

Abstract—Catch rates in the South African rock lobster (*Jasus lalandii*) fishery declined after 1989 in response to reduced adult somatic growth rates and a consequent reduction in recruitment to the fishable population. Although spatial and temporal trends in adult growth are well described, little is known about how juvenile growth rates have been affected. In our study, growth rates of juvenile rock lobster on Cape Town harbor wall were compared with those recorded at the same site more than 25 years prior to our study, and with those on a nearby natural nursery reef. We found that indices of somatic growth measured during 1996–97 at the harbor wall had declined significantly since 1971–72. Furthermore, growth was slower among juvenile *J. lalandii* at the harbor wall than those at the natural nursery reef. These results suggest that growth rates of juvenile and adult *J. lalandii* exhibit similar types of spatiotemporal patterns. Thus, the recent coastwide decline in adult somatic growth rates might also encompass smaller size classes.

Do fluctuations in the somatic growth rate of rock lobster (*Jasus lalandii*) encompass all size classes? A re-assessment of juvenile growth

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The South African fishery for rock lobster (*Jasus lalandii*) began in the late nineteenth century and expanded rapidly so that catches peaked at approximately 10,000 metric tons (t) per annum between 1950 and 1965 (Pollock, 1986). However, subsequent deterioration in catches in the 1960s and 1970s was arrested only in the mid-1980s by the implementation of a management approach centered on an annual total allowable catch (TAC). Over the following five years, catches were maintained at apparently sustainable levels of 3500–4000 t per annum (Cockcroft and Payne, 1999), still representing the largest yield of any *Jasus* species at that time (Pollock, 1986). However, the period of stability ended after 1989, when catch rates declined in response to reduced adult somatic growth rates and a concomitant reduction in recruitment to that part of the population larger than the minimum legal size (Melville-Smith et al., 1995; Goosen and Cockcroft, 1995; Cockcroft, 1997).

Adult somatic growth rates for this resource are assessed by means of a tag-recapture program. This is relatively simple because mature individuals

molt only once a year, just prior to the start of the commercial fishing season, and samples of these animals can be tagged shortly before they molt. Annual growth increments can therefore be calculated from postmolt-tagged animals recaptured during the subsequent commercial fishing season. This type of tag-recapture data is routinely collected from most of the fishing grounds that are important to the South African commercial fishery (Fig. 1, inset). This tagging program has yielded one of the most comprehensive rock lobster tagging-for-growth databases in the world; it contains continuous time-series for most areas since 1986 and broken time-series for some sites dating back to the 1969–70 season (Goosen and Cockcroft, 1995). Consequently, temporal and spatial trends in adult growth are well described (Melville-Smith et al., 1995; Goosen and Cockcroft, 1995; Cockcroft, 1997; Cruywagen, 1997; Pollock et al., 1997). By contrast, little is known about what may affect juvenile growth rates.

Of particular concern is the lack of information regarding the way in which juvenile growth rates might have been affected by factors that

