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Relationships of vertebral deformity with genetic variation and heterosis in the guppy *Poecilia reticulata*

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Abstract

The present study examined relationships of vertebral deformity with genetic variation and heterosis in the guppy *Poecilia reticulata*. Vertebral deformed rate varied from 7.3% to 30.6% in nine guppy strains, and negatively correlated with mean heterozygosity at microsatellite and allozyme loci. The regression line indicated that vertebral deformity increases at a rate of 12.2% per 10% decrease of heterozygosity. Since the significant correlation was observed among the genetically differentiated strains, overall heterozygosity may be important for vertebral normality. In a cross between strains, the F_1 hybrids showed significantly higher vertebral normality than mid-parent value, indicating heterosis on vertebral normality. Only one of three vertebral deformed types was revealed to show correlation with heterozygosity and heterosis. These results indicate that vertebral deformity is strongly affected by heterozygosity and heterosis in the guppy and the sensitivity differ among the deformed types.

Keywords: Heterosis; Inbreeding depression; Heterozygosity; Vertebral deformity; Guppy

1. Introduction

Inbreeding depression and heterosis are related phenomena of fundamental importance to applied genetics and conservation and evolutionary biology. The phenomena of inbreeding depression and its antithesis, heterosis, have been observed for various fitness-related traits in a variety of organisms (Falconer and Mackay, 1996). Developmental homeostasis is the ability of an organism to maintain a stable development that will produce the fittest phenotype. Although inbreeding depression and heterosis are particularly observed in life-history traits relative to morphological traits (Falconer and Mackay, 1996), several studies have found

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evidence for increasing developmental instability with inbreeding, using individuals or populations varying in heterozygosity (Leary et al., 1983, 1984; Alibert et al., 1994) or comparisons of inbred lines with their F_1 hybrids (Mather, 1953; Beardmore, 1960; Reeve, 1960). However, others have failed to find such a relationship (Clarke, 1992; Fowler and Whitlock, 1994; Sheridan and Pomiankowski, 1997; Gilligan et al., 2000; Hosken et al., 2000; Carchini et al., 2001).

Many studies have examined developmental instability estimated by the degree of fluctuating asymmetry, the difference between the right and left side of a bilateral trait. In a meta-analysis of published data, Vøllestad et al. (1999) found only a weak association between fluctuating asymmetry and heterozygosity, indicating that heterozygosity seems to explain only a very small amount of the variation in fluctuating asymmetry among individuals and populations. As it has been shown that vertebral deformed individuals had significantly higher fluctuating asymmetry than non-deformed individuals (Leary et al., 1984), vertebral deformity might be more sensitive to inbreeding and be more suitable to examine relationships between developmental homeostasis and heterozygosity.

Genetic effects on developmental instability will be clearer under controlled conditions where environmental variation can be minimized, because morphological traits can be affected by both genetic and environmental factors. As a model organism for genetic analysis, the guppy *Poecilia reticulata* is one of the most useful teleosts because of its short life cycle, ease of breeding and establishment of populations in a laboratory, and the availability of many strains (Macaranas and Fujio, 1987, 1990; Barinova et al., 1997a; Shikano and Fujio, 1997). These strains have various kinships and various characteristics in terms of morphological and physiological traits (Macaranas and Fujio, 1987, 1990; Kanda et al., 1991; Shikano and Fujio, 1994).

To elucidate the relationship between vertebral deformity and heterozygosity, the present study examined strain differences in vertebral deformity and its relationship to heterozygosity among nine strains of the guppy. In addition, heterosis for vertebral normality was examined using crosses between strains.

2. Materials and methods

2.1. Animals

Nine domestic strains, S, S3, S3HR, SC, F22, D, D1, B and C, were used in this study. These strains had been maintained as closed colonies since 1975 to 1991, and characterized by body colours, colour patterns and fin shapes. Each strain was maintained in a 60-l aquarium as a closed colony with a density of 200–300 individuals. Further description of guppy strains, and how they were produced and maintained, has been given in previous papers (Macaranas and Fujio, 1987; Barinova et al., 1997a).

2.2. Cross between strains

A reciprocal cross was performed between the S3HR and F22 strains. Immature fish were randomly taken from the parental stocks and reared in 2.5-l aquaria in order to obtain virgin females for crossing. Each virgin female was mated with a male randomly taken from the stock in a 2.5-l aquarium to produce F_1. The F_1 were reared in 2.5-l aquaria for more than 60 days, until fish matured. The F_1 hybrids were designated by letters indicating the female parent followed by the male parent.

2.3. Maintenance conditions

The laboratory for breeding experiments of guppies was maintained at a temperature of 23 ± 1 °C (mean±range) using an air conditioner with lighting for 10 h per day. All breeding experiments were performed in this laboratory. All fish were fed twice daily with ground carp pellets and dried *Daphnia* as a supplementary diet.

2.4. Observation of vertebra

Vertebra was observed using alizarin staining. Mature fish, more than 60 days from birth, were randomly taken from each stock. Fish were fixed with 95% ethanol, and then the internal organs were removed. After fixation, the specimens were put into 1% potassium hydroxide until muscles became transparent. The specimens were stained with 0.01% alizarin S for 16 h. Decolourization was performed