

**GROWTH AND MOULTING OF CAPTIVE *PANULIRUS*
HOMARUS HOMARUS IN KENYA, WESTERN INDIAN OCEAN.**

By

Kulmiye, A. J.^{1*} and K. M. Mavuti¹

¹ Department of Zoology, University of Nairobi

P. O. Box 30197, G. P. O. 00100

Nairobi, Kenya

E-mail: akulmiye@uonbi.ac.ke

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Abstract

Panulirus homarus homarus is the most widely distributed among the three *P. homarus* subspecies and is the second most important spiny lobster in the Kenyan lobster fishery after *P. ornatus*. Growth and moulting of lobsters, held in concrete tanks with a flow-through seawater supply and at ambient temperatures, were monitored for 18 months (October, 2001 - March, 2003). Both moult increment and moulting frequency were inversely correlated with size. Mean moult increment ranged from 4mm in the 36-45 mm CL size class to 0.6 mm in the 86-95 mm CL size class. Mean intermoult period increased from 49 days in the 46-55 mm CL size class to 81 days in the 86-95 mm CL size class. Growth rates were 19% and 46% higher for males and females, respectively during the southeast monsoon (low temperature) period than during the northeast monsoon (high temperature) season. A shift in energy use from growth to reproduction rather than the influence of temperature was responsible for the variation in the growth rates between the two seasons. Marking induced injuries caused a significant 65% growth reduction in the affected individuals. Mean moult increments calculated for most size classes of uninjured lobsters were comparable to those observed in lab reared subtropical *P. homarus rubellus* in South Africa but smaller than those reported in the Indian *P. homarus* under similar conditions. This indicates that growth in our experiment was slightly depressed probably in response to sub-optimal holding conditions.

Key words: *Panulirus homarus homarus*, growth, moulting, injury, Kenya.

Introduction

The scalloped spiny lobster *Panulirus homarus homarus* (Linnaeus) is the most widely distributed among the three subspecies of *P. homarus* and is found throughout the Indo-Pacific region with centers of high concentrations in East Africa and Indonesia (Berry, 1974, Pollock, 1993). The other two subspecies, *P. homarus megasculptus* and *P. homarus rubellus*, are restricted to the Arabian Sea and southeast coasts of Madagascar and Southern Africa, respectively. All the three subspecies inhabit shallow waters mostly between 1 and 5 m depth among rocks, often in the surf zone and sometimes in highly turbid estuarine areas (Holthuis, 1991). However, they respond to different environmental conditions that prevail in their respective areas (George, 1997).

Populations of *P. homarus homarus* on the Eastern African coastline are sandwiched between those of *P. homarus megasculptus* and *P. homarus rubellus* with respective populations overlapping at the flanks. Hybrids are common in areas where the subspecies overlap but the frequency of hybridization appears to decline pole wards (Pollock, 1993). The successful interbreeding suggests that these subspecific separations are fairly recent (George, 1997). *P. homarus homarus* is the second most important spiny lobster in the Kenyan lobster fishery after *P. ornatus* and accounts for about 32% of the total landings (Kulmiye et al., 2003). The Kenyan lobster fishery is artisanal in nature and represents one of the few activities from which local fishermen derive a good return for their work since spiny lobsters fetch far much

higher price per unit weight than finfish and other crustaceans.

In spite of its wide distribution, an in-depth study on many fundamental aspects of the biology, ecology and fishery of *P. homarus homarus* is lacking in the Western Indian Ocean. Previous studies on *P. homarus* group have either exclusively dealt with the other two subspecies (Heydorn, 1969; Berry 1970, 1971 a, b; Smale, 1978; Al-Abdulsalaam, 1989; Johnson & Al-Abdulsalaam, 1991; Liss *et al.*, 1994; Mohan 1997 and Fielding, 1997;

Fielding & Mann, 1999) or addressed *P. homarus homarus* populations outside the region (De Bruin, 1962; 1969; Jayawickrema, 1991; Jayakody, 1989, 1993; Thuy, 2000). In this paper we present and discuss the growth and moulting of male and female *P. homarus homarus* monitored for 18 months in captivity.