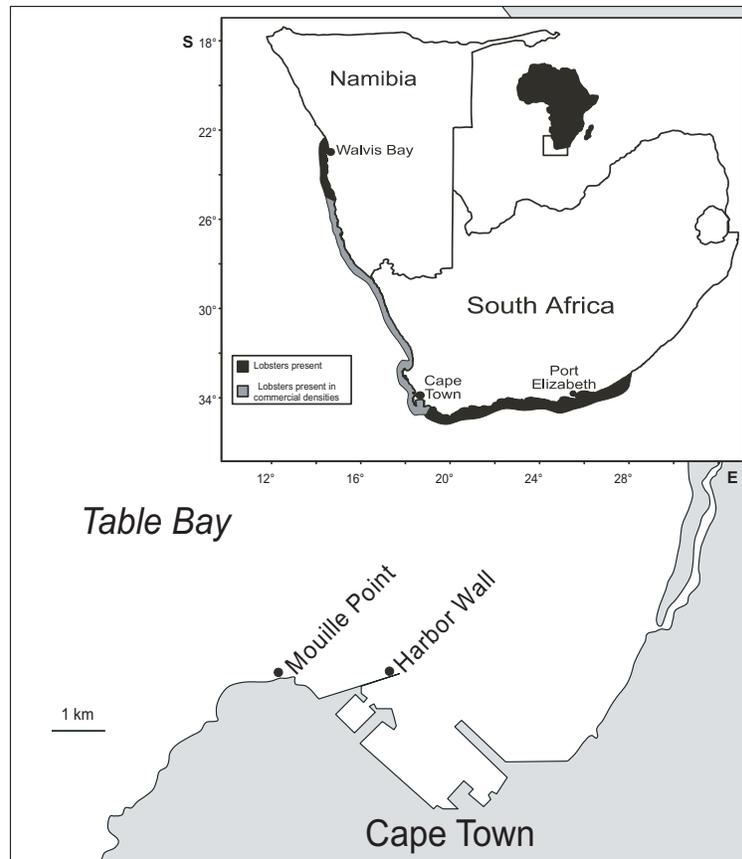


Figure 1

Map of Table Bay showing the position of the two study sites. Inset: map of southern Africa showing the distribution of rock lobster, *Jasus lalandii*.

caused the decline in adult growth rates during the early 1990s. A decrease in the size of females at 50% maturity provided indirect evidence that juvenile growth rates may also have been adversely affected (Pollock, 1987; Cockcroft and Goosen, 1995; Pollock, 1995; Pollock, 1997), but this decline in juvenile growth rates has not been confirmed by direct measurement.

Despite both this substantial gap in our knowledge of the ecology of *J. lalandii* and the growing international recognition of the importance of understanding the early life history stages of species with complex life cycles (Herrnkind et al., 1994), juvenile growth of this species was last assessed more than 25 years ago (Pollock, 1973). It was therefore essential that juvenile growth be re-examined by repeating Pollock's (1973) study at Cape Town harbor wall. This site was originally selected because of the large numbers of juvenile rock lobster present on the vertical face of the harbor wall and because these lobsters were easy to collect. In our study, a second, natural nursery reef site at nearby Mouille Point (Fig. 1) was selected to compare with the original artificial harbor wall site.

This paper addresses two hypotheses. The first is that somatic growth rates of juveniles on the harbor wall have

not declined since Pollock's (1973) study. The second is that juvenile growth rates of rock lobster on the harbor wall are not different from those of rock lobster on the nearby natural nursery reef at Mouille Point.

Methods

Juvenile rock lobsters were collected between March 1996 and February 1997 at two sites: Cape Town harbor wall (seaward side) and Mouille Point (Fig. 1). Only the harbor wall was sampled in March and intervals between samples were approximately one month, although it was not possible to sample either site every month. Two autumn months (one for Mouille Point), two winter months, two spring months, and three summer months were sampled, thereby allowing for seasonal variation in growth.

Juvenile rock lobsters were sampled by two SCUBA divers who collected specimens for roughly 20–30 minutes, or by one diver for about twice as long (Table 1). At the harbor wall, divers started at the base of the wall (>10 m depth) and worked their way up to the surface, collecting every lobster encountered, where possible. At Mouille

Table 1

Summary of data relating to the field sampling of juvenile rock lobster at Mouille Point and Cape harbor wall, 1996–97.

| Site | Sample date | Number of divers | Effort (diver minutes) | Water temperature ¹ (°C) | Postmolt | | Intermolt | Premolt | | Total |
|---------------|-------------|------------------|------------------------|-------------------------------------|----------|----------|-----------|----------|----------|-------|
| | | | | | Soft new | Hard new | Hard | Hard old | Soft old | |
| Mouille Point | 4 Apr 1996 | 1 | 40 | 11.2 | 2 | 4 | 202 | 65 | 0 | 273 |
| | 21 Jun 1996 | 1 | 50 | 13.5 | 2 | 3 | 167 | 67 | 0 | 239 |
| | 24 Jul 1996 | 2 | 30 | 13.3 | 8 | 15 | 174 | 56 | 0 | 253 |
| | 17 Oct 1996 | 2 | 75 | 12.5 | 2 | 10 | 239 | 80 | 4 | 335 |
| | 27 Nov 1996 | 2 | 50 | 9.4 | 4 | 12 | 291 | 58 | 0 | 365 |
| | 20 Dec 1996 | 1 | 40 | 10.0 | 4 | 14 | 212 | 60 | 1 | 291 |
| | 30 Jan 1997 | 2 | 50 | 8.8 | 2 | 19 | 224 | 52 | 0 | 297 |
| | 25 Feb 1997 | 2 | 65 | 9.2 | 5 | 17 | 176 | 77 | 0 | 275 |
| Harbor wall | 15 Mar 1996 | 1 | 60 | 10.0 | 12 | 6 | 325 | 121 | 0 | 464 |
| | 24 Apr 1996 | 2 | 55 | 12.5 | 3 | 7 | 228 | 52 | 0 | 290 |
| | 21 Jun 1996 | 1 | 20 | 13.5 | 1 | 1 | 210 | 42 | 2 | 256 |
| | 24 Jul 1996 | 1 | 45 | 13.3 | 8 | 13 | 243 | 29 | 6 | 299 |
| | 17 Oct 1996 | 2 | 60 | 12.5 | 3 | 15 | 205 | 80 | 0 | 303 |
| | 29 Nov 1996 | 2 | 45 | 12.9 | 4 | 9 | 262 | 30 | 0 | 305 |
| | 20 Dec 1996 | 1 | 40 | 10.0 | 6 | 7 | 275 | 38 | 0 | 326 |
| | 30 Jan 1997 | 2 | 50 | 8.8 | 2 | 13 | 280 | 38 | 2 | 335 |
| | 25 Feb 1997 | 2 | 64 | 9.2 | 10 | 34 | 210 | 76 | 0 | 330 |

