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The Early Growth of Artificially Reared American Lobsters

Part 1: Genetic Parameters Within Environments

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Summary. Twenty families of the lobster, *Homarus americanus*, were reared at 10°, 15° and 20°C with and without bilateral eye-stalk-ablation. At 20°C both eye-stalk-ablated and non-eye-stalk-ablated lobsters from each family were assigned to one of two dietary treatments: 1) frozen whole brine shrimp, or 2) a diet of cheap, local constituents. The means of growth traits improved while viability decreased with increasing temperature. The ablation technique shows promise since improved performance for growth was apparent in eye-stalk ablated lobsters, but mortality was greater. Important genetic variation of all traits was found in each of the environments tested. The genetic correlations between growth traits were reinforcing, but the correlations between growth and viability traits were mainly negative. Ease and reliability of measurement should be considered when choosing growth traits in any artifical selection program.

Key words: Genetic parameters – Early growth – Lobsters – Muliple-environment

Introduction

At present, lobsters (*Homarus americanus*) used for commercial culture must be hatched from egg-bearing (berried) females caught in the wild. Such 'wild' lobster larvae and juveniles are aggressive and tend to have high mortality under commercial culture conditions as well as having highly variable growth rates. In agricultural species, similar traits have been greatly improved by the application of human controlled breeding-selection. A primary aim of the present research is to estimate the extent of genetic control and the relationships among growth rate and mortality traits with view to improving these traits under human controlled breeding programs.

The nutrient requirements of the lobster are largely unknown and this remains a major problem in lobster culture (Castell et al. 1975). Bilateral eyestalk ablation enhances molting frequency and growth rate, but its usefulness is related to the adequacy of diets (Mauviot and Castell 1976). Growth rate varies with temperature and although 19°C appears to be close to an optimal temperature for growth (Richards 1976) economic considerations may indicate a lower temperature is preferable.

The present work estimates genotypic and phenotypic parameters of growth rate and conditions with regard to diet, temperature and mortality. Since optimal conditions with regard to diet, temperature and ablation are unknown, variations in these parameters were included to access genetic potential under a wide variety of conditions and to determine the significance of genotype-environment interactions.

Materials and Methods

Gravid inshore female lobsters from southern Nova Scotia were held in constant-flow ambient sea water. To accelerate egg development each berried female was placed in constant-flow degassed sea water heated to 15°C. Newly hatched larvae from each female were collected in an overflow trap and transferred to 136 litre standing culture tanks for group rearing. Water at 15°C in these tanks was heavily aerated and saturated with freshly hatched *Artemia Salina* to feed the lobster larvae.

Fourth stage lobster larvae were removed from group rearing tanks and transferred to individual containers formed from $3\frac{1}{2}$ inch PVC tubing covered sides and bottom with fibreglass mesh. Containers were held upright in tanks in non-recirculating degassed flowing sea water. Lobsters were reared from fourth stage to 150 days of age at 10°, 15° and 20°C. Sea water at each temperature originated from a common source.

One-half of the lobsters reared at 20°C were fed frozen whole brine shrimp (*Artemia salina*). The remainder were fed a compound diet of inexpensive locally available constituents (Diet): 40% rock crab, 25% squid, 20% sea urchin, 20% lobster body, 5% wheat germ

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and 0.1% vitamin E with a gelatin binder (approximate percentages by weight).

Within each diet-temperature combination lobsters were assigned to either a normal or a bilateral, eyestalk ablated (ablated) group. Ablation was carried out three days after the sixth molt.

All lobsters were checked for molts, mortality and cleanliness at least once day. Carapace length (size) was taken on cast molts dorsally from the back of the eye hole at the base of the rostrum to the mid-dorsal region of the most anterior portion of the cephalothorax. Individual live weights were taken at 50 days (W50), 150 days (W150) and even numbered molt stages from the eighth onward. Lobsters in individual containers were placed on paper towels, allowed to blot dry for about 90 seconds and weighed.

The progeny of twenty families of lobsters were randomly distributed into eight groups of approximately equal size. Each group as placed in a different test environment: 1) 10°C-Ablated-Diet (AD10); 2) 10°C-Normal-Diet (ND10); 3) 15°C-Ablated-Diet (AD15); 4) 15°C-Normal-Diet (ND15); 5) 20°C-Ablated-Diet (AD20); 6) 20°C-Normal-Diet (ND20); 7) 20°C-Ablated-Brine Shrimp (AB20); 8) 20°C-Normal-Brine Shrimp (NB20).

A total of 2116 lobsters were entered on test. Sixteen of the families had an average of 16 lobsters per environment with a minimum of 9 lobsters in any environment. The remaining four families averaged only 4 lobsters per environment with a minimum of 2 lobsters in any environment.

