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# Genetic Study on Shell Shape and Growth-Related Traits in the Pacific Abalone *Haliotis discus hannai*

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## Summary

In order to estimate the relative importance of heredity in determining phenotypic value of several quantitative traits, 18 cultured lots of the Pacific abalone were examined for shell shape and growth related traits. The shell shape parameters were expressed as the proportion of length, width, and height of the shell, and the growth parameters were expressed as the proportion of whole body weight, soft part weight and shell weight with respect to the size.

In comparison to the natural population, the proportion of whole body weight and soft part weight in the cultured population indicated larger fluctuation among lots, and the other parameters indicated lower fluctuation. Larger fluctuation could show genetic variation which depends on the number of loci controlling variation of quantitative traits.

Pacific abalone (*Haliotis discus hannai*) is one of the commercial shellfish in Japan. Artificial seeds of this specimen have been produced and cultured to release size (30 mm in shell length) at many culture centers in Japan. In the artificial seed production of the Pacific abalone, each culture lot is produced from a few parents sampled from the natural population. A previous paper reported larger fluctuation of *Pgm-1* gene frequencies and soft part weight (SP)/whole body weight (BW) among cultured lots of abalone compared to that observed among natural abalone populations (1), suggesting the existence of genetic variation for SP/BW.

Quantitative characters are said to show polygenic inheritance if their variation depends on allelic differences at more than just a few loci. However, in genetical analysis of quantitative traits, genetic-environmental interaction can be an important factor. The partitioning of phenotypic variance into genotypic and environmental components is necessary to estimate the relative importance of the various determinants of the phenotype, in particular the role of heredity versus environmental factors. Estimating the relative importance of heredity in determining phenotypic value is relevant to genetic improvement of cultured aquatic organisms.

In this study, the level of fluctuation of metric traits was estimated using family comparisons of the Pacific abalone.

## Materials and Methods

Sixteen specimens of wild Pacific abalone (*Haliotis discus hannai*) were collected from the following: Okujiri (N1) in Hokkaido, Shiriya (N2, N3, N4) in Aomori, Taroh (N5), Miyako (N6), Kesencho (N7) in Iwate, Kesen-numa (N8), Utatsu (N9), Onagawa (N10), Enoshima (N11, N12, N13), Ajishima (N14), Sabusawa (N15) and Shichigahama (N16) in Miyagi (Table 1).

Eighteen lots of cultured population were collected from each of several culture centers (Table 2). Each of the cultured lots were produced by mating parents drawn from natural Pacific abalone population on the Sanriku coast (from Aomori to Miyagi) (2).

Shell length (L), shell width (W), shell height (H), whole body weight (BW), and soft part weight (SP) of sampled abalone were measured. The shell shape

TABLE 1. *Quantitative parameters in natural population of the Pacific abalone*

| Specimen (location) | No. of samples | Parameters related to shell shape | | | Parameters related to growth | | |
|---|---|---|---|---|---|---|---|
| | | Proportion of | | | Density of | | |
| | | length | wides | height | whole | soft part | shell |
| N1 | 105 | 0.517 | 0.357 | 0.126 | 0.817 | 0.581 | 0.236 |
| N2 | 33 | 0.508 | 0.353 | 0.139 | 0.865 | 0.627 | 0.238 |
| N3 | 98 | 0.517 | 0.361 | 0.122 | 0.772 | 0.505 | 0.267 |
| N4 | 60 | 0.521 | 0.358 | 0.121 | 0.748 | 0.550 | 0.198 |
| N5 | 60 | 0.500 | 0.350 | 0.150 | 0.692 | 0.494 | 0.198 |
| N6 | 80 | 0.514 | 0.356 | 0.130 | 0.730 | 0.523 | 0.207 |
| N7 | 105 | 0.519 | 0.357 | 0.124 | 0.797 | 0.571 | 0.226 |
| N8 | 101 | 0.522 | 0.363 | 0.115 | 0.867 | 0.594 | 0.273 |
| N9 | 32 | 0.511 | 0.359 | 0.130 | 0.734 | 0.516 | 0.218 |
| N10 | 50 | 0.521 | 0.360 | 0.119 | 0.852 | 0.641 | 0.211 |
| N11 | 50 | 0.512 | 0.357 | 0.131 | 0.766 | 0.527 | 0.239 |
| N12 | 80 | 0.514 | 0.358 | 0.128 | 0.792 | 0.543 | 0.249 |
| N13 | 57 | 0.524 | 0.370 | 0.106 | 0.859 | 0.665 | 0.194 |
| N14 | 30 | 0.523 | 0.359 | 0.118 | 0.783 | 0.549 | 0.234 |
| N15 | 61 | 0.521 | 0.349 | 0.130 | 0.839 | 0.568 | 0.271 |
| N16 | 55 | 0.504 | 0.348 | 0.148 | 0.776 | 0.557 | 0.218 |
| Mean | | 0.516 | 0.357 | 0.127 | 0.793 | 0.563 | 0.230 |

