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CARBONATE DEPOSITION ON TAIL FEATHERS OF RUDDY DUCKS USING EVAPORATION PONDS[1]

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Abstract. Substantial carbonate deposits were observed on rectrices of Ruddy Ducks (*Oxyura jamaicensis*) collected during 1982–1984 on evaporation ponds in the San Joaquin Valley, California. Carbonate deposits were composed of about 75% aragonite and 25% calcite, both polymorphous forms of $CaCO_3$. Significantly more carbonate deposits were observed on Ruddy Ducks as length of exposure to agricultural drain water increased, during the 1983–1984 field season when salt concentrations in the ponds were higher, and in certain evaporation-pond systems.

Key words: Carbonate deposits; evaporation ponds; rectrices; Ruddy Ducks; San Joaquin Valley; waterfowl.

INTRODUCTION

The Central Valley of California once contained about 1,620,000 ha of wetlands that supported large concentrations of water birds (U.S. Fish and Wildlife Service 1978). Most of the valley, including nearly all of the Tulare Lake Basin, has been converted to agricultural production. The arid climate requires irrigation of cropland but poor natural drainage necessitates subsurface drainage of irrigation water to prevent excessive accumulation of salts in upper soil profiles. This subsurface drain water often contains toxic concentrations of environmental contaminants as well as salts (Presser and Barnes 1985) and cannot be discharged into watercourses in the Tulare Lake Basin. Presently, the sole means of disposing of agricultural drain water in the Tulare Basin is by evaporation in shallow ponds. Wetland loss in the Tulare Lake Basin has been severe (Tiner 1984, Jones and Stokes Assoc. 1988) and the proliferation of drain-water evaporation ponds is important to water birds. We collected waterfowl as part of an investigation of the quality of these drain-water ponds as habitat for wintering waterfowl. Many of the Ruddy Ducks (*Oxyura jamaicensis*) we collected had tail feathers encrusted with a whitish mineral deposit. Objectives of this paper are to report the chemical composition of this encrustation and to discuss factors that may cause its deposition.

Our study was conducted on three evaporation-pond systems built in 1980 and operated by the Tulare Lake Drainage District (TLDD) in Kings and Kern counties, California. Each pond system consisted of several interconnected cells with 10 cells in one system and four in each of the others. Ponds (cells) averaged about 65 ha in size and were typically shallow (< 1 m) with gradually sloping sides and flat bottoms. Water flow within a pond system was unidirectional with no outflow from terminal ponds. Conductivity of drain water entering the pond systems was about 5–10 mS/cm, but increased steadily in successive ponds due to evaporation, and frequently exceeded 300 mS/cm in terminal ponds. For comparison, seawater is approximately 54 mS/cm at 25°C.

METHODS

Ducks were shot on evaporation ponds from September through March, 1982–1983 and 1983–1984. Birds were weighed to the nearest gram, sex and age were determined by wing-plumage characteristics (Carney 1964), and rectrices were examined for deposits. Standard X-ray diffraction analysis (Nuffield 1966) was used to identify chemical species forming the deposits. A linear model ANOVA was performed using a General Linear Models Procedure (SAS Institute 1985). This procedure expressed presence or absence of

