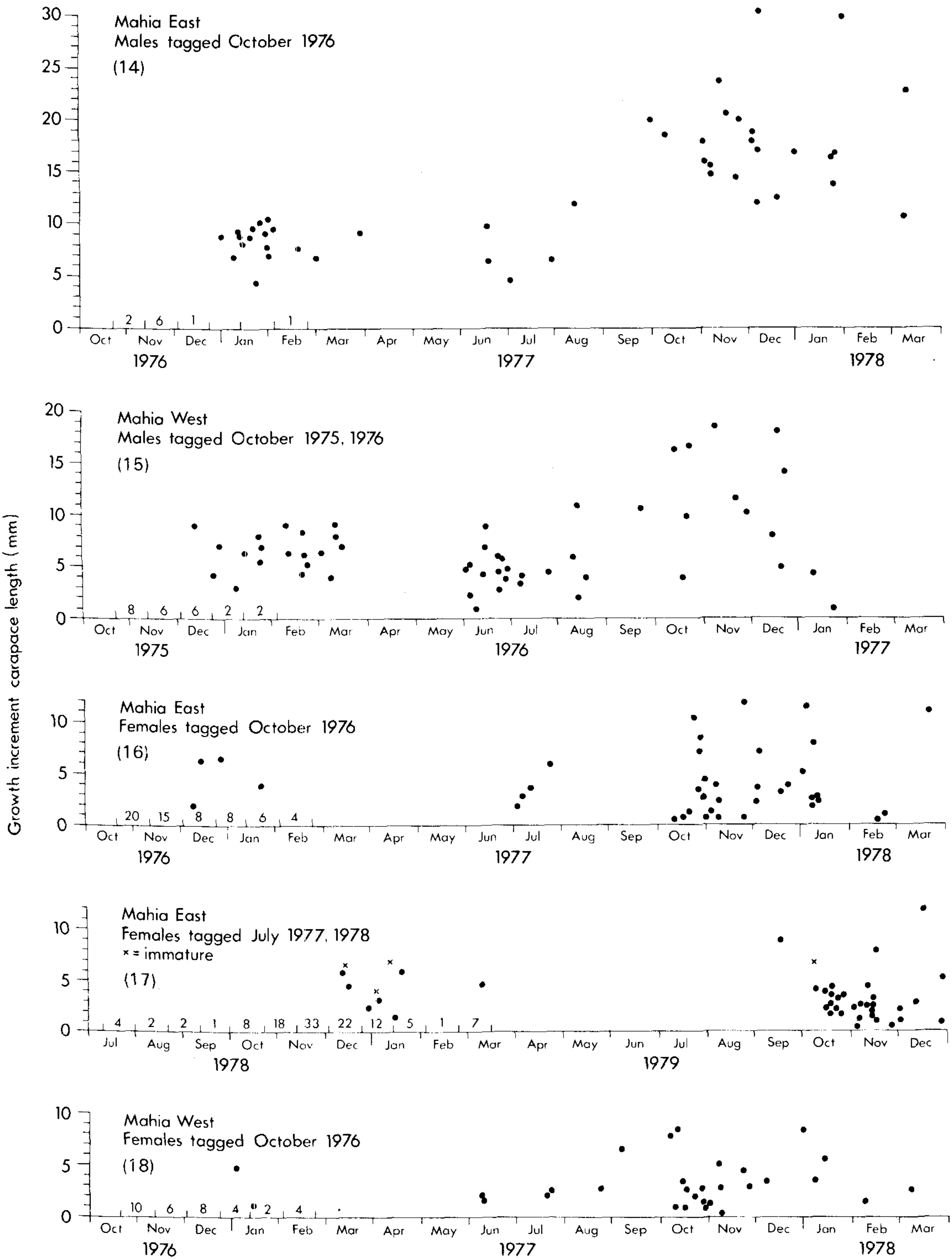
Mahia East
Males tagged October 1976
(14)
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
1976
1977
1978
Mahia West
Males tagged October 1975, 1976
(15)
1975
1976
1977
Growth increment carapace length (mm)
Mahia East
Females tagged October 1976
(16)
Mahia East
Females tagged July 1977, 1978
× = immature
(17)
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1978
1979
Mahia West
Females tagged October 1976
(18)

Fig.14–18

Table 3 Estimates of annual growth of *Jasus edwardsii* based on tag–recapture data; periods after tagging chosen to represent annual growth are 300–400 days for Mahia West females and 330–400 days for all other sets; all sizes and increments in mm carapace length; –, no data; all females sexually mature except 1 (86 mm CL, 8.5 mm annual growth, at Mahia East).

