Enhancement of Lobster Growth

Abstract. *Selected captive lobsters have been successfully mated at the Massachusetts Lobster Hatchery. Progeny raised in warm seawater grew at least four times as fast as lobsters grown at ambient ocean temperatures. These studies demonstrate that lobsters will reach sexual maturity (a weight of about 454 grams) in less than 2 years, compared to 8 years at ambient temperatures in Canadian waters. A further reduction in this time has been achieved by phenotypic selection for fast-growing lobsters. Our initial success in accelerating growth and in mating selected parents suggests that lobster farming may be possible.*

In 1906 Hadley completed the first extensive studies of lobster growth in captivity (*1*). These studies indicated that lobsters required about 12 years to reach sexual maturity, about 1 pound (454 g) in size. Templeman reported that the intermolt periods in the ocean were much shorter than had previously been determined (*2*). He suggested that animals held in captivity could not achieve normal growth rates. Wilder verified Templeman's observations and supported the theory that growth studies conducted in the laboratory could not be used to describe normal lobster growth in the ocean (*3*). Using data on the sizes of larval lobsters (stages 1 to 4) from plankton tows and on size increments of marked and recaptured legal-sized adults, Wilder derived equations to describe the growth per molt of lobsters in the wild. These equations indicated that a lobster required 8 years to attain legal size (454 g) in Canadian waters. There had been no experimental verifications of Wilder's predictions because of the difficulty in obtaining large numbers of wild juvenile lobsters (stage 4 to 20).

We report experiments that verify Wilder's theoretical equations and demonstrate that lobsters grown in both ambient and 22°C seawater in the laboratory display the increments per molt that he predicted. Furthermore, the animals in this study achieved growth rates in excess of those previously described as normal. Under our experimental conditions (22° to 24°C), it is possible to produce a sexually mature 1-pound lobster in less than 2 years compared with 8 years for wild lobsters (*3*).

As part of a stocking program conducted by the Lobster Hatchery, Massachusetts Division of Marine Fisheries (Martha's Vineyard) during the past 20 years, small numbers of stage 4 lobsters were retained for growth studies. These lobsters were fed regularly and maintained in tanks through which ambient seawater was circulated. Recorded size increments for more than 1000 molts of 300 individual lobsters were used to calculate the size increment per molt of lobsters reared in captivity.

We initiated studies in the 22° to 24°C temperature range to verify and extend Templeman's observations on lobsters grown to stage 12. Thirty sibling lobsters reared from hatching to stage 12 in ambient seawater were used initially (*4*). These experimental lobsters were maintained in covered aquariums in rooms kept at temperatures between 22° and 24°C. Water was pumped and filtered continuously, and changed bimonthly. Oxygen concentrations were maintained by aeration with a diaphragm pump. Control animals were reared in hatchery troughs and kept separate by screened partitions. Seawater at ambient tempera-