¹ Temperature readings were taken from a temperature logger located in 10 m of water approximately 2 km east of Mouille Point.

Point, divers swam around the reef area, covering different habitat types (ledges, vertical walls, cracks, etc.), and attempted to catch every lobster encountered.

The catch was maintained in a bin of seawater until the sex, shell state (*sensu* Pollock, 1973) and carapace length (CL) of each animal could be recorded. Hard old and soft old shell states were considered to represent premolt animals, soft new and hard new to represent postmolts, and those animals in the hard shell state were considered to be in the intermolt phase of the molt cycle. Postmolt and intermolt specimens were released, whereas premolt animals were measured to the nearest 0.1 mm and transported to the laboratory. Whenever relatively few premolt specimens of a particular size-category were captured during routine searches, additional dive time was spent collecting these. In the laboratory, captive specimens were transferred to perforated plastic jars (either 250 or 500 cm³ in volume, with square perforations of approximately 25 mm²), which were placed in a 2-m³ holding tank. To mimic natural conditions (Table 1), aquarium water temperature was controlled between 11° and 14°C during holding, with a mean of 12.6°C (SD=0.48°C), and salinity was maintained at 35–36‰ by periodic addition of freshwater or partial replacement of seawater. Stocking density did not exceed three specimens per jar, and larger specimens were held singly or in pairs. By using a combination of jar number, sex, premolt carapace length, and the pattern of missing limbs, it was possible to identify each individual. Because *J. lalandii* are unable to feed shortly before molting

(Zou-tendyk, 1988), it was assumed that no feeding was required. Jars were checked for molting individuals at least every second day. Cast exoskeletons were examined to identify those molting, and each new carapace length, as well as any limb regeneration, was recorded once the shell had hardened. Increment data recorded for December 1996 were discarded because of aquarium failure: raised temperatures and lower oxygen levels resulted in high mortality during molting. Because increments from specimens maintained in the laboratory for more than 18 days were considered unreliable, only animals that molted within this period were included in analyses.

Tests of the hypothesis that somatic growth rates of juveniles on the harbor wall had not declined since Pollock's (1973) study were complicated by the absence of his original data. All that remain are mean molt increments for male and for female specimens categorized into 5-mm-CL size classes, their standard deviations, and their sample sizes. Calculation of combined mean increments for males and females of a given size is simple, but their standard deviations had to be approximated by adding corresponding sums of squares for males and females and dividing this value by the overall degrees of freedom within the size class (Table 2). It had been our intention to compare these reconstructed data with those from our study by using a two-way ANOVA (site × size class), but this was not possible, given the limitations of Pollock's (1973) data. Instead, the data were subjected to a one-way ANOVA and subsequent Student-Newman-Keuls

Table 2

Mean molt increments and their standard deviations (mm CL) of juvenile *Jasus lalandii* measured on the harbor wall in 1971–72 and 1996–97, and at Mouille Point in 1996–97.