Materials and Methods.

Specimen collection and laboratory conditions

This experiment was performed at the Kenya Marine and Fisheries Research Institute laboratory at the Mombasa Centre. Lobsters were hand-collected at night by wading fishermen from the reefs at Mamburi (Fig.1) and were immediately put in large polythene bags with aerated seawater. They were brought to Mombasa and released into outdoor, sheltered concrete tanks (193 cm x 103 cm x 106 cm) with a flow-through seawater system as well as aeration. After a 5 day acclimatization period, each lobster was measured (CL), sexed and tagged by punching coded holes in the uropods and telson with a sterile leather punch for easy identification (Chittleborough, 1976; Plaut & Fishelson, 1991). Lobsters were provided with artificial shelters using flat coral rocks, which leaned one another on end in an intricate cone-shaped fashion. Additionally, asbestos tubes were placed in the tanks to create extra shelters for the lobsters. Density of lobsters in the tanks was maintained at almost similar levels throughout the study period either by replacing mortalities with wild specimens or via inter-tank redistribution. The animals were fed daily ad libitum on a diet of deck mussel (*Septifer bilocularis*), bivalve (*Anadara antiquata*) and chopped fish (mostly reef fish). Food was supplied in late afternoon and any uneaten food items removed the following morning. Tanks were cleaned thoroughly once a week with minimal disturbance to the captive animals.

Although no complications were reported for captive *P. Cygnus* and *P. penicillatus* tagged through punching in telsons and uropods (Chittleborough, 1976; Plaut & Fishelson, 1991), the case was different for *P. homarus homarus* and almost half of the specimens

marked this way later developed deteriorating necrotic wounds which resulted in the complete loss of both telson and uropods. For treatment, both the infected and uninfected lobsters were quarantined in a recirculating anti-bacterial solution (one milliliter Sera Baktapur to twenty liter seawater ratio) for three days. While the animals were in quarantine, the holding tanks were also thoroughly cleansed with antiseptic solutions and several freshwater rinses. Except for a few animals with advanced injuries that later succumbed to the same, majority of the affected lobsters were successfully treated as shown by the scarring of wounds within a few days. After treatment, all markings of both wild replacements and newly moulted animals were made by tying a numbered Dymo Scotch tape to the base of an antenna with a nylon monofilament line.

Growth measurements of newly moulted lobsters were made 3 days after ecdysis when the carapace was hard enough to ensure precise measurements. Carapace length (CL) was measured mid-dorsally from the transverse ridge between the frontal spines to the posterior margin of the cephalothorax using sliding vernier caliper to the nearest millimeters.

Temperature and Salinity

The rearing experiment was run for 18 months (October, 2001-March, (2003) under ambient conditions of seawater quality and temperature. Measurements of temperature and salinity were simultaneously made at each tank and at the creek once daily with a portable sonde (Aanderaa S/T/D Sensor 3230/Aanderaa Dupley Unit 3315). Since no marked differences were observed between temperature and salinity readings recorded from the tanks and those from the adjacent Tudor Creek (pumping station) the daily data were combined and mean monthly readings calculated for both temperature and salinity.

Analytical methods

For statistical purposes, data sets for injured and uninjured lobsters were treated separately and compared for differences using Students' t-test and ANOVA. Data for uninjured lobsters were further used to estimate growth parameters as well as to relate the

effect of temperature on growth and the intermoult period. For interpretation of moult increment and intermoult period, size class averages were taken. The Bertalanffy growth function (von Bertalanffy, 1938) was used to estimate growth rates:

$$L_t = L_{\infty} [(1 - e^{(-K(t - t_0)})] \quad (1)$$

where L_t is the predicted carapace length at age t , L_{∞} , the asymptotic carapace length (mm), K , the growth constant (year^{-1}), t , the age (year) and t_0 , the age at zero length.

