

## Birds: flying air filters

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The Horned Lark (*Eremophila alpestris*) [1] is a small migratory bird with a melancholic song. It has a white belly and a yellowish throat (Figure 1A). More than a hundred years ago in the United States, at the height of urban smoke pollution, this bird's pale feathers were stained with dark grey. In fact, ornithologists have long observed that bird specimens in the collections of natural history museums dating from the late 19<sup>th</sup> or early 20<sup>th</sup> century were darker than those currently found in nature. Without absolute proof, they implicated atmospheric soot, made up of microparticles of black carbon present in the air (see [Air pollution](#)).

In a recent study [2], two American researchers - a biologist and an art history specialist - analyzed more than a thousand birds stored in museums such as the *Field Museum* in Chicago, the *Carnegie Museum of Natural History* in Pittsburgh and the *University of Michigan Museum of Zoology* in Ann Arbor. They had been collected over the last 135 years in a region with a dense industry that was historically dependent on coal. Over time, this region has been called the *Rust Belt* or *Manufacturing Belt*. It covers part of the northeastern United States and extends from Chicago to the Atlantic coast along the Great Lakes and the Canadian border.

The birds studied had a particularity: they developed a new set of feathers every year. Thus, the lark's moult sometimes starts in June and ends between mid-September and early October. It is thus certain that the plumage of the birds in the museum collections is that of the year preceding their harvest. From the first observation, a general trend was apparent: older birds were "dirtier" than more recently harvested birds.

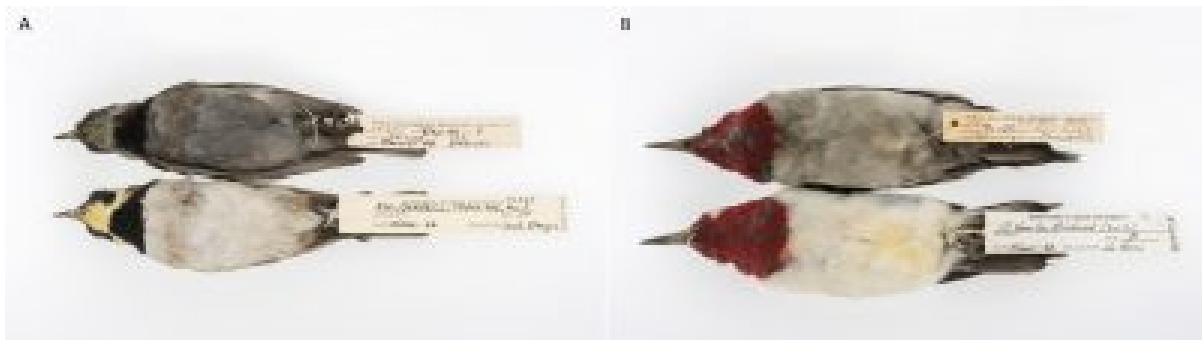


Figure 1. A. Horned lark harvested in 1904 (top) and 1966 (bottom). B. Red-headed Woodpecker harvested in 1901 (top) and 1982 (bottom). [Source: The Field Museum ; Photo © Carl Fuldner & Shane DuBay].

To measure the evolution of this coloration over time, the researchers implemented a photographic approach measuring the light reflected by the plumage. A total of 1347 birds were studied. They represented 5 different bird species [3] that lived in the *Rust Belt* region and were collected between 1880 and 2015. The images, representing the contrast between grey, soiled birds and clean white birds, are spectacular (Figure 1). Scanning microscopy analysis shows the presence of many aggregates of carbon-containing particles on the plumage of birds harvested in the early 20<sup>th</sup> century. These aggregates are no longer visible on samples taken at the end of the 20<sup>th</sup> century.

The researchers then examined the social history of urban air pollution in the areas where the birds were harvested. Changes in bird colour reflect changes in air pollution levels due to industrial activity (Figure 2):