| Size class (mm CL) | Harbor wall 1971–72 ¹ | | | Harbor wall 1996–97 | | | Mouille Point 1996–97 | | |
|-----------------------|----------------------------------|------|-----------------|---------------------|------|------|-----------------------|------|------|
| | <i>n</i> | Mean | SD ² | <i>n</i> | Mean | SD | <i>n</i> | Mean | SD |
| 15–20 | 14 | 2.65 | 0.76 | 35 | 1.94 | 0.56 | 21 | 2.10 | 0.46 |
| 20–25 | 37 | 3.12 | 0.82 | 98 | 2.45 | 0.56 | 74 | 2.72 | 0.64 |
| 25–30 | 28 | 3.71 | 1.08 | 95 | 2.78 | 0.64 | 80 | 2.93 | 0.68 |
| 30–35 | 14 | 4.36 | 0.73 | 64 | 3.07 | 0.75 | 93 | 2.86 | 0.96 |
| 35–40 | 17 | 4.71 | 0.54 | 33 | 3.39 | 0.93 | 44 | 3.56 | 0.90 |
| 40–45 | 23 | 4.72 | 0.93 | 13 | 3.66 | 0.93 | 29 | 3.74 | 0.77 |
| 45–50 | 23 | 5.02 | 0.62 | 6 | 3.50 | 0.79 | 3 | 4.00 | 0.69 |

¹ After Pollock (1973).

² An approximation of the standard deviation calculated by adding the sums of squares for males and females, and dividing by the overall degrees of freedom.

multiple range *post hoc* tests (SigmaStat, version 2.03, [SPSS Inc., 1997]). Of greatest interest in this analysis were the results of *post hoc* tests in which means of the corresponding size classes of the two sample periods were compared.

For comparison of length-related growth increments at the two sites in our study, individual molt increments were plotted against premolt carapace lengths, for each combination of sex and site, and their linear regressions were compared by using a two-way ANCOVA (Zar, 1984; Norman and Streiner, 1994).

Investigating relative intermolt periods from field samples requires identifying those specimens that are considered to be molting. Rock lobster juveniles in the hard old shell state (*sensu* Pollock [1973]) were easily identified as such by visual inspection, and we confirmed this by breaking the tip off an antenna and inspecting the condition of the underlying integument. Furthermore, on returning these specimens to the laboratory, they generally molted within 20 days. Because field samples were taken at intervals at least this long (Table 1), the proportion of each sample found to be in the hard old shell state was a reasonable indication of the relative number of juveniles molting during that sample month. This proportion, in turn, was used as a proxy for intermolt period under the assumption that shorter intermolt periods would result in relatively higher numbers of juveniles that were molting. The numbers of specimens with soft old or soft new shells did not accurately reflect the relative rate of molting because, as a result of behavioral modifications, rock lobster in these conditions may have had a lower catchability than those with hard shells.

Using this index of relative intermolt period, we performed a log-linear analysis (Zar, 1984; Norman and Streiner, 1994) to assess the interdependence of the factors site, size-category, sample month, and molt state with regard to the frequency of observations in each subcategory. Only

size classes smaller than 40 mm carapace length were used in our analysis because the decreasing molt frequency with increasing carapace length means that larger sample sizes are required to accurately estimate the proportion of animals of the size class in which rock lobsters are molting in the population. However, the length distribution of juvenile lobsters meant that sample sizes decreased above 40 mm CL.

Results

An average of 323 juvenile *J. lalandii* was collected per sample at the harbor wall (256–464), and 291 at Mouille Point (239–365). After directed collections for additional premolt specimens of various sizes, a total of 375 juveniles from the harbor wall and 383 from Mouille Point were maintained in the laboratory for analysis of growth rates. Mortality rates were low (<1%) among these specimens, except during December 1996, when aquarium malfunction resulted in extensive fatalities during molting. Cannibalism was not observed during laboratory trials.

Individual molt increments amongst the captive specimens were highly variable, ranging from 0.4 to 5.5 mm. However, mean molt increments for each of seven consecutive 5-mm-CL size-intervals (Table 2) were consistently and significantly smaller in our study (1996–97 season) than those measured in 1971–72 (Table 3, Fig. 2). Thus, the hypothesis that somatic growth rates of juveniles on the harbor wall had not declined since Pollock's (1973) study could be rejected at one level. Unfortunately, there were no comparative data to provide accurate information on corresponding intermolt periods.