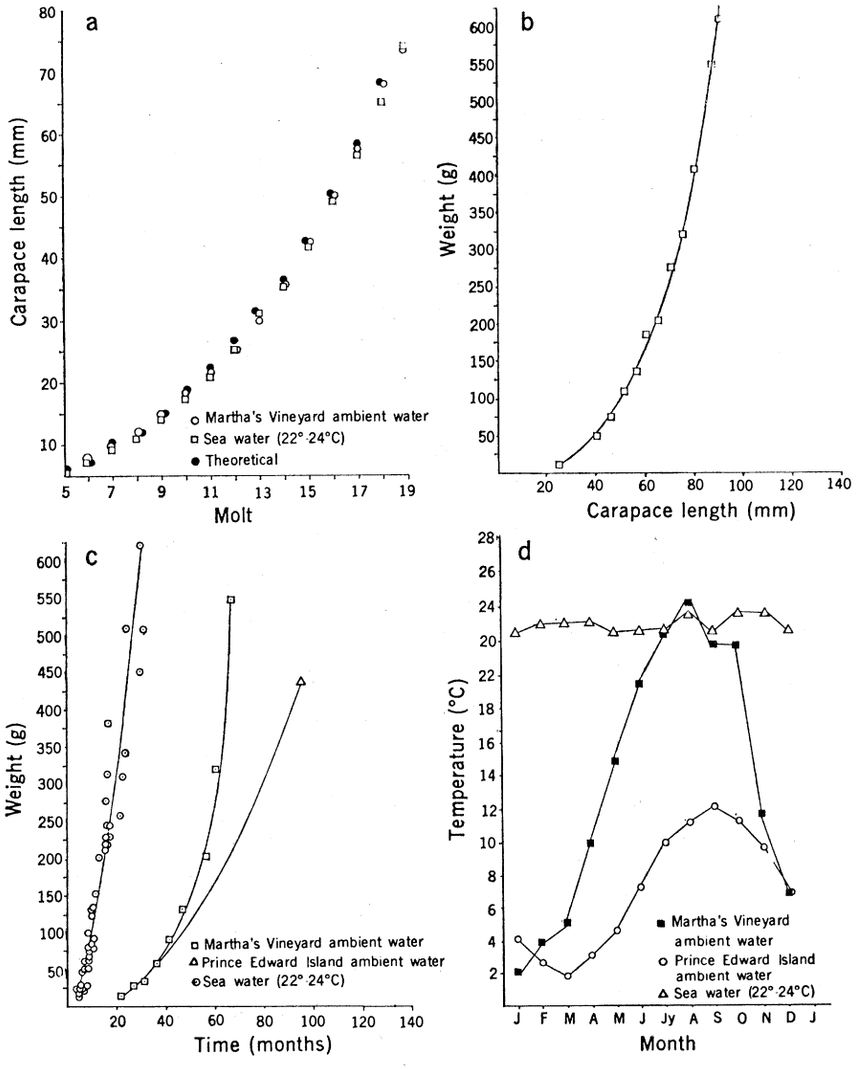

Fig. 1. (a) Growth per molt. Average carapace lengths of lobsters during successive molts at ambient and warm temperatures (22° to 24°C) are compared to theoretical values (*3*). Values were averaged for 12 animals in ambient water and for 18 experimental animals in warm water. (b) Relation of lobster weight to carapace length. Each square represents the average value for 20 lobsters. (c) Comparative weight gains in lobsters at ambient temperature and in warm water (22° to 24°C) in relation to theoretical values (*3*). (d) Mean monthly temperatures. Values for warm water and ambient water are averages of daily temperatures during the study period. The Canadian ambient temperatures were measured by Wilder (*3*) for the Atlantic Ocean in the vicinity of Prince Edward Island.

ture (Fig. 1d) was pumped from the outside lagoon adjoining the lobster hatchery. The animals were fed daily in excess of demand, and uneaten food was removed after 24 hours.

In Fig. 1a the increase in size per molt of lobsters reared at the hatchery at ambient temperature is compared with values predicted by Wilder's equations for growth in Canadian waters (*3*). Our experimental lobsters, reared at elevated temperatures, exhibited increments per molt similar to those predicted by Wilder for wild lobsters.

The significance of the apparent differences for molts 18 and 19 between empirical and theoretical results is unknown. It may be more apparent than real, because of the small numbers of animals studied.

The relation of carapace length (*5*) to weight is shown in Fig. 1b. The increase in weight per molt in these studies can be determined by comparing Fig. 1, a and b.

In addition to his studies of lobster growth in the sea, Templeman (*2*) also measured growth rates of lobsters from stages 4 to 12 at temperatures between 19° and 22°C. The frequency of molting increased at higher temperatures in these limited studies. Hughes and Matthiessen reported later that optimum growth for larval lobsters in stages 1 to 4 is achieved between 20° and 23°C (*6*).