With the exception of the mortality data, analysis of variance and covariance was carried out within each environment for all characters using the model:

$Y_{ijk} = u + b_i + f_{ij} + e_{ijk}$

where Y_{ijk} is the observation on the k^{th} progeny within the j^{th} family within the i^{th} block,

u is the population mean, common to all observations,

b_i is a random effect due to the i^{th} block

f_{ij} is a random effect due to the j^{th} family within the i^{th} block and e_{ijk} is a random residual effect due to the k^{th} progeny within the j^{th} family within the i^{th} block.

Heritabilities (h^2) were estimated as twice the family variance over the sum of the block, family and residual variances. Genetic correlations (r_g) were estimated as twice the family covariance over the square root of the product of the family variance of each pair of traits. Standard errors were calculated according to Becker (1975), and Hammond and Nicholas (1972). Heritability estimates and standard errors for mortalities were calculated according to Robertson and Lerner (1949).

Results and Discussion

The Effect of Temperature

Time from hatch to each molt stage (time) decreased as temperature increased (Table 1). This reduction was greater between 10° and 15°C than between 15° and 20°C. A similar trend is apparent in weight gained (growth rate) from 50 to 150 days of age. Growth rate increased dramatically from 10° to 15°C, but the increase to 20°C resulted in very little change in growth rate over that achieved at 15°C. Carapace length (size) increased almost linearly with each molt stage, but size at each molt stage did not vary with temperature (Table 1).

Mortality rose with increasing temperature (Table 1). While mortality due to all causes increased from 10° to

Table 1. Means and standard errors of growth traits and percentage mortality for all environments

	Time from hatch (Days)				Size (mm)				Weight gain from	Mortality to 150 days (%)		
	Molt stage				Molt stage							
Environment	7	8	9	10	7	8	9	10	50 to 150 days (g)	Molting	Post Molt	Total
ND10[a]	125.1 ± 1.4	174.3 ± 1.6	215.4 ± 1.9		5.97 ± 0.03	7.37 ± 0.05	8.39 ± 0.10		20.7 ± 0.7	1.1	0.6	19.5
AD10	115.8 ± 1.4	148.7 ± 1.4	185.0 ± 2.2		6.01 ± 0.03	7.31 ± 0.05	8.79 ± 0.08		27.2 ± 1.2	6.3	1.0	41.0
ND15	75.2 ± 1.0	101.2 ± 1.2	126.1 ± 1.8	155.5 ± 3.2	6.01 ± 0.07	7.44 ± 0.07	8.80 ± 0.15	9.86 ± 0.25	56.7 ± 3.5	4.6	3.3	53.3
AD15	71.8 ± 1.0	90.7 ± 1.1	110.3 ± 1.9	130.6 ± 7.4	6.05 ± 0.06	7.40 ± 0.07	8.89 ± 0.12	9.72 ± 0.66	73.0 ± 16.5	15.8	12.0	92.4
ND20	54.2 ± 0.6	70.2 ± 0.9	89.1 ± 1.2	109.8 ± 1.9	5.87 ± 0.11	7.37 ± 0.11	8.14 ± 0.24	9.66 ± 0.21	65.3 ± 5.2	2.1	20.0	74.0
AD20	52.8 ± 0.6	63.6 ± 0.6	77.8 ± 1.4	96.0 ± 5.9	5.68 ± 0.11	6.89 ± 0.18	9.04 ± 0.23	9.05 ± 1.32	65.7 ± 20.1	12.6	30.6	96.1
NB20	58.5 ± 0.8	76.7 ± 1.2	98.9 ± 1.1	119.3 ± 1.5	5.71 ± 0.17	6.87 ± 0.15	7.60 ± 0.21	8.81 ± 0.33	88.0 ± 3.1	0.4	1.3	30.8
AB20	53.8 ± 0.6	67.6 ± 0.8	82.2 ± 1.0	101.2 ± 1.4	5.73 ± 0.12	6.55 ± 0.17	8.25 ± 0.26	9.66 ± 0.25	212.2 ± 10.9	2.9	9.8	59.5

[a] N = Normal, A = Ablated, D = Diet, B = Brine Shrimp, 10 = 10°C, 15 = 15°C, 20 = 20°C

15°C, it was the increase in postmolt mortality alone that resulted in an overall increase in mortality at 20°C as compared to 15°C.

On the basis of the growth traits, a growth temperature of 10°C does not seem feasible for commercial culture. At that temperature, the time required for any returns on investment would seem to be prohibitive. The plateauing of growth rates evident between 15° and 20°C is in agreement with the results of Hedgcock et al. (1976) and Richards (1976). Since mortality also plateaued between 15° and 20°C, it would seem that an optimal temperature for commercial culture might be between 15° and 20°C. The results of Richards indicate that 19°C may be the highest feasible temperature since growth advantages beyond this would be negligible. Systematic studies of temperatures between 15° and about 23°C are needed.