In terms of our samples from Mouille Point and the harbor wall, significant, positive linear relationships were found between molt increment and premolt carapace length for both males and females at both sites (Fig. 2,

Table 3

Results of one-way ANOVA comparing growth increments among size-intervals at the harbor wall from the two sample periods. Subsequent *post hoc* Student-Newman-Keuls multiple-range test results are summarized in the matrix below; an asterisk indicates that molt increments differ significantly ($P < 0.05$) between the two samples being compared.

| Source of variation | df | SS | MS | <i>F</i> | <i>P</i> |
|---------------------|-----|--------|-------|----------|----------|
| Between groups | 13 | 332.57 | 25.58 | 48.1 | <0.001 |
| Within groups | 486 | 258.48 | 0.53 | | |
| Total | 499 | 591.06 | | | |

| Size class (mm CL) | 1971-72 | | | | | | | 1996-97 | | | | | | |
|--------------------|---------|-------|-------|-------|-------|-------|-------|---------|-------|-------|-------|-------|-------|-------|
| | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 |
| 1971-72 15-20 | | | * | * | * | * | * | * | | | | | | * |
| 20-25 | | | * | * | * | * | * | * | * | | | | | |
| 25-30 | * | * | | | * | * | * | * | * | * | * | | | * |
| 30-35 | * | * | | | * | * | * | * | * | * | * | * | * | * |
| 35-40 | * | * | * | * | | * | * | * | * | * | * | * | * | * |
| 40-45 | * | * | * | * | * | | * | * | * | * | * | * | * | * |
| 45-50 | * | * | * | * | * | * | | * | * | * | * | * | * | * |
| 1996-97 15-20 | * | * | * | * | * | * | * | | * | * | * | * | * | * |
| 20-25 | | * | * | * | * | * | * | * | | * | * | * | * | * |
| 25-30 | | | * | * | * | * | * | * | * | | * | * | * | * |
| 30-35 | | | * | * | * | * | * | * | * | * | | * | * | * |
| 35-40 | | | * | * | * | * | * | * | * | * | * | | * | * |
| 40-45 | * | | * | * | * | * | * | * | * | * | * | * | | * |
| 45-50 | | | | | * | * | * | * | * | * | * | * | * | * |

$P < 0.0001$ in all cases). Three females at the harbor wall >50 mm CL were excluded from all analyses (unshaded circles, Fig. 2A) because they were the only specimens of this size. Further, females >50 mm CL might have had smaller than expected molt increments due to approaching maturity (Pollock, 1973).

Two-way, fixed effects ANCOVA comparing these linear regressions indicated no interaction between the factors site and sex; nor was there a significant sex-effect (Table 4). However, there was a significant site-effect: the relationship for samples from Mouille Point had a significantly higher regression constant than that for samples from the harbor wall (Table 4). These results imply first that there were no differences in length-specific growth increments between the sexes within sites. The second implication is that molt increment increased with carapace length at the same rate, irrespective of sex or site. Finally, juvenile lobsters of any given size or sex at Mouille Point grew significantly more during each molt stage than corresponding specimens at the harbor wall (see also Table 2 and Fig. 2).

Log-linear analysis indicated significant first-, second-, and third-order interactions among the factors site, size-category, sample month, and molt state (Table 5). However, the only significant third-order interaction was that among the independent factors site, size-category, and sample month. This interaction simply confirmed that size-frequency distributions differed between sites over

Table 4

Summary of ANCOVA results from length-specific molt increments classified according to sex and site.

| Factor | df_{effect} | df_{error} | <i>F</i> | <i>P</i> |
|------------|---------------|--------------|----------|----------|
| Slope | | | | |
| Site | 1 | 597 | 0.70 | 0.40 |
| Sex | 1 | 597 | 0.66 | 0.42 |
| Site × sex | 3 | 595 | 0.61 | 0.61 |
| Elevation | | | | |
| Site | 1 | 598 | 4.63 | 0.03 |
| Sex | 1 | 598 | 1.11 | 0.29 |
| Site × sex | 1 | 598 | 0.01 | 0.93 |

the sample period, as would be expected if growth rates differed. Of the three remaining nonsignificant third-order interactions, the most important for our purposes were those including the site factor. These imply that the temporal pattern of molting is similar between sites, as is the size-specific pattern of molting. These results are supported by graphical representations of the data (Fig. 3), which suggest that for both sites 1) the proportion of molters per size-category decreases as size increases, and 2)