TABLE 2. *Quantitative parameters in cultured population of the Pacific abalone*

| Specimen (location) | No. of samples | Parameters related to shell shape | | | Parameters related to growth | | |
|---|---|---|---|---|---|---|---|
| | | Proportion of | | | Density of | | |
| | | length | wides | height | whole | soft part | shell |
| C1 | 50 | 0.526 | 0.353 | 0.121 | 0.813 | 0.547 | 0.266 |
| C2 | 77 | 0.536 | 0.356 | 0.108 | 1.004 | 0.693 | 0.311 |
| C3 | 58 | 0.531 | 0.357 | 0.112 | 0.854 | 0.593 | 0.261 |
| C4 | 84 | 0.531 | 0.356 | 0.113 | 0.950 | 0.685 | 0.265 |
| C5 | 148 | 0.528 | 0.351 | 0.121 | 0.853 | 0.599 | 0.254 |
| C6 | 164 | 0.531 | 0.351 | 0.118 | 0.804 | 0.568 | 0.236 |
| C7 | 152 | 0.529 | 0.351 | 0.120 | 0.816 | 0.567 | 0.249 |
| C8 | 137 | 0.542 | 0.349 | 0.109 | 0.848 | 0.602 | 0.246 |
| C9 | 106 | 0.537 | 0.350 | 0.113 | 0.839 | 0.608 | 0.231 |
| C10 | 209 | 0.535 | 0.354 | 0.111 | 0.819 | 0.545 | 0.274 |
| C11 | 90 | 0.539 | 0.357 | 0.104 | 0.693 | 0.391 | 0.302 |
| C12 | 109 | 0.535 | 0.360 | 0.105 | 0.629 | 0.338 | 0.291 |
| C13 | 96 | 0.539 | 0.358 | 0.103 | 0.771 | 0.476 | 0.295 |
| C14 | 80 | 0.539 | 0.358 | 0.103 | 0.818 | 0.548 | 0.270 |
| C15 | 112 | 0.535 | 0.357 | 0.108 | 0.849 | 0.584 | 0.265 |
| C16 | 100 | 0.534 | 0.355 | 0.111 | 0.905 | 0.623 | 0.282 |
| C17 | 100 | 0.542 | 0.348 | 0.110 | 0.978 | 0.676 | 0.302 |
| C18 | 100 | 0.529 | 0.356 | 0.115 | 0.901 | 0.636 | 0.265 |
| Mean | | 0.535 | 0.354 | 0.111 | 0.841 | 0.571 | 0.270 |

was expressed as the proportion of length, width, and height of the shell. The proportions were calculated by L/(L+W+H), W/(L+W+H), and H/(L+W+H), respectively. The density was expressed as the proportion of whole body weight (BW), soft part weight (SP), and shell weight (SW) with respect to the size. The proportions were calculated by BW/ (L×W×H), SP/ (L×W×H), and SW/ (L×W×H), respectively. These values were used as the metric traits, because no apparent difference in shell length has been demonstrated by the correlation of these values with shell length (2). Therefore, the metric traits used in the present work are considered to be stable throughout the growth. Moreover, these values were not observed to be different between mature female and male abalone.

## Results and Discussion

Table 1 shows the parameters related to shell shape and growth traits in natural population of the Pacific abalone. In parameters related to shell shape, the proportion of shell length, width, and height varied from 0.500 to 0.524 with a mean of 0.516, from 0.348 to 0.370 with a mean of 0.357, and from 0.106 to 0.150 with a mean of 0.127, respectively. It indicates that the proportion of shell height varied widely in comparison with the proportions of shell length and width.

In the parameters of density related to growth traits, the whole body weight varied from 0.692 to 0.867 with a mean of 0.793 ; the soft part weight varied from 0.494 to 0.665 with a mean of 0.563 ; and the shell weight varied from 0.194 to 0.273 with a mean of 0.230.

Table 2 shows the parameters related to shell shape and growth traits in cultured population. In the parameters related to shell shape, the proportion of shell length, width, and height varied from 0.526 to 0.542 with a mean of 0.535, from 0.348 to 0.360 with a mean of 0.354, and from 0.103 to 0.121 with a mean of 0.111. Fluctuation among cultured lots was smaller in the parameters related to shell shape than that of the natural population.