The Effect of Diet

Although diet had no effect on size at any molt stage, lobsters fed Brine Shrimp took succeedingly longer to molt into later stages than those fed the Diet (Table 1). However, the weight gain of lobsters fed Brine Shrimp was greater than that of those fed the Diet and mortality was much higher in all cases for lobsters fed the Diet. This was especially true for mortalities associated with molting.

Although the Diet was not totally adequate, molting frequencies were greater with it and early growth was better with it than with Brine Shrimp – at 50 days lobsters fed the Diet were significantly heavier than those fed Brine Shrimp. Cost and availability are the major drawbacks of feeding Brine Shrimp and more work on lobsters nutrition is indicated.

The Effect of Ablation

Ablation had two general effects: 1) an increase in growth traits and 2) an increase in mortality (Table 1). The mean time to a molt stage was lower for Ablated than Normal lobsters and the response difference increased with succeeding molt stages. The growth rate of Ablated lobsters was higher than that of Normal lobsters. However, there were no systematic differences for mean size at any molt stage as a result of ablation. Ablated lobsters had higher percentage mortalities than Normal lobsters. The greatest difference between Ablated and Normal lobsters was due to molting mortalities.

At 20°C, the Normal and Ablated lobsters fed the Diet had identical weight gains, but the Ablated lobsters fed Brine Shrimp gained more than twice the weight of the Normal lobsters fed Brine Shrimp (Table 1). This interaction resulted largely from mortality in the ablated lobsters fed the Diet at 20°C. Adequate nutrition seems to be more crucial in bilaterally eyestalk ablated lobsters. More critical studies on ablation need to be done with an improved dietary ration. In any case, the ablation technique holds future promise.

Heritabilities and Correlation Between Traits

The heritabilities of the growth traits were moderate to high with a few exceptions (Table 2). In general, the heritabilities of growth traits decreased with increasing temperature. The heritability of size was higher among Normal lobsters than their Ablated counterparts and there was a trend for increasing heritability of size with succeeding molt stages. However, there was a corresponding trend for the heritability of molting frequency to decrease with molt stages.

Table 2. Heritabilities and standard errors of growth traits

Environment	T[a]	S[a]	W50	W150
ND10	0.81 ± 0.18	0.52 ± 0.15	0.44 ± 0.08	0.52 ± 0.09
AD10	1.36 ± 0.31	0.45 ± 0.19	0.39 ± 0.08	0.47 ± 0.09
ND15	0.25 ± 0.09	0.62 ± 0.18	0.33 ± 0.07	0.44 ± 0.11
AD15	0.31 ± 0.11	0.38 ± 0.14	0.42 ± 0.08	
ND20	0.11 ± 0.08	0.39 ± 0.26	0.12 ± 0.04	0.10 ± 0.05
AD20	0.32 ± 0.13	0.17 ± 0.14	0.17 ± 0.05	
NB20	0.21 ± 0.09	0.20 ± 0.26	0.03 ± 0.03	0.48 ± 0.11
AB20	0.29 ± 0.10	0.15 ± 0.23	0.31 ± 0.07	0.45 ± 0.28

[a] Average of heritabilities and standard errors for molt stages 7, 8 and 9, T = Time to a molt stage, S = Size at a molt stage, W50 = Weight at 50 days, W150 = Weight at 150 days

Table 3. Heritabilities and approximate standard errors of percentage mortalities

Environment	Total mortality	Molting mortality	Postmolt mortality
ND10	0.11 ± 0.05	0.19 ± 0.07	0.20 ± 0.08
AD10	0.08 ± 0.05	0.20 ± 0.08	0.25 ± 0.12
ND15	0.10 ± 0.07	0.32 ± 0.14	0.34 ± 0.14
AD15	0.17 ± 0.08	0.32 ± 0.28	0.54 ± 0.26
ND20	0.11 ± 0.06	0.48 ± 0.17	0.19 ± 0.09
AD20	0.20 ± 0.07	1.07 ± 0.23	0.59 ± 0.16
NB20	0.06 ± 0.05	0.06 ± 0.09	0.26 ± 0.09
AB20	0.10 ± 0.06	0.41 ± 0.14	0.35 ± 0.12

Table 4. Genotypic, r_g (above main diagonal), and phenotypic, r_p (below main diagonal), correlation coefficient between traits by environment