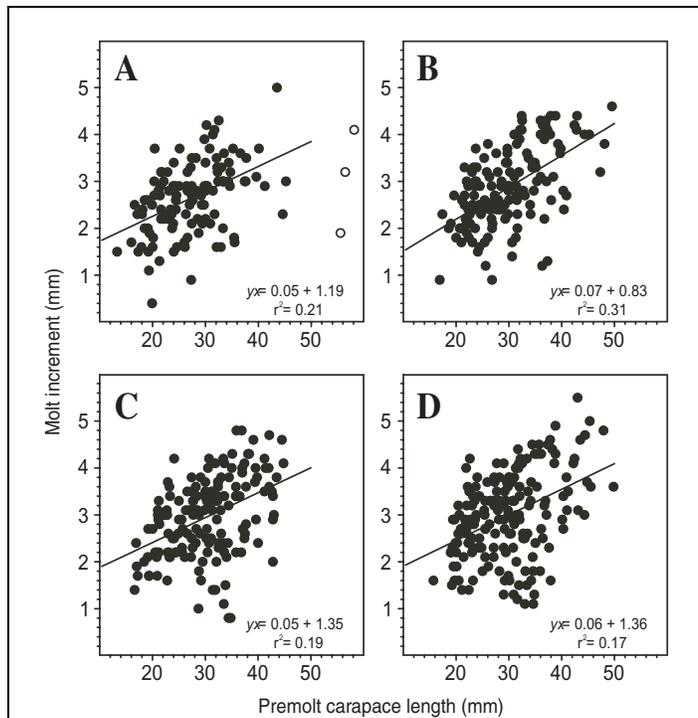


Figure 2

Relationship between molt increment and premolt carapace length of juvenile lobsters at the harbor wall and Mouille Point: (A) harbor wall females, (B) harbor wall males, (C) Mouille Point females, (D) Mouille Point males. Shaded circles represent data included in analyses; unshaded circles represent data excluded from analyses (see text for details).

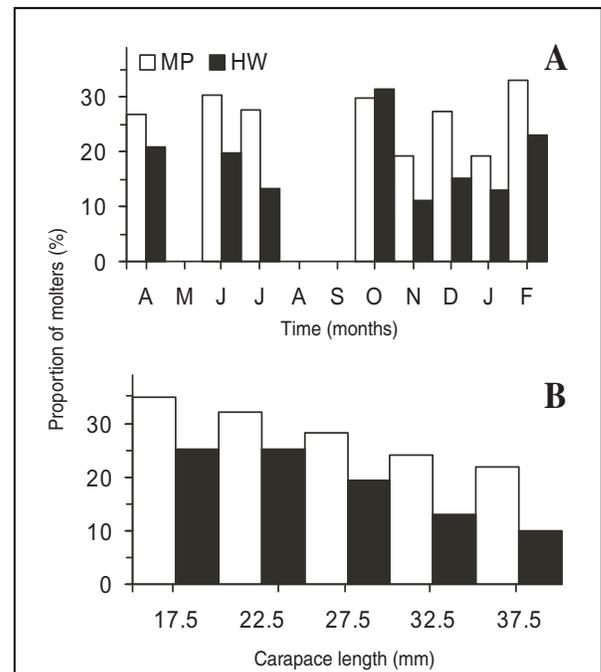


Figure 3

Site-specific patterns of the proportions of sampled juvenile rock lobster that were considered to be molting with respect to (A) sample month and (B) 5-mm-CL size classes. MP = Mouille Point; HW = harbor wall.

the proportion of lobsters in the molt state fluctuates over time. In both cases, the proportion of lobsters in the molt state was consistently lower at the harbor wall than at Mouille Point (with the exception of the sample taken in October 1996). This apparent dependence of molt state on each of the factors site, size-category, and sample date is confirmed by the corresponding significant second-order interactions (Table 5).

Together with the molt-increment data, these results give reason to reject the hypothesis that current juvenile growth rates on the harbor wall are no different from those on the nearby natural nursery reef in Mouille Point; growth is significantly faster at the latter.