The size increments we observed for the first 12 molts coincided with Templeman's observations for the same growth stage. We transferred 12 lobsters to warm water tanks (20° to 24°C) and observed them for size increment and molting frequency. Rates of weight increase in both warm and ambient seawater at the lobster hatchery (Fig. 1c) are compared with a theoretical curve for growth rate in the sea in the vicinity of Prince Edward Island, Canada. Lobsters reared in warm water grew faster as a result of a shorter intermolt period. Lobsters molt more frequently at elevated temperatures but have the same size increment per molt as do wild lobsters. The apparent difference between Wilder's calculations and our observations of growth rate or molting frequency can be explained by examining the monthly temperatures in the three situations (Fig. 1d). If growth rate is temperature-dependent, it is not surprising that lobsters exposed to the warmer average temperatures on Martha's Vineyard grow to sexual maturity in 5½ years whereas animals growing in the colder Canadian environment take approximately 8 years (*3*).

In nature, most lobsters with carapace lengths of 90 mm have reached sexual maturity. All of the experimental lobsters that have 83-mm carapaces and were raised in warm water to this size have demonstrated normal sexual responses and have mated. Also, the developmental period for fertilized eggs is decreased by 33 percent in warm water.

Encouraged with these results and the potential to mate chosen parents, we tried to select lobsters that grew faster than average or were molting more frequently. More than 100,000 lobster larvae were screened for rapid growth. In two steps we selected 200 and finally 13 individual animals displaying at least a 1.5-fold increase in molting frequency. We have also selected lobsters that are much larger than average for their age. The results of these selections suggest that it may be possible to produce lobsters of marketable size in about 18 months.

It is possible to estimate food conversion for lobsters from these studies. The amount of food offered daily was proportional to body size. When the water temperature dropped below 5°C, control animals ate very little. Conversion factors of 4 : 1 and 11 : 1 were calculated for the animals grown in warm water and ambient seawater, respectively. Uneaten food was not considered in these calculations; therefore, these values are considered to be maximum and tentative conversions. Precise experiments to measure actual food conversion with a variety of inexpensive or synthetic diets are needed. The results of these studies indicate that there may be a lobster farm in the future.

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References and Notes

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2. W. Templeman, *J. Biol. Bd. Can.* **1**, 213 (1936).
3. D. G. Wilder, *J. Fish. Res. Bd. Can.* **10**, 371 (1953).
4. Martha's Vineyard water is taken from a shallow bay, which is subject to seasonal temperature fluctuations that are greater than those normally experienced by natural lobster populations in open coastal waters.
5. Carapace length is the distance from the rear of the eye socket to the rear end of the body shell, measured along a line parallel to the center of the body shell. In Massachusetts a legal-size lobster has a carapace length of at least 81 mm (3 3/16 inches).
6. J. T. Hughes and G. C. Matthiessen, *Limnol. Oceanogr.* **7**, 414 (1962).

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DNA Polymerases from RNA Tumor Viruses and Human Cells: Inhibition by Polyuridylic Acid

Abstract. *Polyuridylic acid inhibited DNA polymerases purified from three species of oncornaviruses as well as three out of seven DNA polymerases purified from cells. Viral and cellular DNA polymerases could not be distinguished by polyuridylic acid inhibition, but were easily distinguished by their template preferences in the presence of magnesium.*

A report appeared suggesting that inhibition by polyuridylic acid [poly(U)] might be useful in distinguishing DNA polymerase (reverse transcriptase) of RNA tumor viruses from cellular DNA polymerases (*1*). That report demonstrated that two cellular DNA polymerases were not inhibited by poly(U), a potent inhibitor of a crude preparation of the RNA tumor viral enyzme (*1*). The possibility that poly(U) might be a specific inhibitor of the oncornaviral DNA polymerase has interesting ramifications, especially for identification of this or a similar enzyme in cells, particularly human neoplastic cells. Tuominen and Kenney (*1*) discussed the possibility of using poly(U) in the detection of oncornaviral DNA polymerases in cellular systems, as well as separating these viral and cellular polymerases by specific elution from DNA-cellulose columns with buffers containing poly(U). Therefore, it was imperative to confirm and extend their observations, particularly those relating to the specificity of poly(U).

We have examined the inhibitory effects of poly(U) on ten partially purified DNA polymerases, three from RNA tumor viruses and seven from cells. Three types of templates were