Growth parameters were estimated using Fabens' method (Fabens, 1965) by fitting a rearranged function of Equation (1) to the data on moult increment and intermoult period using FISAT software (Gayanillo et. al., 1994):

$$L_2 = L_1 + (L_{\infty} - L_1) * (1 - e^{-K(t_2 - t_1)}) \quad (2)$$

where L_1 is the carapace length at marking (initial moult), L_2 is the carapace length at remarking (next moult), and $t_2 - t_1$.

Results

Growth in captivity

The mean moult increments of male and female spiny lobsters separated into injured and uninjured individuals are presented in Fig. 2 a&b. The moult increments between the individuals and between moults of the same individual were observed to be highly variable. In the 36-45 mm size class, uninjured males and females attained almost similar moult increments (ca 4 mm CL). Moult increment of uninjured males steadily decreased from 2.5 mm CL in the 46-55 mm CL size class to 1.5 mm in the 76-85 mm CL size class after which it abruptly dropped to 0.6 mm in the 86-95 mm CL size class. The lowest moult increment (1.1 mm CL) for uninjured females was observed in the 46-55 mm CL size class but the growth rate rapidly increased to 2.6 mm CL in the 56-65 mm size class. Between the 66-75 and 76-85 mm CL size classes, the moult increment of uninjured females remained constant at 1.6 mm CL. There was no significant difference in moult increment among size classes

and within sexes of uninjured lobsters except in the 46-55 and 56-65 mm CL female size classes ($p < 0.05$, multiple comparisons among pairs of means, Spjotvoll/Stoline test). The 36-45 mm CL size class was not included in the analysis because of the small sample size.

The injured males grew at 1.0 mm CL per moult in the 46-55 and 56-65 mm CL size classes but attained lower growth increment of 0.6 and 0.7 mm CL per moult in the 66-75 and 76-85 mm size classes, respectively. The moult increment for injured females was relatively high in the 56-65 mm CL size class (1.8 mm), decreased to 0.6 mm CL in the 66-75 mm CL size class but rose again to 0.9 mm in the 76-85 mm CL size class. There were no significant differences in moult increment for injured lobsters among size classes and within sexes ($F = 1.2695$, $p > 0.05$). The effect of injuries on growth was examined by comparing the moult increment of injured and uninjured lobsters (Table 1). Injuries significantly affected the moult increment of lobsters, regardless of size, having depressed it by an average of 1.06 mm CL (range 0.77 to 1.16 mm CL) amounting to 65% reduction.

Growth parameters

By directly fitting Fabens' method (Eq. 2) to the data on moult increment and intermoult period for uninjured male and female lobsters, growth parameters, L_{∞} and K , were estimated (Table 2). However, the theoretical L_{∞} values estimated for the captive lobsters (Table 2) were smaller than the maximum size attained in the wild for both males and females (115 mm CL and 105 mm CL, Unpublished data) respectively. This indicates that L_{∞} was underestimated while K was overestimated because the two growth parameters are inversely related (Pauly, 1979). Misleading values of L_{∞} can be obtained when high variability in moult increment is observed among individual captive lobsters, as was the case in this study.

In an attempt to obtain more realistic growth parameters, the data were recalculated by running the growth routine again with fixed L_{∞} taken as the maximal values observed in

the catch (i.e. 105 and 105 mm CL) and the resulting parameters are given in Table 2. These parameters were also used to plot the corresponding growth curves (Fig. 3). The predicted growth patterns are very similar for both sexes until a carapace length of 70 mm is attained whereby the predicted growth curve of females detaches and starts to slow thereafter.

Moulting in captivity

Intermoult periods for injured and uninjured animals that moulted more than twice in captivity are summarised in Table 3. Intermoult period increased with increase in size in both injured and uninjured lobsters. This pattern was, however, more pronounced for the uninjured animals where there were significant differences among the size classes and within sexes ($F = 7.492$, $p < 0.05$). The intermoult period of smaller uninjured lobsters (46-55 mm CL) was about 50 days, while that of the larger uninjured ones (76-85 mm CL) was 66 days. For the injured lobsters, the corresponding intermoult period for the smaller and the larger individuals was 57 and 67 days, respectively. On annual basis, the smaller uninjured lobsters potentially undergo an average of 7.4 moults as compared to 5.5 moults for the larger ones.