	Males				Females			
CL range	Mean size at tagging	Mean incre-ment	s.d.	n	Mean size at tagging	Mean incre-ment	s.d.	n
Gisborne Local								
70-79	79	11.1	-	2	78	2.6	-	1
80-89	83	8.3	4.1	10	84	-0.1	1.0	5
90-99	94	5.9	3.1	10	-	-	-	-
100-109	101	1.9	-	1	-	-	-	-
South of Young Nicks Head								
80-89	87	10.4	3.6	5	-	-	-	-
90-99	95	7.9	4.3	23	-	-	-	-
100-109	-	-	-	-	-	-	-	-
110-119	117	6.3	-	1	-	-	-	-
120-129	120	3.2	-	1	-	-	-	-
Mahia East								
80-89	85	12.8	5.2	3	87	3.0	2.6	7
90-99	93	12.2	4.0	8	93	3.5	3.0	9
100-109	109	18.3	-	1	107	2.1	-	2
110-119	-	-	-	-	117	1.8	-	1
120-129	128	9.9	-	1	-	-	-	-
130-139	134	5.6	4.5	3	-	-	-	-
Mahia West								
79-79	-	-	-	-	76	3.4	4.2	3
80-89	-	-	-	-	85	2.7	2.2	14
90-99	-	-	-	-	92	3.7	4.0	4

their juvenile growth data were based on growth in the laboratory in Wellington. The curves are therefore not strictly comparable. The present study includes a larger data base permitting the calculation of separate von Bertalanffy parameters for each of these 3 areas. However, reliable data on moult frequency and growth per moult over a suitably wide size range are not available for any of the areas considered individually here, so that we cannot produce empirical growth curves, such as those produced by Saila et al. (1979), with confidence for any one area.

Table 4 Parameters of the von Bertalanffy growth function for male *Jasus edwardsii* near Gisborne; L_{∞}, K, and t_0 as defined in text.

	Gisborne Local	South of Young Nicks Head	Gisborne Local & South of Young Nicks Head combined	Mahia East
No. of samples	25	30	55	16
L_{∞} (mm CL)	118	125	128	190
Standard deviation of L_{∞}	5.8	11.6	6.6	50.6
K (per year)	0.29	0.33	0.25	0.15
Standard deviation of K	0.05	0.15	0.05	0.09
t_o (years)	-0.36	-0.30	-0.38	-0.40

The use of the von Bertalanffy function for describing growth has recently been criticised (e.g., Roff 1980). However, given the type of data available in this study, and the relatively narrow size range over which growth data are available, this function provides a reasonable and convenient first approximation description of growth.

GROWTH PER MOULT

Growth of recaptured animals within the following periods after each tagging was assumed to represent one moult, based on the estimates of moulting seasons above: Gisborne Local males — October 1975, 0–140 days; February 1976, 0–180 days; July 1976 and 1977, 0–200 days; South of Young Nicks Head males — March 1977, 0–260 days; July 1977, 0–180 days; all Mahia East and Mahia West males — 0–200 days; all Mahia East and Mahia West females — 0–300 days.

Estimates of growth per moult for the combined taggings for each of the 4 areas are presented in Table 5. Since the only evidence of a moult having taken place was change in carapace length, some bias may have been introduced, particularly with females in which moult increments tend to be small, and some animals may have moulted without any detectable increase in CL. Estimates of mean growth per moult may, therefore, be too high and estimates of moult frequency too low.

Except for Gisborne Local males, there were no significant correlations between growth per moult and carapace length at tagging. The absence of significant correlations may be the result of high individual variability in moult increment associated with a relatively small range of carapace lengths at tagging. For Gisborne Local males, for which CL is between 71 and 105 mm, growth per moult (mm) = $13.7 - 0.1 \times \text{CL}$ ($r = 0.295$, $n = 128$, $P < 0.01$).

Differences in growth per moult of male rock lobsters between 80 and 99 mm CL were determined between years and between areas where sufficient data were available. Growth per moult was not significantly different between years at Gisborne Local for October 1975 (5.0 mm), July 1976 (4.8 mm), and July 1977 (4.8 mm) (Kruskal-Wallis *H*-statistic) and at Mahia East for July 1977 (8.4 mm) and July 1978 (7.8 mm) (Mann-Whitney *U*-test).

