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Lobster Growth Profiles

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Abstract

Growth increments and rates were determined from 2500 molts of more than 600 cultured juvenile lobsters between 14 and 93 mm carapace length (CL), with up to 15 molts recorded from a single individual. Growth to 63 mm CL ("canner" size) averaged 0.085 mm/day, with a maximum of 0.14 mm/day (0.1 mm/day will produce a 450-g "market" lobster in 2 yr). This maximum is 40% greater than that reported by others. Above 63 mm CL, growth rates were severely reduced in both males and females (0.05 mm/day). Eyestalk ablated lobsters at 15°C grew at almost twice the rate of the fastest intact lobster at 20°C. These growth rates produce Hiatt diagrams that are progressive in the juvenile phase and retrogressive for both males and females in the mature phase.

Résumé

Nous avons déterminé les augmentations et les taux de croissance à partir de 2 500 mues de plus de 600 jeunes homards d'élevage, mesurant de 14 à 93 mm de longueur de carapace (LC), jusqu'à 15 mues étant observées sur un individu. La croissance jusqu'à 63 mm de LC (taille pour la conserve) étaient en moyenne de 0,085 mm jour, avec maximum de 0,14 mm/jour (une croissance de 0,1 mm/jour produira un homard de taille marchande, 450 g, en 2 ans). Ce maximum est de 40% supérieur à celui qui a été signalé par d'autres. Au-delà de 63 mm de LC, les taux de croissance diminuent brusquement, tant chez les mâles que chez les femelles (0,05 mm/jour). Des homards dont on avait enlevé les pédoncules oculaires et qu'on avait maintenus à 15°C crûrent à un taux presque deux fois plus rapide que le homard intact dont la croissance avait été la plus rapide à 20°C. Ces taux de croissance produisirent des diagrammes de Hiatt progressifs dans la phase juvénile et rétrogressifs, tant chez les mâles que chez les femelles, dans la phase mature.

Introduction

There are still significant gaps in the literature on lobster molting and growth (Aiken 1980). Much of the published information is incomplete and is often contradictory. Growth data obtained in past years from commercial fisheries or from observations on lobsters in captivity have often produced conflicting information on molt frequency and growth. A lobster's rate of growth is a function of both the increment per molt and intermolt time. The effects of temperature on growth rates have been recognized for more than 40 yr (see Aiken 1980 for review). The only report of long-term effects of elevated temperatures on growth rate is from Hughes et al. (1972). Although they produced market size lobsters in as little as 2 yr, it appears from their figure that only two individuals reached this size. This high temperature accelerating effect on growth is mainly due to a shortening of the intermolt period, as the increase in size per molt is not as strongly affected by temperature (Templeman 1936; Kurata 1962; Mauchline 1977).

Hadley (1906) reported the first studies for growth of lobsters in captivity concluding that lobsters take about 12 yr to reach 1 lb size, while MacKay (1926) reported even slower growth. Herrick (1911) and Hadley (1906) recognized that greater growth occurred in nature than under artificial conditions and this has been demonstrated in other crustaceans as well (Drach 1939; Hiatt 1948). Recently, the effects of restricted space on growth of *Homarus* have been the subject of several studies (Aiken and Waddy 1978; Sastry and French 1977; Van Olst and Carlberg 1978).

It has been said that a typical arthropod under good conditions doubles its weight and increases its linear size by 1.26 at each ecdysis (Przibram and Megusar 1912, cited by Needham 1964). This was disputed by Kurata (1962) who also objected to the Brookes-Dyar generalization that arthropod growth remains constant at each molt. In crustaceans it has been well demonstrated that size increase at ecdysis is relatively greater in younger individuals, and this is certainly true for *Homarus* (Logan and Epifanio 1978; MacKay 1926, 1929; Mauchline 1977; Templeman 1936, 1940).

The use of the Hiatt growth diagram to summarize and display lobster growth increment data is widespread (Ennis 1972; Kurata 1962; Mauchline 1976; Wilder 1963). Kurata detected inflection points in the straight line relationship over the lifetime of a crustacean and attributed these to the transitions from larval to juvenile, and juvenile to mature growth phases. Mauchline (1976) criticized the use of straight lines to fit data on Hiatt growth diagrams, suggesting instead the use of a hyperbolic model. He felt the juvenile-adult inflection was an artifact arising from the shape of the hyperbola. Somerton (1980) compared the hyperbolic and straight-line models and found that a pair of straight lines fit crustacean growth data significantly better. He felt the inflection point was real because the hyperbola does not describe the data as well as a pair of intersecting straight lines in the region of the intersection and that the abrupt change implicit in the straight-line model is consistent with the growth pattern of many crustaceans.