The effects of sex and injuries on intermoult period were examined (two-way ANOVA, Table 4). Injuries affected the intermoult period with injured animals moulting generally less frequently than uninjured lobsters. However, this effect progressively diminished as size increased. Overall, the intermoult period of injured lobsters was 8 days longer than that of uninjured individuals. The intermoult period was not affected by sex ($p > 0.05$), though females tended to have slightly longer intermoult periods than males especially those below 66-75 mm CL size class.

Temperature and salinity

The mean monthly water temperature and salinity pooled from the rearing tanks and adjacent Tudor creek (from which seawater was pumped) are shown in fig. 5. Temperature showed a seasonal trend with high values during the northeast monsoon period (November – March) and with low values between May and October (southeast monsoon season). There

was a 3 °C difference between the month with the highest temperature (February, 28.7 °C) and the one with the coldest temperature (August, 25.7 °C). For salinity, there was no a clearly defined seasonal trend except for the marked drops in values in both April and November which correspond to the long and short rains, respectively.

Growth and temperature

The relationship between temperature and growth was investigated by plotting the average monthly seawater temperature against the mean moult increment for uninjured males and females that moulted in respective months (Fig. 6). The moult increment is inversely correlated with temperature, with both males and females attaining higher mean moult increment at lower temperatures (25.7 °C) than at higher temperatures (28.7 °C). However, the moult increment for females shows a stronger correlation with the seawater temperature ($r^2 = 0.918$, Fig. 6). Analysis of covariance (ANCOVA) also reveals that the difference in the moult increment between the southeast monsoon period (low temperatures) and the northeast monsoon period (high temperatures) is significant for females ($p = 0.001$) but not for males ($p = 0.321$). On average, males and females exhibited 19% and 46% larger carapace length increment per moult, respectively, during the southeast monsoon period as compared to the northeast monsoon season values.

Moulting and temperature

The relationship between temperature and moulting was investigated by plotting the average monthly seawater temperature against the mean intermoult period for uninjured males and females that moulted in respective months (Fig. 7). The intermoult period is positively correlated with the seawater temperature, with rising temperature resulting in prolonged intermoult periods for both males and females. This correlation is, however, more pronounced for females ($r^2 = 0.653$) than for males ($r^2 = 0.280$). Analysis of covariance (ANCOVA) also reveals that the difference in the mean intermoult period between the southeast monsoon and the northeast monsoon period is significant for females ($F = 48.026$,

$p < 0.000$) but not for males ($F = 0.6614$, $p > 0.4211$). The mean intermoult period (days) of males and females was 5% and 21% shorter, respectively, during southeast monsoon period in comparison with the values recorded during northeast monsoon season.

Discussion

Growth and moulting of uninjured lobsters

The mean moult increment of uninjured *P. homarus homarus* calculated for most size classes in the present study is comparable to that observed by Berry (1971b) in captive *P. homarus rubellus* in South Africa but is noticeably smaller than that reported by Nair *et al.* (1981) in the Indian *P. homarus* held under lab conditions (Table 5). In contrast, the mean intermoult period of uninjured *P. homarus homarus* is similar to that of *P. homarus* but is considerably shorter than that of *P. homarus rubellus* (Table 6). That the mean moult increment of the tropical *P. homarus homarus* is comparable to that of the subtropical *P. homarus rubellus*, which has longer intermoult period, indicates that the growth in the present study was depressed probably in response to sub-optimal holding conditions. However, the similarity between the intermoult periods of the Kenyan *P. homarus homarus* and the Indian *P. homarus*, which are both tropical, also suggests that the effect of sub-optimal holding conditions was reflected as reduced carapace length increment at moulting rather than as decreased frequency of moulting.

