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NUCLEAR POLLUTION AND GYNANDROMORPHIC BUTTERFLIES IN SOUTHERN RUSSIA

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ABSTRACT.– An unusual population of the lycaenid butterfly, *Meleageria daphnis* (Lepidoptera: Lycaenidae), is found in the Kislovodsk area (43.8°N lat., 42.7°E long.) of southern Russia; 60% of the observed females in the adult population have been partial gynandromorphs or sexual mosaics during the period of 1988 to 1993. This site is within 30 km of the center of the refining area where uranium was processed for the first Soviet atomic bombs, and is also within the southeastern boundary (extent as of 2 May 1986) of the cloud of radiation released from the Chernobyl disaster on 26 April 1986. The situation may reflect a high level of radiation-induced somatic mutations or a genetic alteration in the Y-chromosome carried by most of the females in the population.

KEY WORDS: *Agrodiaetus*, gynandromorph, Leguminosae, Lycaenidae, *Meleageria*, nuclear pollution, *Pseudophilotes*, sexual mosaic, somatic mutations.

The lycaenid butterfly *Meleageria daphnis daphnis* ([Denis & Schiffermüller]), occurs through Europe to the Ural Mountains, with several subspecies (Nekrutenko, 1990; Tuzov, 1993). This species is sexually dimorphic, with the males being bright blue in coloration and females being dark brown. Usually, a few females with patches of blue are found in each population. These are more common in the western part of the distribution area. This coloration is determined by the presence of structurally refractive "blue" scales which otherwise match the pigmented brown scales. However, at a site in the Kislovodsk area near Piatigorsk, a town east of the Black Sea in southern Russia, a population of *M. daphnis* was discovered in 1988 which had quite different characteristics. This site is in the northern foothills of the Great Caucasus with secondary forest and chalkstone steppes. Sampling carried out in subsequent years showed that there was a remarkable number of sexual mosaics or partial gynandromorphs in this population. A large sample of 150 specimens taken during the flight season in 1993 consisted of 120 females and 30 males. Fully 60% of the observed females were phenotypically gynandromorphs or sexual mosaics (Fig. 1-2).

The behavior of gynandromorph females was unusual for this species. When males were patrolling, feeding and mating as normal, gynandromorph females were observed only sitting passively on the grass, sometimes in copula with males. It was possible to pick them up with the fingers from the grass. No feeding or ovipositing behavior was observed in these females and there was no significant difference in the activity of the females during the course of the day.

Extensive sampling carried out in 1992 and 1993 showed that this population flies, like other ones, in a single generation during July-August and is associated with *Coronilla varia* L. (Leguminosae) as a foodplant. Males emerge starting approximately 2 weeks before any female. Then gynandromorphic females emerge about 1 week prior to normal females. Hence virtually all freshly emerged partially gynandromorphic females are promptly mated by waiting mature males; normally, then, differential mate selection between gynandromorphic (sexually mosaic) and normal females is minimal.

DISCUSSION AND POSSIBLE EXPLANATIONS

In these lycaenid butterflies, as in all Lepidoptera, males are the homogametic sex (XX) and females are heterogametic (XY). Gynandromorphs in butterflies and moths (e.g., see Davis, 1994 for an excellent discussion) may result from one of two primary mechanisms: (1) a loss of an X chromosome during one of the early cleavage divisions or (2) the simultaneous fertilization of a binucleate egg (Robinson, 1971). The latter scenario would not apply here, since few or no specimens are demonstrably perfect bilateral gynandromorphs (e.g., with half male and half female genitalia). Such bilateral gynandromprhs with defective genitalia could not mate or reproduce, of course. The simplest hypothesis for loss of a sex chromosome either in the formation of a bilateral or less-dramatic, sexual-mosaic gynandromorph is that of irregular disjunction of a Y chromosome shortly after fertilization, resulting in two developmental lineages, one of XX genotype (male) and the other X alone (female). In the *Meleageria* case, it is more accurate to refer to the abnormal females as sexual mosaics. Here, the gynandromorph is expressed in switches of portions of the wing, ranging from transformation of nearly the whole wing surface to transformation of small patches of only a few scales,

Fig. 1. Normal male phenotype (top specimen) and three sexual mosaic females, from a nearly perfectly bilateral gynandromorph to a slightly marked sexual mosaic, of the lycaenid butterfly *Meleageria daphnis* from Kislovodsk, Russia (collected in 1992 by A. V. Dantchenko).

