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High frequency of albinism and tumours in free-living birds around Chernobyl

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ABSTRACT

The effects of radioactive contamination on the phenotype of free-living organisms are poorly understood, mainly because of the difficulty of capturing the large numbers of individual specimens that are required to quantify rare events such as albinism and tumour formation. We hypothesized that the frequency of abnormalities like albinism and the frequency of radiation-induced diseases like cancer would increase with the level of background radiation, that the two markers of radiation would be positively correlated, and that the reduction in abundance of animals would be greater in species with a higher frequency of albinism and tumour formation, if these markers reliably reflected poor viability. Here we analyzed the frequency of albinistic feathers and tumours in a sample of 1669 birds captured during 2010–2012 at eight sites around Chernobyl that varied in level of background radiation from 0.02 to more than 200 μSv/h. We recorded 111 cases of partial albinism and 25 cases of tumour formation. Nominal logistic models were used to partition the variance into components due to species and background radiation. Radiation was a strong predictor of the two markers in birds, with a small, but significant effect of species for albinism. The slope of the relationship between abundance and radiation in different bird species was significantly inversely correlated with the frequency of albinism and tumours, as was to be expected if a common underlying cause (i.e. radiation) affects both variables. These findings are consistent with the hypothesis that background radiation is a cause of albinism and tumours, that albinism and tumours are biomarkers of radiation exposure, and that high frequencies of albinism and tumours were present despite the low viability of birds with these conditions.

1. Introduction

Radioactive contamination is known to increase mutation rates with significant effects on phenotype [1,2]. A recent review suggests that natural populations may be almost an order of magnitude more sensitive to ionizing radiation than previously predicted by laboratory models [3], implying that natural variation in background radiation [4], but also low-dose radioactive contamination from Chernobyl and other nuclear accidents may cause significant changes in the appearance of animals and other organisms [2]. Abnormalities are disproportionately frequent in radioactively contaminated areas [2,5–10]. For example, for barn swallows *Hirundo rustica* from Chernobyl, Møller [7] reported abnormal barbs in feathers, which prevented these feathers from fusing normally. This novel condition was associated with a significant delay in reproduction, suggesting that the condition had significant fitness costs. Likewise Hesse-Honegger and Walliman [10] observed elevated levels of abnormalities in bugs from contaminated areas, including the vicinity nuclear power plants. We have documented this abnormality in several bird species in 2012, more than 25 years after the Chernobyl disaster. Furthermore, Møller et al. [8] reported elevated frequencies of ten different kinds of abnormalities in barn swallows from Chernobyl compared with frequencies in four local and more distant control populations. These abnormalities included changes in patterns of colouration, morphology and shape of feathers, and malformed or missing digits, beaks and eyes. Such abnormalities were rare or completely absent in control populations despite very large sample sizes, nor have they been described in the extensive literature on this species anywhere throughout its range [8,9].

Albinism, the result of absence of melanin pigments from tissue, occurs with a frequency that is typically extremely low in free-living organisms (*e.g.*, [11,12]). In particular small and inbred populations show an increased frequency of albinism in accordance with the expectation that albinism is caused by a recessive allele [13–17]. Barn swallows from around Chernobyl show a highly elevated frequency of partial albinism reaching 13–15%. This albinism is of germ-line origin as determined from a significant parent-offspring resemblance, and barn swallows with this condition