Growth per moult for males in each area was compared (Kruskal-Wallis *H*-statistic, Dunn's correction for unequal sample sizes) for all taggings combined for each area.

Growth per moult at Gisborne Local (4.8 mm) was significantly less than at the other 3 areas and that at South of Young Nicks Head (5.6 mm) was

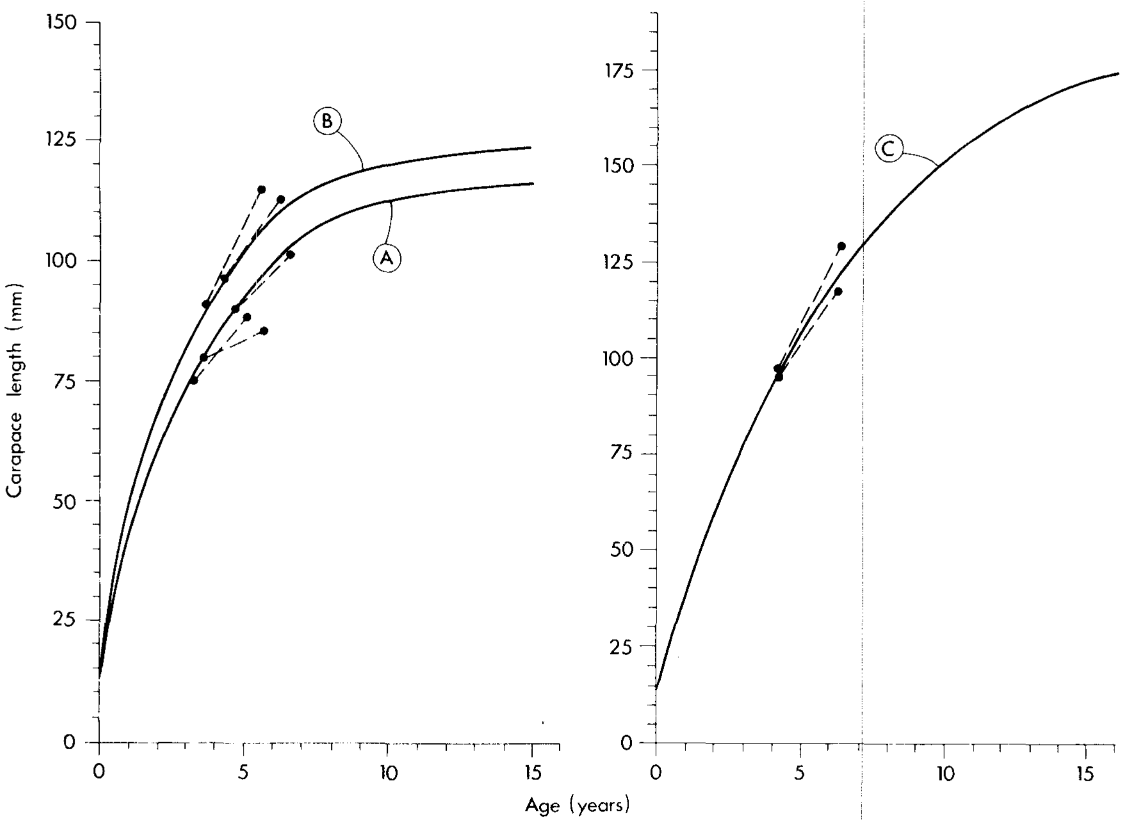

Fig.19 von Bertalanffy curves of growth in length for male rock lobsters based on annual growth estimates from tag-recapture and juvenile size-frequency modes, 1975–79. A, Gisborne Local; B, South of Young Nicks Head; C, Mahia East. Broken lines show growth of individual rock lobsters recaptured near 2nd anniversary of tagging, starting from a point on the calculated curve corresponding with carapace length at tagging.

significantly less than at Mahia East (7.9 mm) ($P < 0.01$). Growth per moult at Mahia West (6.7 mm) was not significantly different from that at South of Young Nicks Head or Mahia East.

Growth per moult of females between 80 and 99 mm CL at both Mahia East (4.4 mm) and Mahia West (6.7 mm) was significantly less than that of males (Mann-Whitney *U*-test $P < 0.01$).

MOULT FREQUENCY

The mean annual moult frequency (mf) for a given size group can be estimated by dividing the mean annual growth for each size group by the mean growth per moult for that group. Such estimates were made from the data in Tables 3 and 5.