Mauchline (1977), using Templeman's (1948) data, related log percent growth factor and log intermolt period on carapace length and produced linear relationships called molt slope factor and intermolt period slope factor. The molt slope factor is the factor by which size increase decreases with successive molts, and the intermolt period slope factor defines the increase in intermolt period for successive molts. On referring back to Templeman's paper it was found the values used by Mauchline were from a table which Templeman constructed from a possible growth curve. No actual data were used for lobsters from 4th stage to 50 mm CL, so these two points were connected and the values in Mauchline's table were derived from this hypothetical line. This produces growth factors in excess of 20 until the lobster reaches 50 mm CL. Although size increase at ecdysis is relatively greater in younger individuals (Templeman 1936, 1940; MacKay 1926, 1929; Kurata 1962; Mauchline 1977), usually only larval and adult stages are compared, and there is little examination of juvenile growth. Because of these problems, Mauchline's interpretations, conclusions and relationships based on Templeman's data should not be accepted without further verification.

Methods of Lobster Maintenance

All lobsters were housed in individual cubicles in self-cleaning flush tanks. Temperature was constant at 20°C ± 1°, except for brief periods when temperature was lowered due to equipment failure (hours) or low salinity (days). The cubicles used were either 310 cm^2 or 620 cm^2. Lobsters were transferred to the larger cubicle at 40 mm CL. Lobsters were fed six times per week on a varied diet of fresh-frozen whole shrimp, cod, beef liver, squid, herring, and other natural foods as available. At this time over 2500 measurements have been recorded for molts from over 600 lobsters ranging in size from 14-93 mm CL. As many as 15 molts have been recorded from a single individual.

The eyestalk-ablated (EA) lobsters in this experiment were cultured lobsters with an average CL of 22 mm at time of ablation. They were acclimated to 15°C prior to bilateral eyestalk ablation with an 18-gauge hypodermic needle.

Results and Discussion

A. Increase in carapace length in mm/day

A growth rate of 0.1 mm/day produces a 450-g "market" lobster in approximately 2 yr. Up to "canner" size (63.5 mm CL), growth of intact cultured lobsters averaged 0.085 mm/day and ranged to 0.14 mm/day in intact animals. This maximum rate of 0.14 mm/day is 40% greater than that previously reported (Van Olst et al. 1980). From canner to market size the rate decreased to an average of only 0.05 mm/day, although one animal (#19) attained 0.09 mm/day from 63.5 to 74.8 mm CL, indicating rapid growth at this size is possible. The eyestalk ablated (EA) lobsters increased their length at an average rate of 0.246 mm/day at 15°C, or almost twice as fast as the fastest intact lobster held at 20°C. This increased growth rate in EA lobsters was due to a marked reduction in the intermolt time. Eyestalk ablation had very little effect on percent increase in CL.

B. Hiatt growth diagram for cultured lobsters

The Hiatt growth diagram (as termed by Kurata) enables the calculation of size at each successive instar as well as number of molts to reach a particular size. There is no adequate explanation why Hiatt's method of plotting growth data gives a straight line nor is it known whether the growth constants have any biological significance. But it has been well demonstrated that growth data from a wide variety of crustaceans gives a straight line when plotted according to Hiatt's method (Kurata 1962).

Hiatt growth equations were determined for both male and female intact and EA cultured lobsters.

	Female	Male	EA
N	538	483	29
CL range	13.4-93.0	14.0-91.5	21.4-93.3
a	1.1076	0.773	2.87
b	1.1026	1.1256	1.15
r	0.995	0.993	0.990

These slopes (b) are all progressive ($b > 1$) and the differences between them are not significant. Conan (1978) found the female slope for H. vulgaris and Nephrops norvegicus to be always <1.0, but using Ennis' (1972) and Wilder's (1953) data for H. americanus he found the slope to be >1.0. Although the overall data show a progressive slope, this is not the case for mature individuals.

Dividing the data at 60 mm CL (approximate size at maturity) gave separate regressions for the approximate juvenile and adult phases for intact lobsters.

For females the two regressions are:

juvenile, N = 502: $Y = .3379 + 1.1245X$ ($r = .994$)

adult, N = 50: $Y = 9.8892 + 0.9598X$ ($r = .975$)

The two phases for males are of the form:

juvenile, N = 451: $Y = -.0068 + 1.1366X$ ($r = .993$)

adult, N = 48: $Y = 16.8870 + 0.8628X$ ($r = .900$)

Both males and females have a retrogressive slope in the adult phase. An analysis of covariance revealed no significant differences between male and female regression slopes for either phase.