In the parameters of density, the whole body weight, soft part weight and shell weight varied from 0.629 to 1.004 with a mean of 0.841, from 0.338 to 0.693 with a mean of 0.571 and from 0.231 to 0.311 with a mean of 0.270, respectively.

TABLE 3. *Summary of quantitative parameters in natural and cultured population*

| | Natural population | | Cultured population | | Differences between natural and cultured population |
|---|---|---|---|---|---|
| | Mean±SD | CV (%) | Mean±SD | CV (%) | |
| *Pgm-1* allele frequency* | | | | | |
| *A* | 0.071±0.032 | 45.1 | 0.030±0.051 | 170.0 | − |
| *B* | 0.255±0.059 | 23.1 | 0.259±0.214 | 82.6 | − |
| *C* | 0.641±0.074 | 11.5 | 0.633±0.193 | 30.5 | − |
| *D* | 0.032±0.030 | 93.8 | 0.076±0.127 | 167.1 | − |
| *E* | 0.001±0.002 | 200.0 | 0.002±0.004 | 200.0 | − |
| Parameters related to shell shape | | | | | |
| proportion of length | 0.516±0.007 | 1.4 | 0.535±0.005 | 0.9 | + |
| proportion of width | 0.357±0.006 | 1.7 | 0.354±0.004 | 1.1 | − |
| proportion of height | 0.127±0.011 | 8.7 | 0.111±0.006 | 5.4 | + |
| Parameters related to growth | | | | | |
| density of whole body | 0.793±0.053 | 6.7 | 0.841±0.091 | 10.8 | − |
| density of soft part | 0.563±0.049 | 8.7 | 0.571±0.093 | 16.3 | − |
| density of shell | 0.230±0.026 | 11.3 | 0.270±0.023 | 8.5 | + |

* : Data from the previous paper (Kobayashi and Fujio, 1994)
+ : Significant differenc ($P<0.01$)

The densities of whole body and soft part weight indicated a significant fluctuation among cultured lots in comparison with that of the natural population.

The quantitative parameters in the natural and cultured population were summarized in Table 3. If the cultured lots are randomly produced from the natural population, overall mean is expected to be the same as that of the natural population. The overall mean of gene frequency at the isozyme locus *Pgm-1* in cultured population was the same to that of natural population. However, there was observed a larger fluctuation of *Pgm-1* gene frequency among cultured lots than that of the natural population. These facts indicate that each of the cultured lots randomly made from a few parents drawn from the natural population and the varied sampling parents can lead to a change in gene frequency compared to that of natural population.

Parameters from the density of whole body and soft part were observed to vary in a similar way to the gene frequencies at the isozyme locus *Pgm-1*. This phenomenon suggests the existence of high genetical variance. On the other hand, lower fluctuation among cultured lots was observed in the parameters related to shell shape and shell density in comparison with that of the natural population, suggesting low genetical variance.

The previous paper (1) reported larger fluctuation of *Pgm-1* gene frequencies and proportion of soft part weight (SP) per whole body weight (BW) among cultured lots of abalone in comparison with what was observed among natural

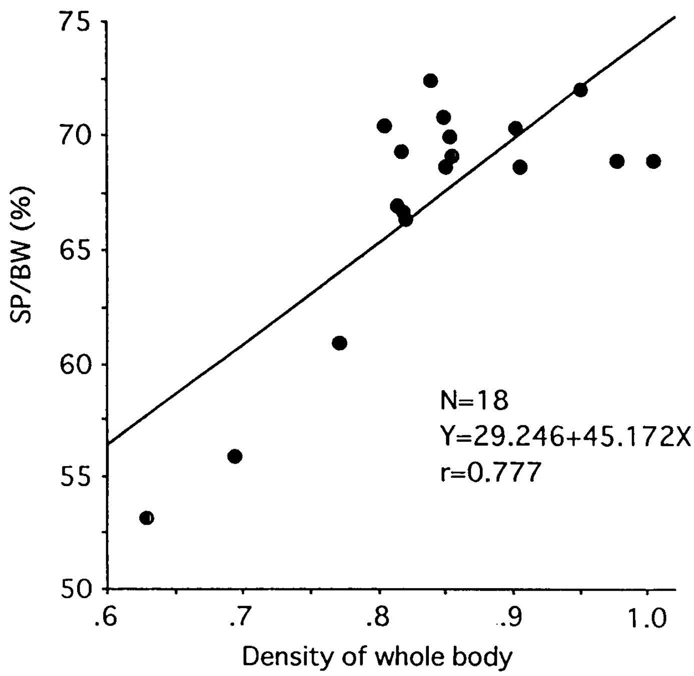


FIG. 1. Correlation between the whole body density and the value of SP/BW in the cultured lots of the Pacific abalone.

population. It suggests genetic variation which depends on the number of loci controlling variation of quantitative characters. In this study, significant correlation between the SP/BW and the density of whole body was observed in cultured population (Fig. 1). This indicates that genetic variation for the whole body density depends on the number of loci controlling variation of the trait.