It is not easy to exactly pinpoint any single stress causing factor(s) that may have been responsible for growth depression of the uninjured lobsters since all the factors that have been described to influence growth of palinurid lobsters (see Aiken 1980 for review) were either provided in excess (food, shelter, etc) or were taken care of by the tropical climate (temperature, photoperiod, etc). However, there were several occasions when oxygen levels in the water gradually dropped from 90% down to 60% saturation as a result of power failure that interrupted both aeration and water inflow for hours. Chittleborough (1975) working with *P. Cygnus* reported that low oxygen availability not only decreased size

increase at moulting but also increased risk of death if the saturation level drops to between 47% and 50% during ecdysis. Pollock and Shanon, (1987) observed variations in the growth rates of male *Jasus lalandii* among different areas and suggested oxygen depletion of bottom waters as the main cause of depressed growth rates in the northern areas of the species' distribution. It is therefore possible that the depressed growth rates observed in *P. homarus homarus* occurred as a result of low oxygen availability during those power interruptions. Another factor that cannot be ruled out, as a possible cause of low growth rate, is the effect of pathogens on uninjured lobsters in the early part of the research when serious bacterial infection overwhelmed the experiment. Although these lobsters did not show any obvious signs of infection and/or injuries, the presence of pathogens in the holding environment may have affected them in other ways detrimental to their general well being. Alternatively, they may have shifted some energy that would have otherwise been available for growth to defense mobilization and in the process limiting their growth.

In spite of the growth depression, both moult increment and intermoult period of *P. homarus homarus* followed the general growth pattern of palinurid lobsters where the moult frequency and percent size increase at moult tend to decrease gradually with advancing age. However, the absence of a significant difference in the mean moult increment among the four size classes tested could be attributed to the narrow size range of the lobsters studied majority of which were mature, well past their rapid growth phase. The mean moult increments of mature specimens between the size range of 56 and 85 mm CL were almost similar except for the notable increase in the females of 56-65 mm CL size class. The growth rate of another subspecies, *P. homarus rubellus*, was also reported to remain constant throughout much of the sexually mature size range until the upper extremes were attained (Berry, 1971b). The marked drop in female moult increment in the 46-55 mm CL size class signifies the onset of sexual maturity and resource allocation to reproductive activity instead

of growth. The attainment of sexual maturity at this size class is also discernible in the predicted female growth curve which gets detached from the male curve at a carapace length of about 58 mm and starts to gradually decrease thereafter. It is around this size class that females of the other two *P. homarus* subspecies also reach sexual maturity and start reproducing (Hydorn, 1969a; Berry, 1971b; Fielding & Mann, 1999).

Although the maximum variation in water temperatures between the southeast and northeast monsoon seasons is only 3⁰C, the growth rates of *P. homarus homarus* is distinctly seasonal and appears to be optimal at the lower limit of the prevailing temperatures in the East African coastal waters. Laboratory held lobsters grew faster at lower temperatures than at higher temperatures because of both increased moult increments and shortened moulting intervals. However, the strong positive correlation observed to exist between the female intermoult periods and temperature as well as the ovipositing of three captive females in February suggest that a shift in energy use from growth to reproduction rather than the influence of high temperature was responsible for the lower growth rates achieved during the northeast monsoon season. Similarly, the higher growth rates attained during the southeast monsoon period are undoubtedly a manifestation of increased energy apportioned to growth since little spawning activity was observed both in the field and in the laboratory. In the field conditions, the main mating and egg-bearing season of this subspecies falls within the northeast monsoon period (Unpublished data).

The alternating cycles of high growth rates and spawning activity in line with the changing monsoon seasons suggest that energy use is dictated by the prevailing environmental factors. The incidence of high temperatures, relatively calm seas and light winds as well as ocean-bound currents during the northeast monsoon (McClanahan, 1988) seem to be the ideal conditions for successful release and dispersal of larvae. It is therefore advantageous for the animals to invest energy in reproductive activity during this period

rather than during the southeast monsoon season when the prevailing conditions are the exact opposite of the above, unfavourable for the spawned larvae. In the absence of much spawning activity, high growth rates are therefore to be expected.