Kurata (1962) found that growth coefficients for dimensional increase were generally between 0.8 and 1.4 and were greater in the younger than the older growth phase - and this is true of the data presented here. He also reported that male American lobsters do not show a change in growth pattern throughout the entire size range. I found this was not the case with cultured lobsters and the differences are significant between juvenile and adult phases for both males and females.

Kurata also stated that females as a general rule show a smaller value of the growth coefficient than do males - the reduced rate being attributed to loss of nutrients to egg development. Conan (1978) also found the slope to be less for females. The cultured lobsters show no differences in growth coefficients between males and females.

The inflection points as determined by Hiatt's equation are at 56 mm CL for females and 60 mm CL for males. These approximate the sizes at maturity of these cultured lobsters as determined by egg extrusion and secondary sex characteristics, such as female AWI (Waddy and Aiken 1980) and male CPI (Aiken and Waddy 1980).

C. Weight/length

Correlation of length-weight data over the size range 14-93 mm CL produced the equations:

$$\frac{\text{female}}{(N = 168)} \quad Y = 0.00067X^{3.05} \qquad (r = 0.99)$$

$$\frac{\text{male}}{(N = 125)} \quad Y = 0.00063X^{3.07} \qquad (r = 1.00)$$

An analysis of covariance showed no significant difference between these slopes, or in the intercepts.

Briggs and Muschake (1979) calculated length-weight relationship for Long Island Sound male and female lobsters (which are very similar in size at maturity to our cultured lobsters) in the size range 17-118 mm CL. They likewise found no differences between males and females and produced the equation:

$$Y = 0.000254X^{3.27}$$

Over the range of sizes examined their equation produces weights within $\pm$ 20 g of the one we determined for cultured lobsters.

The length-weight relationship of the EA lobsters is of the form

$$Y = 0.00025X^{3.38}$$

Surprisingly, the slope of increase in relative weight of EA lobsters (3.38) is not that much greater than that for intact cultured male lobsters (3.07) and is even closer to that for wild lobsters (3.27). EA lobsters are more robust in appearance, especially in carapace and cheliped volume, and appear to increase more than the data suggest. The reason for this is probably the low meat yield from the eyestalk ablated lobsters. The meat yield ranges from 10.3-11.8%, whereas 25% is the accepted standard for wild intact lobsters. The only other available information on meat yield from EA lobsters is from Murchison and Burleigh (1976) and Castell et al. (1977) which showed that meat yield averaged 16.2% following one post-ablation molt. The lower meat yield in this study may be characteristic of EA lobsters over the long term. Equally interesting is the fact that there is no apparent relationship between meat yield and molt stage for the EA lobsters. In intact lobsters there is a progressive increase in meat yield from early stage C through stage D. In these five large EA lobsters that relationship is not apparent. Murchison and Burleigh reported the same phenomenon, there being no significant change in meat yield from 0-120 days postmolt.

D. Mauchline relationships

Mauchline (1977) obtained several additional linear growth relationships. We applied some of those to our data on intact cultured lobsters and obtained the following correlations:

1. log growth factor vs carapace length

female	(N = 281)	Y = 1.17 + (-.002)X	(r = .21)
male	(N = 243)	Y = 1.31 + (-.004)X	(r = .19)

2. log IM time vs carapace length

female	(N = 300)	Y = 3.013 + .029X	(r = .720)
male	(N = 258)	Y = 2.9695 + .029X	(r = .657)

3. log weight increment vs log body weight

female	(N = 299)	Y = 2.85 + 2.24X	(r = .822)
male	(N = 259)	Y = 19.25 + 1.73X	(r = .664)

To establish these linear correlations Mauchline used Templeman's (1948) constructed growth curve. No actual data were used for lobsters from 4th stage to 50 mm CL. This produces percent growth factors in excess of 20 until the lobster reaches 50 mm CL. Mauchline used only 18 data points to obtain these correlations and 9 of those were interpolated rather than measured values. Our data, although highly significant ($p < .05$ for correlation coefficient r), does not have nearly as good a fit as that described by Mauchine. Our data are much more extensive than those used by Mauchline and cover the carapace length range 14-93 mm. Mauchline gives no explanation of the physiological basis of these relationships and only provides them as a means of obtaining better estimates of growth rates. Data from these cultured lobsters indicate that caution should be exercised when applying these to growth studies.

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