Fig. 2. An enlarged view of a nearly perfectly bilateral gynandromorph from the *Meleageria daphnis* population at Kislovodsk, Russia, with the left side female and the right side male.

probably resulting from transformations occurring at many different times in development of the wing. Each patch would then represent a clone of individually mutated cells (Nijhout, 1991). Thus the wings of these butterflies resemble the pattern of somatic mutations caused in leaves and mammal coat colors, to name but two examples, by radiation or other somatic mutagenic agents.

If this last assumption is correct, then one of two other mechanisms could pertain: (3) independent somatic mutations occurring continually in individual developing-adult wing cells in pupae exposed to a high background radiation, or (4) a germ-cell-line mutation occurring in the female-producing gene/s located on the Y chromosome, which now suppresses femaleness and allows male scaling to develop from those cells. In the last case, such a mutation in egg-cell DNA could have occurred once and been passed to offspring for the observed number of years, except that it would likely affect genitalia, behavior, and physiology, and make a less viable adult. Under those circumstances, the abnormality ought to to be eliminated by natural selection. Since it persists at such a high level in the population over many years, and since normal flight behavior and oviposition activity is reduced or nearly absent in gynandromorphic females, the most parsimonious explanation is number (3), independent somatic mutations occurring due to an extraordinary mutagenic environment. Exposure probably occurs during a short critical period during mitotic division at the wing-pad stage of adult development in the pupa, with somatic mutations later becoming visible as wing scale patches in the emerged adult.

In searching for an explanation of this extraordinary population, we note several possibly contributing factors. The nearest town, Piategorsk, was the source of uranium for the first atomic bomb development in the Soviet Union, and safety precautions at the time were minimal in terms of distribution of waste products from this site, both on the surface and in the air. Second, this site was the southern boundary (Netschert, 1987) of the spread of the cloud of radioactive materials, including plutonium and cesium, generated in the Soviet Ukraine by the Chernobyl nuclear power plant disaster on 26 April 1986. However, such gynandromorphic populations of *Meleageria daphnis* have not been found in other locations exposed to extensive Chernobyl fallout. Additionally, the fact that the presence of gynandromorphs at this high frequency has been essentially stable over a six-year period suggests that the phenomenon at Kislovodsk may predate the Chernobyl disaster and thus more likely could be related to high background radiation dating from contamination starting perhaps in the late 1940's.

Butterfly collecting was conducted in this area before 1940 and resulted in the description of a few taxa, such as *Agrodiaetus ciscaucasica* Forster, 1956. Several well-known Russian entomologists, such as L. A. Sheljuzhko, V. V. Sovinsky, and others were working in exactly this area and collecting butterflies in this locality. However, the gynandromorph population was never mentioned by any of them, and no abnormal specimens were found subsequently in their collections. We can reasonably conclude that the appearance of the gynandromorph population happened in the 1940's, when the last collecting in this locality before 1988 took place. This population is not the only unusual occurrence of altered butterflies in the region. V. Lukhtanov (pers. comm.) reports that he collected a specimen of *Pseudophilotes vicrama* (Moore) (Lycaenidae), normally tailless, but with small tails on the hindwings in this specimen.

If the triggering of this mutational phenomenon was or is being caused by radiation resulting from buried nuclear waste in the area or by other anthropogenic mutational factors, it will be difficult to verify, as such nuclear-related information is still considered secret in Russia and radiation testing and measurement at the site by independent observers would be difficult to achieve at present. It would be particularly interesting to examine the karyotypes of populations of this species in the Kislovodsk area and the rest of its distribution, as has been done in other Palearctic lycaenids (e.g., Lukhtanov, 1989). We suggest that elevated frequencies of unusual wing phenotypes of butterflies in well-studied species in various parts of the world could reflect the presence of mutagenic agents derived from human activities, and might provide a sensitive barometer to the presence of such factors and prompt their subsequent investigation.

In this particular case, the question arises whether the mutation has occurred only once, and if so then how long will the present balance in this abnormal gynandromphic population last? If the mutation factor is constantly present, then the question becomes: What is this factor and what is its possible effect on the other life forms in this area? In either event, intensive study of this extremely strange population is required, including study of all stages of development.

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