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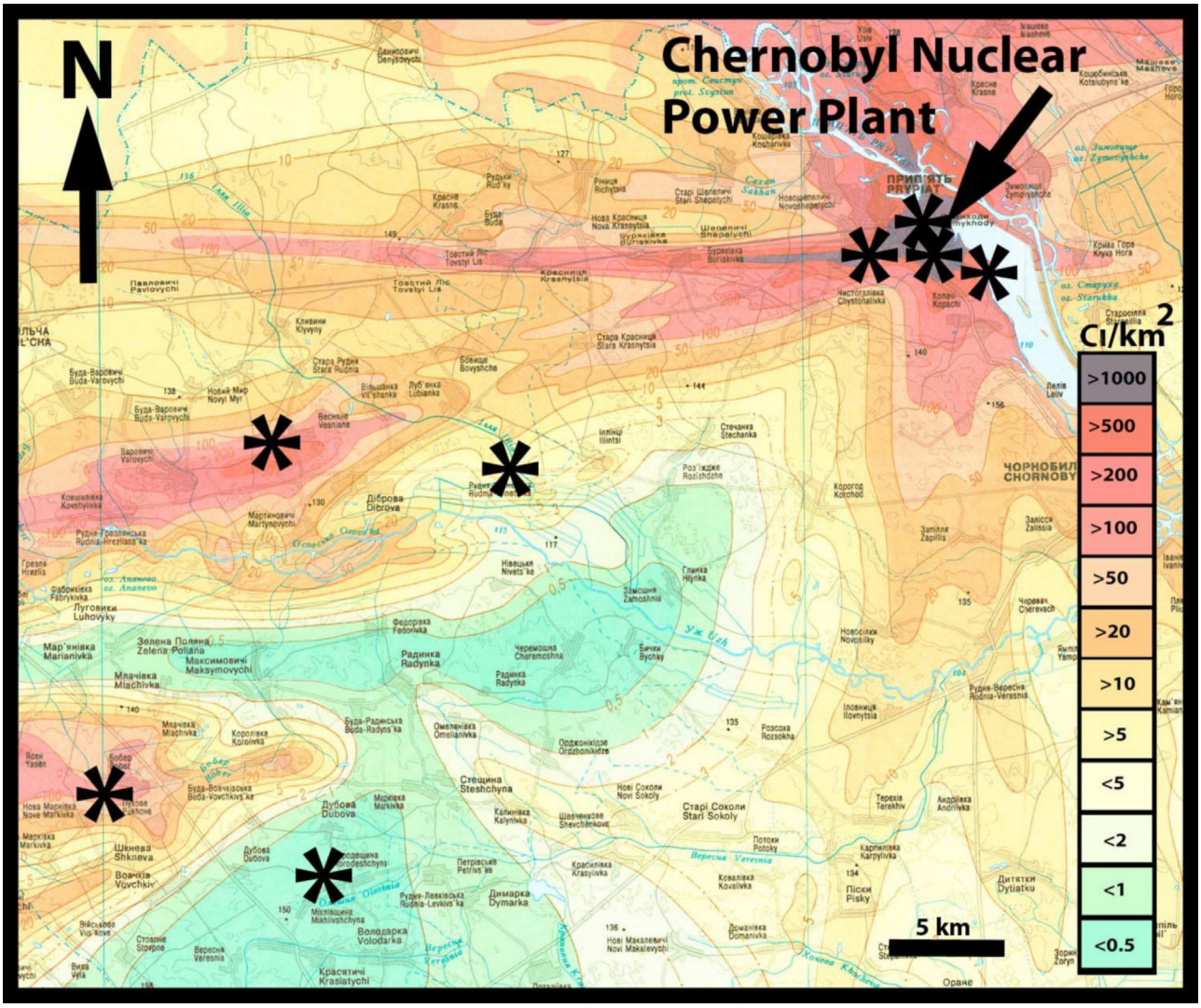

Fig. 1. Location of the eight study sites in relation to background radiation level (Cu/km^2) around Chernobyl, Ukraine.

suffer from reduced survival prospects [18]. This was also found in another study of birds [19]. A disproportionate fraction of partial albinism in the barn swallow occurs in the facial red plumage, but hardly any is seen in the dark blue plumage of the neck, back, wings and tail [20,21]. Individual barn swallows with partially albinistic plumage had on average lower mean phenotypic values than other individuals [21], as also reported for the hooded crow, another bird species [19].

A fraction of invasive cancers in humans is caused by radiation exposure, which includes non-ionizing radiation and in particular ionizing radiation (*e.g.*, [22,23]). Natural variation in background radiation due to radon and other radioactive elements has a significant impact on the incidence of cancer in humans [4,24]. The incidence of all cancers caused by ionizing radiation increases with effective dose [25]. Many kinds of cancer often take a long time to develop (i.e. they have a long latency period), implying that long-term effects on cancer incidence from radioactive contamination from Chernobyl are not yet detectable. Serdiuk et al. [26] and Cardis and Hatch [27] reviewed the extensive evidence for other cancers being linked to radiation due to the Chernobyl catastrophe. However, next to no information exists on cancers in free-living vertebrates, although their short generation time would provide insights into long-term effects that cannot yet be studied in humans (Fig. 1).

The objectives of this study were to determine (1) the relationship between the incidence of albinism and tumours, respectively, and background radiation, using a large database of free-living birds captured around Chernobyl during 2010–2012. In other words, we intended to assess the reliability of the rate of albinism and the incidence of tumours as biomarkers of species decline due to radiation exposure. Because the lifespan of most free-living animals with abnormalities is short [8,18,21] due to elevated risk of predation, field estimates of prevalence of abnormalities are by definition conservative. If mortality related to abnormalities tumours were a major cause of disappearance of individual animals from free-living populations, we should expect that a smaller number of individuals remained in contaminated areas in species with a high frequency of abnormalities. Therefore, the second objective of this study was (2) to investigate the relationship between the slope of the relationship between abundance and background radiation for different species of birds and the relative frequency of albinism and tumours.

2. Materials and methods

2.1. Study areas

We captured birds in mist nets at eight sites around Chernobyl in the period 25 May–5 June during the years 2010–2012 [28,29]. We used a total of 35–45 mist