Discussion

The significance of puerulus and postpuerulus ecology to the management of rock lobster fisheries is now widely accepted (Herrnkind et al., 1994). In the South African *J. lalandii* resource, the current controversy surrounding the question of whether or not temporal trends in juvenile growth rates reflect those of adults provides a good example of why so much emphasis should be placed on early life

history stages. For this species, adult somatic growth rates have declined substantially since the mid-1980s (Melville-Smith et al., 1995; Cockcroft, 1997; Cockcroft and Payne, 1999). Although the causes of this phenomenon are not yet clearly understood, its widespread nature is indicative of a large-scale environmental perturbation. This has prompted hypotheses that the anomalous *El Niño* years of 1990–93 may have resulted in dramatic changes in the productivity of the southern Benguela Current (Pollock et al., 1997; Pollock et al., 2000). Alternatively, it is plausible that heavy, size-selective fishing of this resource may have caused a decline in growth rates by removing individuals genetically predisposed to more rapid growth (see for example Stokes and Law [2000]). Notwithstanding the causes, if it is incorrectly assumed that juvenile growth rates mirror the trends of the regularly monitored adults, overly conservative estimates of recruitment into the fishery might result, whereas assuming the converse could lead to a higher risk of overfishing.

Results from our re-examination of the growth rates of juvenile *J. lalandii* provided some evidence that temporal trends in their growth rates are consistent with those of the adults of the species. Specifically, juvenile molt increments at the Cape Town harbor wall were smaller in

Table 5

Results of log-linear analysis investigating the interdependence of the factors site (S), size-category (SC), sample month (M) and molt state (MS) with regard to the frequency of observations in each subcategory. χ^2 statistics are reported for conventional tests of observed versus expected frequencies and have been calculated for model fits with different numbers of levels of interactions as well as for partial and marginal associations among combinations of factors. In the latter sense, partial associations take into account the effect of all factors at each given level, whereas marginal associations take into account only those factors listed (Norman and Streiner, 1994).

Tests of hypotheses that all K -level interactions are simultaneously zero.

| Level (K) | df | χ^2 | P |
|---------------|----|----------|--------|
| 1 | 13 | 1833.48 | < 0.01 |
| 2 | 51 | 626.90 | < 0.01 |
| 3 | 67 | 168.45 | < 0.01 |
| 4 | 28 | 39.51 | 0.07 |

Tests of marginal and partial association

| Factor | df | Partial association | | Marginal association | |
|-------------------------|----|---------------------|--------|----------------------|--------|
| | | χ^2 | P | χ^2 | P |
| Site (S) | 1 | 6.60 | 0.01 | | |
| Size-category (SC) | 4 | 500.95 | < 0.01 | | |
| Sample month (M) | 7 | 42.78 | < 0.01 | | |
| Molt state (MS) | 1 | 1198.48 | < 0.01 | | |
| $S \times SC$ | 4 | 142.77 | < 0.01 | 125.72 | < 0.01 |
| $S \times M$ | 7 | 23.89 | < 0.01 | 21.05 | < 0.01 |
| $S \times MS$ | 1 | 52.47 | < 0.01 | 35.73 | < 0.01 |
| $SC \times M$ | 28 | 320.55 | < 0.01 | 307.70 | < 0.01 |
| $SC \times MS$ | 4 | 68.53 | < 0.01 | 41.78 | < 0.01 |
| $M \times MS$ | 7 | 68.24 | < 0.01 | 55.70 | < 0.01 |
| $S \times SC \times M$ | 28 | 121.80 | < 0.01 | 129.12 | < 0.01 |
| $S \times SC \times MS$ | 4 | 7.99 | 0.09 | 4.91 | 0.30 |
| $S \times M \times MS$ | 7 | 16.04 | 0.03 | 11.51 | 0.12 |
| $SC \times M \times MS$ | 28 | 28.66 | 0.43 | 32.55 | 0.25 |

1996–97 than those recorded in 1971–72 (Pollock, 1973), irrespective of size. Although corresponding measures of intermolt period are not available, established trends in juvenile rock lobster biology indicate that such data would probably not have exhibited conflicting trends. In general, their growth rates tend to respond first by changes in molt frequency and then, under more extreme conditions, by changes in molt increments (Chittleborough, 1975; Serfling and Ford, 1975; Phillips et al., 1977; Dennis et al., 1997). Therefore, the trend to smaller growth increments among juvenile *J. lalandii* at the Cape Town harbor wall between 1971–72 and 1996–97 was most plausibly accompanied by an increase in intermolt period.