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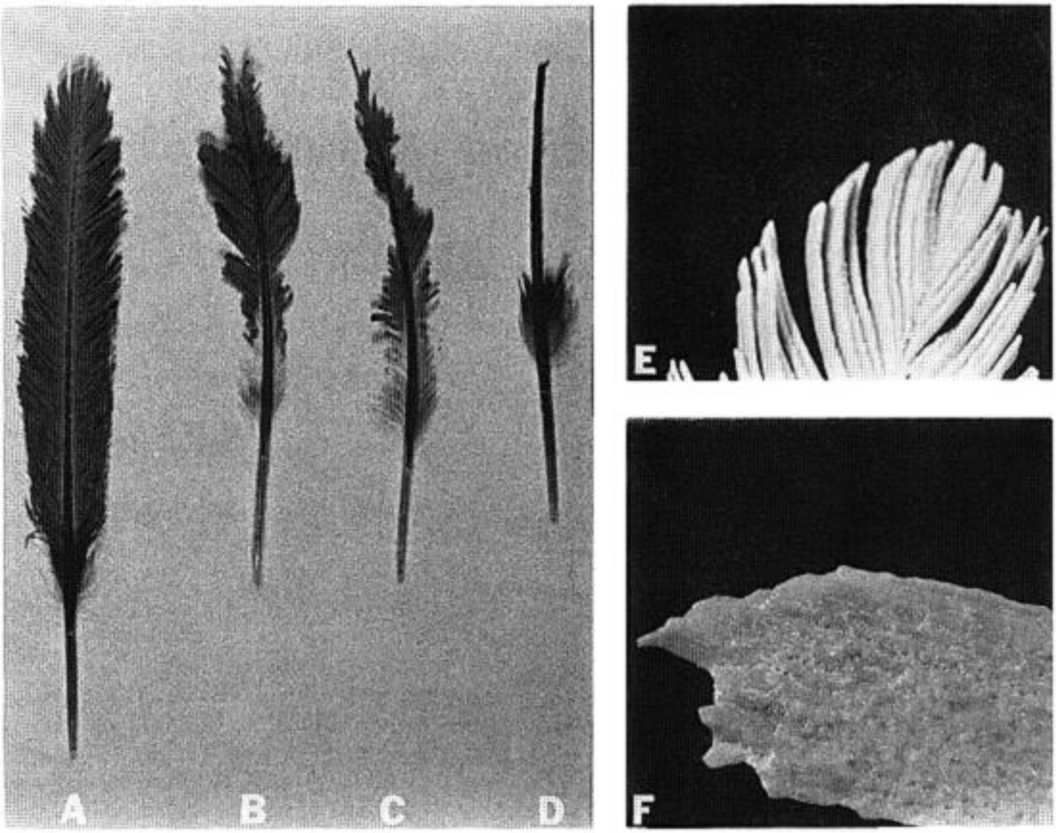

FIGURE 1. Erosion of Ruddy Duck rectrices resulting from carbonate deposits. A general pattern of feather erosion (a–d), a close-up of the tip of an affected rectrix (e), and a heavily plated area where several feather barbs are united (f).

deposits as a function of explanatory variables: year, month, age, sex, weight of birds, and pond system. A two-stage weighted least squares method (Neter and Wasserman 1974, p. 326–328) was used to compensate for unequal variances. Chi-square analysis was used to evaluate yearly differences in the presence or absence of deposits (Siegel 1956).

RESULTS

The number of Ruddy Ducks with deposits on their rectrices increased significantly ($\chi^2 = 8.846$, df $= 1$, $P < 0.003$) from 5% ($n = 110$) in 1982–1983 to 18% ($n = 139$) in 1983–1984. The increase likely resulted because the drain water was more saline in 1983–1984 ($\bar{x} = 50$ mS/cm) than in 1982–1983 ($\bar{x} = 37$ mS/cm) (TLDD, unpubl. data). Because most of our records of deposits were from the 1983–1984 field season, only those data were used to examine the effect of independent variables.

Month of collection (i.e., period of exposure) ($F = 14.39$, $P = 0.0002$) and pond system ($F = 13.85$, $P = 0.0001$) were significantly associated with the presence or absence of carbonate deposits. Deposits were observed more frequently on tail feathers as exposure to agricultural drain water increased and in two evaporation-pond systems. No significant differences ($P > 0.05$) were found among sex or age groups.

X-ray diffraction analysis indicated that deposits on tail feathers were carbonate composites containing approximately 75% aragonite and 25% calcite. Aragonite and calcite are polymorphous forms of $CaCO_3$ that crystallize under slightly different environmental conditions. Carbonate deposits were associated with brittleness and a loss of plasticity of the rectrices, with large portions of the vane structure eroding until only

