Do songbirds store calcium in their legs?

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During egg laying, birds must mobilize large amounts of fat, protein and minerals, especially calcium, for the formation of their eggs. Of these three, calcium has been the least well studied. Observations on chickens and pigeons have suggested that the formation of large amounts of "medullary bone" in hollow spaces in the interiors of their leg bones could serve as a store of easily mobilized calcium to provide the large amounts of calcium required for egg shell formation [1,2]. These have apparently never been any studies of the development of medullary bone in laying passerine birds.

There are thought to be two basic strategies of resource use in birds preparing for reproduction: those that accumulate resources over a long period prior to reproduction, storing essential resources in somatic "bank accounts" for later reproduction. These so-called "capital" breeders can be contrasted with "income" breeders which do not store resources but lay eggs on resources that are ingested very shortly before egg laying. Great understanding of which of these strategies are pursued by songbirds have become of more than basic interest in recent years, as increasing evidence is accumulating to indicate that reproductive success in some songbirds can be linked to decreases in calcium availability due to part to the effects of acid rain.

For the past year, we have been studying the structure of the leg bones of songbirds to see whether these birds are best interpreted as income or capital breeders with regards to their calcium metabolism. In a series of experiments on leg from passerine birds we have generated x-ray images that indicate the potential for quantifying calcium stores in live birds without harming them. The leg bones of these birds are tiny (see Fig. 1, about 14 mm long and 1.5 mm in diameter) and contain about 60% minerals, 38% of which are calcium, other components are fat, collagen, and water. The challenge has been to visualize the interiors of the bones with sufficient clarity to measure the differential development of calcium deposits within them [3].

The experiments were carried out at CHESS beamline D3 using x-rays at 12 keV (Fig. 2). We used an asymmetrically cut X-220 monochromator to obtain a beam with a large cross-section and high energy resolution (2E/2E (E)). Radiographs of the bone samples were stored on Kodak high resolution x-ray film. In order to allow for computerized data analysis the recorded information was digitized with a film scanner. The spatial resolution obtained through this process is 9 μm. The use of the synchrotron radiation (SR) at CHESS offers several advantages. The collimation and the monochromatization of the SR eliminate distortions present in images made with conventional x-ray sources providing higher spatial contrast and improved sensitivity for chemical elements. Most important here, the monochromativity reduces the radiation dose to the specimen and the high intensity of the beam (approx. 10¹⁰ photons/sec) allows for short exposure times (less than 0.5 sec.

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In one experiment, we measured the density and internal structure of the leg bones of three swallow species (Hirundo rustica, Fig. 1) before and after egg laying. We captured females in their nests before they laid any eggs, and took detailed radiographs of their leg bones. Immediately after they completed their clutches, we captured the same females again, thus allowing us to compare the thickness, structure, and density of their leg bones both before and immediately after laying. Clearly, bird breeders would be expected to exhibit lower amounts of calcium in the bone prior to laying and some evidence that these calcium stores were depleted by laying. In the three species, we found no evidence of such a change. The bones of females before and after laying were indistinguishable.

To test the robustness of this pattern, we then measured the femora of the three species (Hirundo rustica, Fig. 1) before and after egg laying. We captured females in their nests before they laid any eggs, and took detailed radiographs of their leg bones. Immediately after they completed their clutches, we captured the same females again, thus allowing us to compare the thickness, structure, and density of their leg bones both before and immediately after laying. Clearly, bird breeders would be expected to exhibit lower amounts of calcium in the bone prior to laying and some evidence that these calcium stores were depleted by laying. In the three species, we found no evidence of such a change. The bones of females before and after laying were indistinguishable.

In summary, the high resolution radiography made possible by CRHES has allowed us to determine with a high degree of certainty that songbirds are not capital breeders. Rather, these birds must store the production of egg shells on their islands of calcium over short time periods before and during the laying of a clutch. Thus, these species become very sensitive to any environmental changes, such as acid rain or chemical poisoning of water. The decrease in availability of crucial minerals is likely to have direct and immediate impact on the reproduction of these birds.