Adding credence to this deduction are Cockcroft and Goosen's (1995) results, which demonstrated that the size at which female *J. lalandii* reach sexual maturity on a range of fishing grounds had decreased significantly over the two decades leading up to the mid-1990s. Using simulation models, Pollock (1987) demonstrated that reduced juvenile growth rates would lead to a smaller size at sexual maturity. In combination, these conclusions

provided additional rationale for rejecting the hypothesis that somatic growth rates of juvenile *J. lalandii* on the harbor wall have not declined since the last study.

Pollock (1973) found that a modal size of 38 mm CL was attained approximately 1.6 years after settling. This alone implies a slower growth rate than that for other temperate lobster species (Jernakoff et al., 1994). Because our data suggest that current growth rates are even slower than this, and that they may decline further with falling adult growth rates, recruitment to the fishable part of the *J. lalandii* resource must be seen as a real management concern (Bergh and Johnston, 1992). Therefore, the precautionary assumption made in the operational management procedure designed for this resource (Cockcroft and Payne, 1999; Pollock et al., 2000) that juvenile growth mirrors adult growth is justified.

Another feature of trends in growth rates shared between adult and juvenile *J. lalandii* is small-scale spatial variation. During the monitoring period, juveniles of this species grew relatively faster at Mouille Point than at the harbor wall, both in terms of molt increment

and intermolt period. Amongst adults, this variability has been attributed to patterns of food availability and gradients in environmental characteristics, particularly oxygen content (Newman and Pollock, 1974; Pollock and Beyers, 1981; Pollock, 1982; Pollock and Shannon, 1987; Pollock et al., 1997; Mayfield, 1998). Although there is some spatial separation of juvenile and adult *J. lalandii*, it is likely that the biotic structure of their environment influences juvenile growth rates in a manner similar to that of adults.

In a study of the diets of juvenile lobsters at the Cape Town harbor wall and Mouille Point, Mayfield (1998) found that diets were similar at the two sites, but that the benthic communities differed. He concluded that lobsters on the harbor wall would have to spend more time and energy feeding to maintain a diet similar to those at Mouille Point, where more favored food species (e.g. mussels, barnacles) were better represented. Similar patterns were evident when comparing diets of adults at Olifantsbos and Dassen Island (Mayfield, 1998), a slow- and fast-growth site, respectively (Cockcroft and Goosen, 1995). Subsequently, a more detailed study of the diets of two size classes (<35 mm CL and 40–60 mm CL) of juvenile *J. lalandii* at the Cape Town harbor wall and at Mouille Point was able to detect a significant difference between the diets of inhabitants of the two sites (Mayfield et al., 2000). Juveniles on the harbor wall consumed significantly less black mussel, their preferred prey species. This result, however, does not contradict the suggested link between food distribution and juvenile growth rates; specimens forced to subsist off suboptimal food resources could be expected to grow more slowly than those at liberty to pursue their preferred prey.

The differences in growth rates between juvenile *J. lalandii* at the artificial harbor wall and those at the natural nursery reef at Mouille Point do not necessarily preclude the use of the harbor wall as a legitimate site to continue monitoring juvenile growth. The existence of historical data (albeit for only two seasons) provides a good reference point, and the easy and consistent sampling conditions permit reliable data collection. These sampling conditions are of particular importance, given the established tendencies of early juveniles of other species of rock lobster on natural reefs to be less vulnerable to sampling than later stages (Annala and Bycroft, 1985; Marx and Herrnkind, 1985; Breen and Booth, 1989; Jernakoff, 1990; Childress and Herrnkind, 1994; Forcucci et al., 1994; Jernakoff et al., 1994). Furthermore, knowledge of how growth rates change over time is in itself important to the management of the fishery (Cockcroft, 1997).

Should spatial and temporal variability in juvenile growth continue to be a contentious issue, a juvenile tagging program would provide simpler and more rigorous comparisons. It might also provide reliable estimates of the intermolt period. Mitigating against this, however, are the low rate of recapture of tagged specimens in the wild and potential tag-related growth retardation and mortality. Nevertheless, continued monitoring of juvenile growth may elucidate how close this link is between adult and

juvenile growth, thereby improving our ability to manage this valuable resource.

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