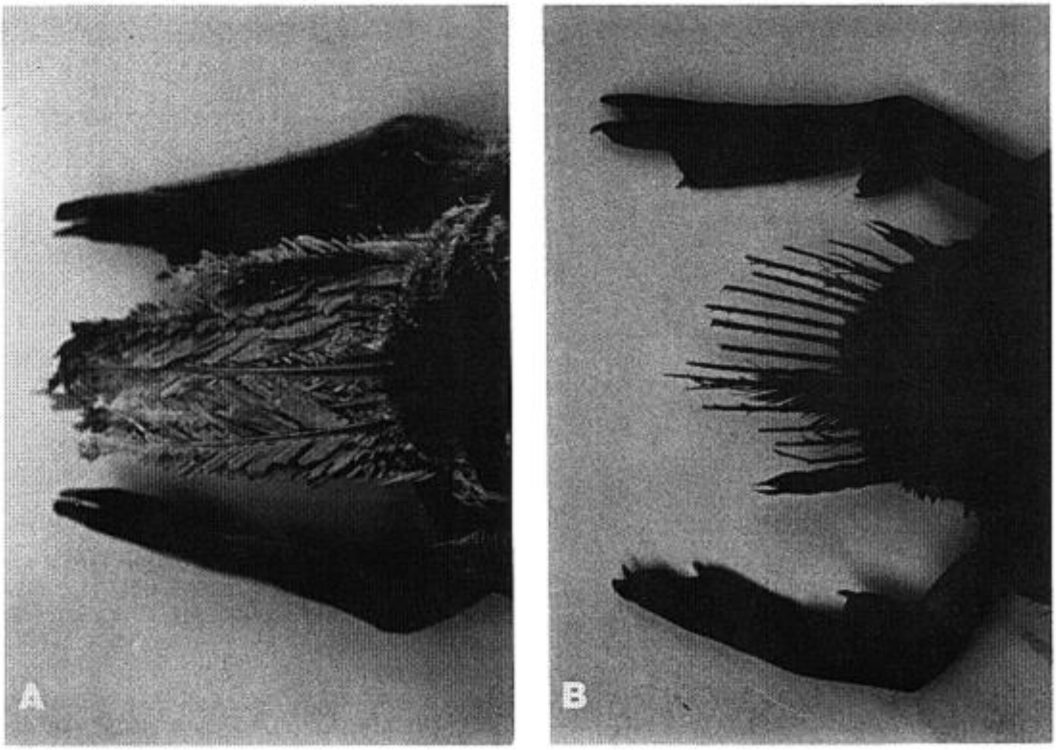

FIGURE 2. Rectrices of a Ruddy Duck with a heavy carbonate deposit (a) and of one that has lost all of its tail structure due to severe feather erosion (b).

rachii remained (Figs. 1, 2). The exact set of environmental conditions that may favor the crystallization of one polymorph over the other on tail feathers is unclear.

DISCUSSION

ANOVA results for month of collection indicated that carbonate deposits on rectrices of Ruddy Ducks increased during their residence on ponds that had high soluble concentrations of $CaCO_3$. ANOVA results for the month of collection produced a positive slope indicating that the incidence of carbonate deposits increased with the length of exposure. Wobeser and Howard (1987) suggested that rapid cooling of hypersaline lakes in Saskatchewan resulted in supersaturation and crystallization of sodium sulfate on several species of waterfowl. We did not collect data on ambient temperatures in this study but it is possible that lowered temperatures in winter and spring affected the incidence of carbonate deposits we observed. Additionally, there were significantly more carbonate deposits on rectrices of Ruddy Ducks collected from the two evaporation-pond systems closest to drained fields than on rectrices of ducks collected from the pond system that received drain water 2 km farther down the delivery canal ($F = 13.85$, $P = 0.0001$). Although no quantitative water chemistry data were collected in this study, $CaCO_3$ may precipitate out fairly early in the evaporative sequence and largely be removed before the drain water reaches more distant ponds.

The avian tail functions in diving and flying; a $CaCO_3$ encrustation on the rectrices may impede both of these activities. Ruddy Ducks forage by diving and migrate long distances (>800 km) (Bellrose 1978) and any impediment to either flying or diving could adversely affect survival. On several occasions, we observed that birds with heavily eroded tail feather vanes had difficulty in flying. We conclude that the potential for adverse effects of encrusted tail feathers is real, but are unable to assess the extent of that effect on the population.

Carbonate deposits were not noted on other bird species using evaporation ponds nor was it noted for feathers other than rectrices on Ruddy

Ducks. Perhaps, the microstructure of Ruddy Duck rectrices enables them to be suitable crystallization sites. Further investigation is needed to determine the extent of carbonate deposition on other wildlife species.

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