Within any male size group there were no major differences in mf between areas (Table 6). Some males moulted more than once in all areas giving a mean mf of 1.3–1.6. This observation is supported by the moulting seasons inferred from the tag recovery data (Fig. 6–18). Males between 80 and 89 mm CL moulted more frequently than those between 90 and 99 mm CL. This is consistent with the pattern of decreasing moult frequency with increasing size which has been reported for many crustaceans.

Females which moulted without detectable increases in CL would not have been included in the calculations of moult increment and some error might be expected in the estimates of moult frequency for females. For females, however, mf is about 1.0 and this is consistent with estimates of one moult per year for sexually mature females from the tag recovery data and from a consideration of the relationship between moulting, mating, and egg-laying discussed above and by McKoy (1979).

Table 5 Growth per moult (mm carapace length) of tagged *Jasus edwardsii*, estimated from tag-recapture studies; taggings from all years in each area are combined ($\bar{x}$, mean; s.d., standard deviation; *n*, sample size; –, no data).

CL range (mm)	Gisborne Local			South of Young Nicks Head			Mahia East			Mahia West		
	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n
Males												
70-79	6.5	4.6	5	5.3	-	1		-		6.6	-	2
80-89	5.2	1.7	78	6.3	2.4	22	7.8	1.4	26	6.8	1.7	8
90-99	4.5	1.8	106	5.5	2.1	104	8.0	2.0	63	6.6	1.9	10
100-109	4.2	2.1	9	4.1	1.1	3	6.4	3.0	14		-	
110-119		-		5.2	2.9	6	9.1	1.4	6		-	
120-129		-		7.3	-	1	9.7	1.4	4		-	
140-149		-			-		2.7	-	1		-	
Females												
70-79		-			-			-		2.2	-	2
80-89		-			-		5.2	2.3	8	2.8	1.5	5
90-99		-			-		3.9	1.6	11		-	

CONCLUSIONS

The growth rate of male *Jasus edwardsii* was highly variable between individuals and between areas. There was no significant correlation between carapace length and annual growth or growth per moult (except for Gisborne Local males) because of this variability and the narrow size range over which data are available. Such individual variability is also a feature of the growth of *J. tristani* (Pollock & Roscoe 1977) and *J. lalandii* (Heydorn 1969).

Annual growth of males between 80 and 99 mm CL differed significantly between areas and appears to be a result of differences in moult increment rather than moult frequency. Newman & Pollock (1974) related growth rate differences in *J. lalandii* between areas to differences in food availability. Similarly, Chittleborough (1976) suggested limited food resources on some shallow nursery reefs as the main reason for retarded growth of juvenile *Panulirus longipes cygnus*. Such factors may be operating in the Gisborne area, since evidence from commercial fishermen and from the trapping of rock lobsters for this study indicates that the population density at Gisborne Local is considerably greater than at Mahia East. No data are available on other factors (such as food availability and hydrographic conditions) which might contribute to differences in growth rate of *J. edwardsii* in the 4 areas studied.

The differences in growth rates between males and females are similar to those described by Street (1969) in that the moult increments of mature females are less than those of similar sized males. The moult frequency of mature females between 80 and 120 mm CL on the east coast of the North Island is probably one per year, similar to that described for mature females in southern New Zealand by Street (1969). However, many males in the same size range appear to be moulting twice each year.

In many studies of palinurids the availability of animals often results in growth rate data being limited to a small size range. Our general understanding of growth as well as the precision of

Table 6 Estimates of annual moult frequency (mf) from annual growth (a) (Table 3) and single moult increments (i) (Table 5), where mf = a/i, for *Jasus edwardsii.*

Area and size group (mm CL)	a	i	mf
Males			
Gisborne Local			
80-89	8.3	5.2	1.6
90-99	5.9	4.5	1.3
South of Young Nicks Head			
80-89	10.4	6.6	1.6
90-99	7.9	5.5	1.4
Mahia East			
80-89	12.8	7.8	1.6
90-99	12.2	8.0	1.5
Females			
Mahia East			
80-89	3.0	5.2	0.6
90-99	3.5	3.9	0.9
Mahia West			
70-79	3.4	2.2	1.5
80-89	2.7	2.8	1.0

mortality and yield estimates will be improved if future studies make a point of examining a wider size range and make a particular study of growth patterns in females over the size at the onset of sexual maturity.