Growth and moulting of injured lobsters

Marking-induced injuries were clearly demonstrated to have a detrimental effect on growth rate of captive *P. homarus homarus* in all the four size classes investigated (Table 1). Mean moult increments were significantly smaller and mean intermoult periods were longer for injured lobsters than for uninjured individuals kept under the same holding conditions. The overall mean increment of 0.66 mm CL per moult attained by injured lobsters was invariably lower than that (1.72 mm CL) recorded for uninjured individuals. Intermoult period of injured lobsters was also 8 days longer than that of uninjured ones. However, the impact of injury was more pronounced on moult increment than on intermoult period. Whereas the impact of injury on moult increment was evident in all the four size classes, the disparity between intermoult periods of injured and uninjured lobsters progressively diminished as size increased with large individuals (76-85 mm CL) of both groups having almost similar mean annual moulting frequency. This may be explained by advancing age and its associated long intermoult period masking the impact of injury in the larger lobsters.

The observed reduction in the mean moult increments of injured lobsters stemmed mainly from numerous moults with zero growth at moulting during and even after the infection period. It is not unusual for crustacean species to register zero or even negative growth at ecdysis (Aiken, 1980) due to a variety of factors including unfavourable holding or adverse environmental conditions (Marshall, 1945; Little, 1972; Ikeda & Dixon, 1982; Cockcroft & Goosen, 1995), advanced age and pathogeny (Needham, 1964; Frey & Hann, 1985); injury (Hopkins, 1985; Skinner, 1985) as well as reproductive activities (Mauchline, 1977; Asakura, 1992). Moults with negative or zero growth seem to signify a shift in energy use from growth to other importunate needs such as reproductive activity, fighting disease or

simply maintenance of basic metabolic requirements in times of hardship. Affected individuals may sacrifice growth altogether at ecdysis but still compensate for the missed growth by markedly increasing in size at subsequent moultings when conditions improve (Travis, 1954; Fielder, 1964; Thomas, 1972). In the present study, several large lobsters showed growth patterns similar to the above observation with zero increase in size at moulting during the infection period and high growth rates at successive moultings following treatment.

The overall 65% reduction in growth observed for injured lobsters is way above that (39%) reported for injured small sub legal *P. argus* returned to the sea by fishermen (Hunt & Lyons, 1986). Although the variation in growth reductions between the two species could have been as a result of several other factors at play, the extent of injuries in *P. homarus homarus* was far much more serious than what was reported for *P. argus* (Hunt & Lyons, 1986). Smale (1978) reported lower growth rates for *P. homarus rubellus* similarly tagged and recaptured with necrotic wounds in a field study in comparison with laboratory-reared individuals of the same species in east coast of South Africa (Berry, 1971b).

Several studies have shown the negative effect of injury on the growth rates of spiny lobsters. Davis (1981) reported that moult increment was 0.5 mm CL smaller and intermoult period was 5 weeks longer for injured juvenile *P. argus* than for uninjured individuals. Hunt & Lyons (1986) also observed that injury caused a 39% reduction in growth of injured small *P. argus* (≤ 60 mm CL) returned by fishermen to the sea in Florida. Brown and Caputi (1985) noticed an inverse relationship between growth increment of injured *P. cygnus* and the number of missing limbs. They further reported that moult increment of injured lobsters was reduced between 0.33 and 0.48 mm CL for every appendage missing. Similarly, Chittleborough (1975) reported that regeneration of four limbs resulted in decreased moult increment. In contrast, Plaut and Fishelson (1991) observed that regeneration of lost

appendages did not affect moult increment of captive *P. penicillatus*, regardless of the number of regenerated limbs and that 80-90% of the original length of affected appendages was regenerated in a single moult. Due to the nature of injuries in the present study, no attempt was made to demonstrate proportional relationship between the degree of injury and that of moult increment reduction.