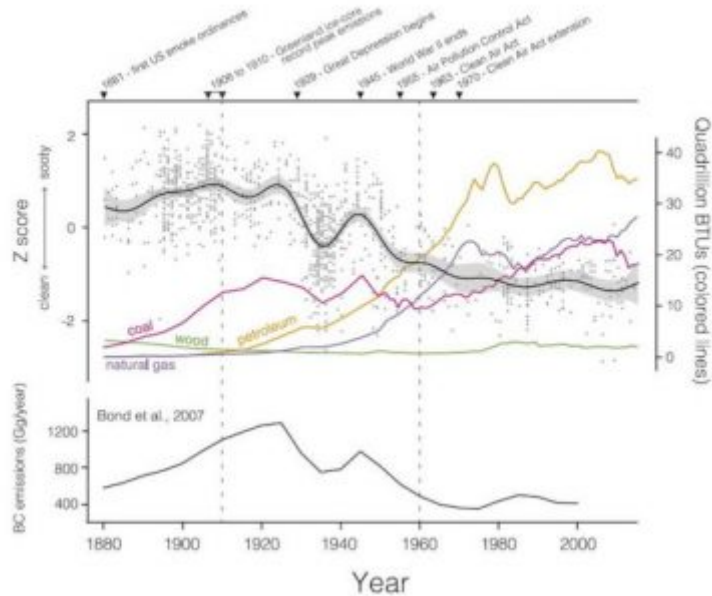


Figure 2. Deposition of black carbon on specimens of birds in the Factory Belt, collected between 1880 and 2015. Each point represents the standard deviation (z-score) of an individual specimen, based on the inverse raw reflectance value derived from the feathers of the chest and belly. The upper black line represents the average of these values (in grey, the 95% confidence limit). The coloured lines are consumption trends for the various fuels expressed in British Thermal Units (BTUs). In 1910 (dotted line) there was a gradual change in cities within the factory belt due to the impact of environmental protection policies. It is estimated that in 1960 (dotted line) the decoupling between carbon emissions into the atmosphere and coal consumption began. [Source: © Carl Fuldner & Shane DuBay]

From 1880 to 1920, the level of pollution was particularly high, with a peak at the beginning of the 20<sup>th</sup> century. Throughout this period, black carbon emissions increased steadily: efforts to improve air quality only began to bear (modestly) fruit after 1910. In fact, the observations are correlated by the study of Greenland ice [4] which shows a carbon peak between 1906 and 1910.

- During the *Great Depression* (1929), the sharp decline in black carbon on birds was due to the fact that coal consumption fell sharply for economic reasons.
- The amount of soot on bird plumage rises significantly around the *Second World War* (maximum in 1945), in parallel with the increase in industrial activity in wartime that led to the massive use of coal.
- Soot levels dropped quickly after the war, when people in the *Rust Belt* began heating their homes with natural gas from the West instead of coal.
- Despite the significant increase in coal consumption during the second half of the 20<sup>th</sup> century, the level of air pollution by black carbon has been steadily decreasing, reflecting the positive impact of environmental protection policies.

This study shows the value of natural history museum collections in placing current environmental concerns in a historical perspective.

The fact that newer birds are cleaner does not mean, however, that there is no longer a problem: the many other pollutants released into our atmosphere are simply not as visible as the soot of the 19<sup>th</sup> century. However, the level of pollution from microparticles - due to, for example, wood heating or car traffic - remains very high in many parts of the world.

Simply put, the clogged air filter represented by the blackened plumage of birds gives a spectacular picture of the condition of our lungs as a filter. Throughout the world, many people still suffer from air polluted by fine particles, both in urban and rural areas.

Thanks to Carl Fuldner & Shane DuBay for their invaluable help in preparing this text.

**To remember**

- Birds held in the collections of various American natural history museums have been used to monitor the evolution of sooty air pollution over the past 135 years.
- In polluted areas, their plumage acted as an air filter and accumulated black carbon particles.

- The observations correlate the presence of carbon black on the plumage with the level of pollution during specimen collection. They show that the level of black carbon pollution in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries has been underestimated in previous studies.
  - This study highlights the value of natural history collections as a resource for addressing current environmental challenges.
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## References and notes

[1] <https://inpn.mnhn.fr/docs/cahab/fiches/Alouette-hausse-col.pdf>

[2] DuBay S.G. & Fulner C.C. (2017) *Bird specimens track 135 years of atmospheric black carbon and environmental policy*. Proc. Natl. Acad. Sci. USA. , October 9, 2017 DOI: 10.1073/pnas.1710239114

[3] Field sparrow (*Spizella pusilla pusilla*), Grasshopper sparrow (*Ammodramus savannarum pratensis*), Red-sided Tobi (*Pipilo erythrophthalmus erythrophthalmus*), Horned lark (*Eremophila alpestris pratensis*), & Red-headed woodpecker (*Melanerpes erythrocephalus*).

[4] McConnell JR, et al (2007) *20<sup>th</sup>-century industrial black carbon emissions altered arctic climate forcing*. Science 317:1381-1384.

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