ACKNOWLEDGMENTS

Invaluable assistance in the field was provided by J.H. Annala, B.T. Hvid, J. Atkinson, B. Bycroft, S. Tarring, and by the many fishermen who allowed us to tag rock lobsters aboard their boats, particularly C. Armstrong, R. Brand, and C. Austin. Fishermen who took the trouble to bring in tagged rock lobsters and the fish-packing factory staff who handled and stored tagged animals are gratefully acknowledged. Thanks are also due to the staff of the Ministry of Agriculture and Fisheries office in Gisborne and the Gisborne Harbourmaster for varied assistance. We thank J.H. Annala, J.D. Booth, and H.J. Cranfield for helpful comments on the manuscript, and C. Hayward for drawing the figures.

REFERENCES

Allen, K. R. 1966: A method of fitting growth curves of the von Bertalanffy type to observed data. *Journal of the Fisheries Research Board of Canada 23*: 163–179.

Annala, J. H. 1979: Mortality estimates for the New Zealand rock lobster, *Jasus edwardsii. Fishery bulletin 77*: 471–480.

———1980: Mortality estimates for the rock lobster, *Jasus edwardsii*, near Gisborne, New Zealand. *New Zealand journal of marine and freshwater research 14*: 357–371.

Annala, J. H. et al. 1980: Size at the onset of sexual maturity in female *Jasus edwardsii* (Decapoda: Palinuridae) in New Zealand. *New Zealand journal of marine and freshwater research 14*: 217–227.

Cassie, R. M. 1954: Some uses of probability paper in the analysis of size frequency distributions. *Australian journal of marine and freshwater research 5*: 513–522.

Chittleborough, R. G. 1974: Development of a tag for the western rock lobster. *CSIRO Division of Fisheries and Oceanography report 56.*

———1975: Environmental factors affecting growth and survival of juvenile western rock lobsters *Panulirus longipes* (Milne-Edwards). *Australian journal of marine and freshwater research 26*: 177–196.

———1976: Growth of juvenile *Panulirus longipes cygnus* George on coastal reefs compared with those reared under optimal environmental conditions. *Australian journal of marine and freshwater research 27*: 279–295.

Cooper, R. A. 1970: Retention of marks and their effects on growth, behaviour, and migrations of the American lobster, *Homarus americanus. Transactions of the American Fisheries Society 99*: 409–417.

Fabens, A. J. 1965: Properties and fitting of the von Bertalanffy growth curve. *Growth 29*: 265–289.

Hancock, D. A.; Edwards, E. 1967: Estimation of annual growth in the edible crab (*Cancer pagurus* L.). *Journal du Conseil Permanent International pour l'Exploration de la Mer 31*: 246–264.

Heydorn, A. E. F. 1969: The rock lobster of the South African west coast *Jasus lalandii* (H. Milne-Edwards). 2. Population studies, behaviour, reproduction, moulting, growth and migration. *Investigational report, Division of Sea Fisheries, South Africa, no. 71.*

Lewis, R. K. 1977: Rock lobster puerulus settlement in the south-east. *SAFIC (South Australia) no. 13*: 9–10.

McKoy, J. L. 1979: Mating behaviour and egg laying in captive rock lobster, *Jasus edwardsii* (Crustacea: Decapoda: Palinuridae). *New Zealand journal of marine and freshwater research 13*: 407–413.

Newman, G. G.; Pollock, D. E. 1974: Growth of the rock lobster *Jasus lalandii* and its relationship to benthos. *Marine biology 24*: 339–346.

Pollock, D. E. 1973: Growth of juvenile rock lobster *Jasus lalandii. Investigational report, Division of Sea Fisheries, South Africa, no. 106.*

Pollock, D. E.; Roscoe, M. J. 1977: The growth at moulting of crayfish *Jasus tristani* at Tristan da Cunha, South Atlantic. *Journal du Conseil Perma-*

nent International pour l'Exploration de la Mer 37 : 144 – 146.

Rao, C. R. 1965: Linear statistical inference and its applications. New York, Wiley.

Roff, D. A. 1980: A motion for the retirement of the von Bertalanffy function. *Canadian journal of fisheries and aquatic science 37* : 127 – 129.

Saila, S. B. et al. 1979: Application of yield models to the New Zealand rock lobster fishery. *New Zealand journal of marine and freshwater research 13* : 1 – 11.

Street, R. J. 1969: The New Zealand crayfish *Jasus edwardsii* (Hutton). *New Zealand Marine Department, fisheries technical report 30.*