The implications of injury-induced lobster growth reductions on onset of sexual maturity, fecundity and fishery yield have been discussed (Davis, 1981, Brown & Caputi, 1985; Hunt & Lyons, 1986). Injury-induced yield losses are reported to be significant in both the Australian and Florida lobster fisheries (Davis, 1981, Brown & Caputi, 1985). In the Kenya lobster fishery, where divers catch lobsters with spears and other sharp objects, a large but as yet, an unquantified number of traumatized and injured lobsters are left behind holed up in narrow crevices after divers fail to flush them out during fishing expeditions due to complexity of the coral reef habitat and the crude nature of the catching methods. However, the fate of the affected lobsters and the actual loss to the fishery as a direct result of injuries are not known.

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Table 1. Comparison of the moult increment between injured and uninjured Individuals within four size classes. *t* = student's *t* static. df = degree of freedom; * = significant, ns = significant.

| Size class (mm CL) | Status | Moult increment (mm CL/moult) Mean (\pm SE.) | <i>t</i> (df) | p |
|-----------------------|-----------|---|---------------|---------|
| 46-55 | Injured | 0.76 \pm 0.12 | 2.3676 (33) | 0.0239* |
| | Uninjured | 1.53 \pm 0.23 | | |
| 56-65 | Injured | 0.87 \pm 0.27 | 0.2218(35) | 0.825ns |
| | Uninjured | 2.03 \pm 0.18 | | |
| 66-75 | Injured | 0.56 \pm 0.12 | 4.0627 (59) | 0.0014* |
| | Uninjured | 1.57 \pm 0.19 | | |
| 76 – 85 | Injured | 0.67 \pm 0.13 | 2.9798 (56) | 0.0042* |
| | Uninjured | 1.51 \pm 0.32 | | |
| Overall mean: | Injured | 0.66 \pm 0.07 | 4.8560 (186) | 0.0003* |
| | Uninjured | 1.72 \pm 0.11 | | |

Table 2. Growth parameters (estimated with “free” and “fixed routine) of uninjured male and female *Panulirus homarus homarus* in captivity. L_{\max} was taken as the maximal values in the commercial catch.

| Sex | Parameter | Method | |
|---------|---------------------------|------------------|--------------------------------|
| | | Fabens (free) | Gulland & Holt Plot (fixed) |
| Males | L_{∞} (mm) | 95.90 | 115.00 |
| | K (year ⁻¹) | 0.49 | 0.26 |
| | L_{\max} (mm) | | 115.00 |
| Females | L_{∞} (mm) | 93.10 | 105.00 |
| | K (year ⁻¹) | 0.40 | 0.30 |
| | L_{\max} (mm) | | 105.00 |

Table 3. Intermoult period of injured and uninjured male and female *Panulirus homarus homarus* in captivity.

| Size class CL (mm) | Sex | Number Of observations | | Mean (\pm SE) intermoult periods (d) | | Mean annual moulting frequency | |
|-----------------------|---------|------------------------------|---------|---|----------|--------------------------------------|---------|
| | | Uninjured | Injured | Uninjured | Injured | Uninjured | Injured |
| 46 – 55 | males | 7 | 2 | 49 (2.3) | 55 (4.9) | 7.4 | 6.6 |
| | females | 11 | 8 | 52 (2.7) | 58 (2.5) | 7.0 | 6.3 |
| 56 – 65 | males | 12 | 5 | 50 (2.3) | 57 (2.7) | 7.3 | 6.4 |
| | females | 7 | 2 | 57 (1.9) | 60 (3.5) | 6.4 | 6.1 |
| 66 – 75 | males | 7 | 4 | 61 (3.0) | 59 (1.5) | 6.0 | 6.2 |
| | females | 6 | 26 | 64 (2.5) | 66 (2.0) | 5.7 | 5.4 |
| 76 – 85 | males | 8 | 31 | 66 (2.5) | 67 (3.6) | 5.5 | 5.4 |
| | females | 3 | 10 | 66 (4.0) | 67 (2.8) | 5.5 | 5.4 |
| 86 – 95 | males | 1 | 3 | 81 | 71 (6.4) | – | 5.1 |
| combined | | 93 | 61 | 57 (1.3) | 65 (1.4) | 5.6 | 6.4 |