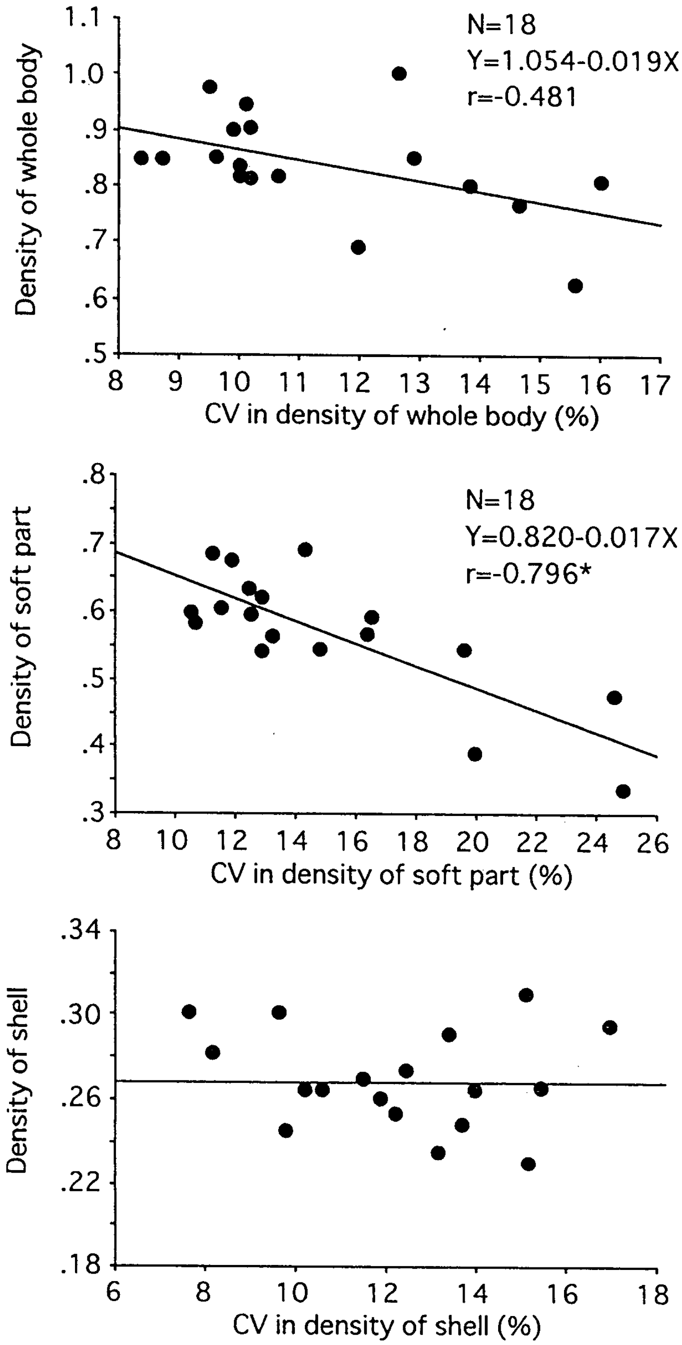


FIG. 2. Correlation between the mean value and the coefficient of variation (CV) in the density of whole body, soft body, and shell.

Correlation between the mean density of whole body and soft part and the coefficient of their variance (CV) was observed in cultured lots (Fig. 2). Similar correlation has been reported in SP/BW of the Pacific abalone (1). This indicates that variance is small in lots with high mean values, but it is large in lots with low mean values. Fujio *et al.* (3) revealed homozygote excess in some natural Pacific abalone populations using starch gel electrophoresis to study variation at 19 isozyme loci, and reported that populations showing high homozygote excess also tended to show a wide range in SP/BW. These results are interpreted as being a reflection of the effect of both harmful and advantageous genes in the homozygous state of the inbreeding population.

On the other hand, correlation between the mean density of the shell and its coefficient of variance was not observed in cultured lots (Fig. 2). From non-correlation in the density of the shell, higher variance within cultured lots was caused by the occurrence of the individuals showing low density of soft part.

In conclusion, fluctuation in the density of soft part might be caused by high genetic variation in the density of soft part, and low density might be controlled by, at least, one major deleterious gene.

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