	ND10						ND15						ND20					
	W50[b]	W150	T8	S8	TD	V	W50	W150	T8	S8	TD	V	W50	W150	T8	S8	TD	V
W50		0.09 ± 0.61	− 0.04 ± 0.63	0.57 ± 0.60		1.83		0.23 ± 0.86	− 0.48 ± 0.53	0.44 ± 0.55	1.08 ± 1.00	− 0.80					− 0.44 ± 0.64	1.56
W150	0.33 ± 0.14		− 0.80 ± 0.26	0.52 ± 0.51		− 0.01	0.62 ± 0.20		− 0.28 ± 0.81	1.07 ± 0.48		1.01	− 0.01 ± 0.13					0.66
T8	0.07 ± 0.19	− 0.40 ± 0.20		− 0.31 ± 0.56		0.69	− 0.64 ± 0.14	− 0.90 ± 0.20		− 0.01 ± 0.60	0.13 ± 0.80	0.55	− 0.35 ± 0.07	0.08 ± 0.14			− 1.11 ± 1.00	− 0.21
S8	0.27 ± 0.14	0.69 ± 0.09	− 0.23 ± 0.14			0.07	0.43 ± 0.10	0.44 ± 0.12	− 0.06 ± 0.08			0.12	0.41 ± 0.08	0.34 ± 0.22	0.54 ± 0.11		− 0.22 ± 0.70	
TD							0.17		− 0.09	0.07			0.04		0.02	0.02		
	AD10						AD15						AD20					
	W50	W150	T8	S8	TD	V	W50	W150	T8	S8	TD	V	W50	W150	T8	S8	TD	V
W50		0.21 ± 0.77	0.07 ± 0.69	0.87 ± 0.66	0.11 ± 0.30	0.13			− 0.78 ± 0.34	0.67 ± 0.47	− 0.50 ± 0.32	− 1.27			− 0.35 ± 0.76		− 0.92 ± 0.74	− 0.17
W150	0.21 ± 0.17		− 0.83 ± 0.31	0.47 ± 0.71		− 0.58												
T8	0.13 ± 0.15	− 0.64 ± 0.08		− 0.23 ± 0.64	− 0.61 ± 0.30	0.99	− 0.73 ± 0.11			− 0.09 ± 0.66	0.92 ± 0.27	1.27	− 0.50 ± 0.07			− 1.03 ± 0.87		− 0.87
S8	0.25 ± 0.17	0.58 ± 0.13	− 0.08 ± 0.12		− 0.07 ± 0.34	− 0.35	0.43 ± 0.19		− 0.04 ± 0.17			− 0.50	0.44 ± 0.25		− 0.11 ± 0.11			− 1.35
TD	0.10		− 0.33	− 0.18			− 0.20		0.16	0.03			− 0.25		− 0.19	0.08		
	NB20						AB20											
	W50	W150	T8	S8	TD	V	W50	W150	T8	S8	TD	V						
W50					− 0.43 ± 0.40	0.05			− 0.28 ± 0.90		− 0.73 ± 0.54	− 0.06						
W150	0.31 ± 0.07						0.07 ± 0.14					1.37						
T8	− 0.33 ± 0.10	− 0.40 ± 0.10			0.16 ± 0.43	0.57	− 0.42 ± 0.07	− 0.17 ± 0.13				− 1.61						
S8	0.33 ± 0.25	0.47 ± 0.18	− 0.25 ± 0.21		0.52 ± 0.37	1.20	0.43 ± 0.18	0.52 ± 0.47	0.18 ± 0.13			− 0.09						
TD	− 0.14		0.14	0.01			− 0.07		0.05	0.01								

[a] N = Normal, A = Ablated; D = Diet, B = Brine Shrimp; 10 = 10° C, 15 = 15° C, 20 = 20° C

[b] W50 = Weight at 50 days, W150 = Weight at 150 days, T8 = Time to 8th molt stage, S8 = Size at 8th molt stage, TD = Time to death, V = Viability

The heritabilities of total mortality were lower than those of two of its components: molting and postmost mortality (Table 3). This indicates that the mortalities connected with molting may be negatively correlated with other causes of mortality or that non-additive genetic effects may be involved in mortality. The heritability of molting mortality increased with increasing temperature.

The correlations (r_g and r_p) of time with both weight (W50 and W150) and size tended to be negative or low in all environments (Table 4). The correlations of weight and size were generally positive. Within each temperature-diet combination where estimates were available with ablated and normal lobsters, both estimates were in good agreement. In environments with greater relative growth rates – at 20°C and with ablated lobsters, weight, time and size were generally negatively correlated with time to death and livability.

The genetic variances of the growth traits – time, weight and size – were large enough to be useful in an artificial selection program. Furthermore, the correlations among them were reinforcing. It would seem that selection on one or a combination of growth traits would improve growth rates as measured by these traits so that ease of measurement and reliability should be considered when chosing the growth traits to be measured.

The heritability of total mortality was about 0.1 in all environments. This is high enough to make important selection gains with the percentage mortalities reported here. Since total variance is associated with the mean incident of mortality, more sophisticated selection procedures or other breeding techniques might be required when percentage mortalities are low. In any case, the negative correlations of the growth traits with viability and time to death indicate that a consideration of mortality would be an important part of any breeding scheme.

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