Table 4. Results from two-way ANOVA of the effects of sex and injuries on intermoult periods of *Panulirus homarus homarus* in captivity.

| Source of variation | df | SS | MS | F | P |
|-----------------------|-----|-----------|----------|--------|----------|
| A (Sex) | 1 | 6.848 | 6.848 | 0.430 | 0.836 ns |
| B (Status) | 1 | 1963.123 | 1963.123 | 12.321 | 0.001* |
| A x B (Interaction) | 1 | 31.302 | 31.302 | 0.196 | 0.658 ns |
| Within groups (error) | 146 | 23263.015 | 159.336 | | |

* = significant, ns = not significant.

Table 5. Comparison of moult increment (mm CL) between populations of *P. homarus* subspecies from three different areas in the Indian Ocean.

| Source | Location | Subspecies | Sex | Size Class (mm CL) | | | |
|----------------------------|------------|-----------------------|--------|--------------------|-------|-------|-------|
| | | | | 40-49 | 50-59 | 60-69 | 70-79 |
| Berry (1971b) | Natal (SA) | <i>P. h. rubellus</i> | male | – | 2.2 | 2.3* | 2.3* |
| | | | female | – | 2.1 | 2.0* | 2.1* |
| Nair <i>et. al.</i> (1981) | India | <i>P. homarus</i> | male | 3.5 | 3.1 | 2.9 | – |
| | | | female | 2.5 | 3.0 | 2.3 | – |
| Present Study | Kenya | <i>P. h. homarus</i> | male | 2.4 | 2.2 | 1.9 | 1.7 |
| | | | female | 1.6 | 1.7 | 2.5 | 1.3 |

(*) slightly modified

Table 6. Comparison of intermoult periods (days) between populations of *P. homarus* subspecies from three different areas in the Indian Ocean.

| Source | Location | Subspecies | Sex | Size Class (mm CL) | | |
|----------------------------|------------|-----------------------|--------|--------------------|-------|-------|
| | | | | 50-59 | 60-69 | 70-79 |
| Berry (1971b) | Natal (SA) | <i>P. h. rubellus</i> | male | 68' | 79 | 79 |
| | | | female | 68' | 75 | 73 |
| Nair <i>et. al.</i> (1981) | India | <i>P. homarus</i> | male | 57 | 62 | 57 |
| | | | female | 64 | 63 | 77 |
| Present Study | Kenya | <i>P. h. homarus</i> | male | 50 | 54 | 63 |
| | | | female | 55 | 64 | 64 |

(') represents the intermoult period of juvenile *P. h. rubellus*

Fig. 1. Map of the Kenyan coast showing location of Mamburi where live lobster samples were collected.

Fig. 2. Mean moult increment of uninjured (A) and injured (B) male and female *Panulirus homarus homarus* in captivity. Bars indicate \pm standard error of the mean.

Fig. 3. Growth curves of the Bertalanffy growth function for uninjured male and female *Panulirus homarus homarus* in captivity. L_t is the predicted carapace length at age t and t_0 is the length at zero length.

Fig. 4. The seasonal trends of water temperature and salinity measured as a mean monthly temperature and a mean monthly salinity (data for all holding tanks and adjacent Tudor Creek pooled).

Fig. 5. A comparison of the average monthly seawater temperature and the respective mean moult increment for uninjured male and female *Panulirus homarus homarus* in captivity.

Fig. 6. A comparison of the average monthly seawater temperature and the respective mean intermoult period for uninjured male and female *Panulirus homarus homarus* in captivity.