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## Mortality of Three Species of Ducks — *Anas discors*, *A. crecca*, and *A. clypeata* — Exposed to Ionizing Radiation

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Three species of wild ducks, held in captivity, were subjected to an acute whole-body dose of gamma irradiation to determine radiation sensitivity of adults. The  $LD_{50(30)}$  as determined by probit analysis was 485 R for *Anas crecca*, 715 R for *Anas discors*, and 894 R for *Anas clypeata*. Birds dying during the first 24 hours after irradiation had extensive intestinal hemorrhages, whereas subsequent deaths appeared to be due to hematopoietic failure.

### INTRODUCTION

This paper reports differences in radiation sensitivity among Blue-winged Teal (*Anas discors*), Green-winged Teal (*A. crecca*), and Shovelers (*A. clypeata*) exposed to acute whole-body gamma irradiation from cesium-137. The experiments were conducted to provide base-line information for our studies of the effects of ionizing radiation on breeding behavior of these species.

It was anticipated that the radiation response of the three species would be similar because all belong to the same genus and are considered to be closely related. In addition, we believed that the  $LD_{50(30)}$  would be in excess of 800 to 900 R, on the basis of lethal dose studies of various species of birds (1). Our experiments show, however, that the three species varied greatly in degree of radiation resistance and that both species of Teal were more radiation-sensitive than other species of birds that have been studied.

### METHODS

Most ducks were obtained directly from the wild. Adult Blue-winged Teal were bait-trapped at the Agassiz National Wildlife Refuge in northwestern Minnesota. Adult Green-winged Teal were bait-trapped in central California and shipped by air

to Minneapolis. The Teal were held in outdoor flight pens for about one month before treatment. Some of the Shovelers had been raised from "wild eggs" at the Delta Waterfowl Research Station in Manitoba, but most were captured as flightless young in the Dakotas. All but one of the Shovelers had been in captivity for more than one year (most for several years); one individual was captured as a molting adult in North Dakota three months before irradiation. The Green-winged Teal had the primaries of one wing clipped to prevent flying; the Shovelers and Blue-winged Teal were full-winged.

The irradiations consisted of single-dose (400 to 1600 R) total-body exposures to a 10,000-Ci cesium-137 source delivered in the University of Minnesota gamma irradiation facility. The dose rate in all experiments was 51 R/min as determined with both a Victoreen rate meter and ferrous sulfate (Fricke) dosimetry. Source configuration was ten cesium-137 pencils in a 5-inch-diameter holder. Boxes, each holding one duck, were centered on the arc of a circle with a 34.5-inch radius from the source center and were oriented so that irradiation was received laterally. The length of time that the source was in the "up" position was varied to give the appropriate dose for each test group. Controls were placed in boxes outside the irradiation chamber.

On October 15, 1964, groups of ten full-winged female adult Blue-winged Teal were exposed to 800, 1000, 1200, 1400, or 1600 R. These doses were too high, and only birds in the 800-R group survived. On October 15, 1965, groups of ten birds were exposed to 600, 700, 800, 900, or 1000 R.

Groups of eight full-winged Shovelers, including adults of both sexes, received 500, 700, 900, or 1100 R on October 20, 1965. All Blue-winged Teal and Shovelers were held in a large outdoor flight pen with an area of 1800 square feet.

A Green-winged Teal test was carried out on May 18, 1966, on adult wing-clipped males. Groups of nine received 400, 600, 800, or 1000 R. Before and after irradiation, these birds were held in small pens (320 to 450 square feet).

The ducks were checked daily during the first month after irradiation to remove dead birds and to make behavioral observations. Dead ducks were either autopsied within a few hours after death or frozen for future autopsy. At the end of 30-day period for some experiments, the surviving birds were captured and brought alive to the University of Minnesota Veterinary Diagnostic Laboratories for autopsy. In other tests, survivors were kept in pens for several additional months.

## RESULTS

Lethal dose levels as determined by probit analysis for the three species are shown in Fig. 1, and percentage of survival by days in Fig. 2. The  $LD_{50(30)}$  obtained for Green-winged Teal was 485 R; for Blue-winged Teal, 715 R; and for Shovelers, 894 R. Only one bird died during the first 30 days in any of the control groups; this

was a Blue-winged Teal which was found dead on the fifteenth day after treatment, for the 1964 experiment.

Most deaths at the higher doses in both species of Teal occurred during the first 24 hours following irradiation. Birds that died during this period were found both on shore and in the ponds of the flight pens. No deaths occurred in the 30-day test period for Blue-winged Teal after day 15 in 1964 or after day 21 in 1965; after day 19 in the Shoveler test; or after day 27 in the Green-winged Teal.

All birds that died after the first 24 hours postirradiation were found on shore. Many of these were in a "natural" resting position with the head upright and resting on the breast. Obviously, they had died peacefully. During the 24 to 48 hours before death many birds were weak and unable to fly.

Birds that died during the first 24 hours postirradiation showed profuse, generalized intestinal hemorrhages. The small intestines were usually filled with clotted blood, and hemorrhages were sometimes present in other parts of the gastrointestinal tract such as the proventricular junction and the pylorus. These findings support those of Stearner and her co-workers, who reported that in chickens, and possibly in other species of birds, the radiation response differs from that in mammals. Mammalian deaths, in general, are characterized by hematopoietic failure and, at higher

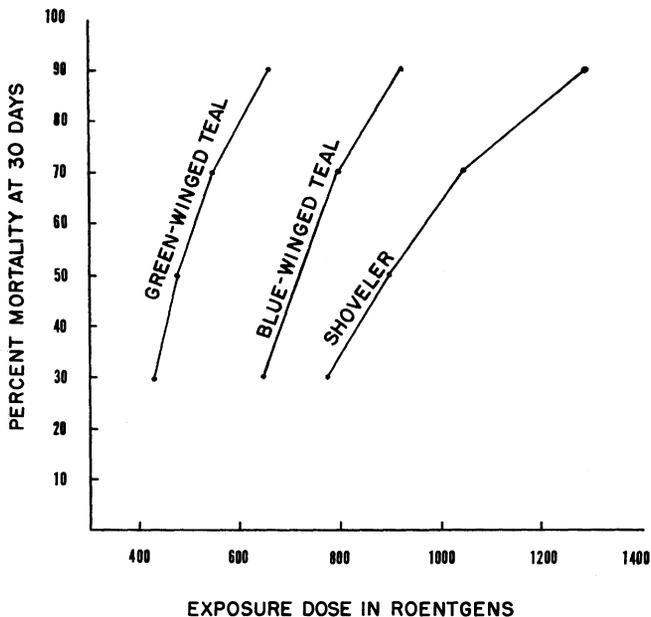


FIG. 1. Computed 30%, 50%, 70%, and 90% lethal dose for a 30-day period after irradiation for three species of ducks as determined by probit analysis.

doses, by intestinal damage. In chickens a third mortality factor, characterized by circulatory collapse and renal failure, seems to operate within the first 2 days after exposure (2, 3). Individuals that died beyond 4 days after irradiation showed pale pink to white bone marrow on gross examination.

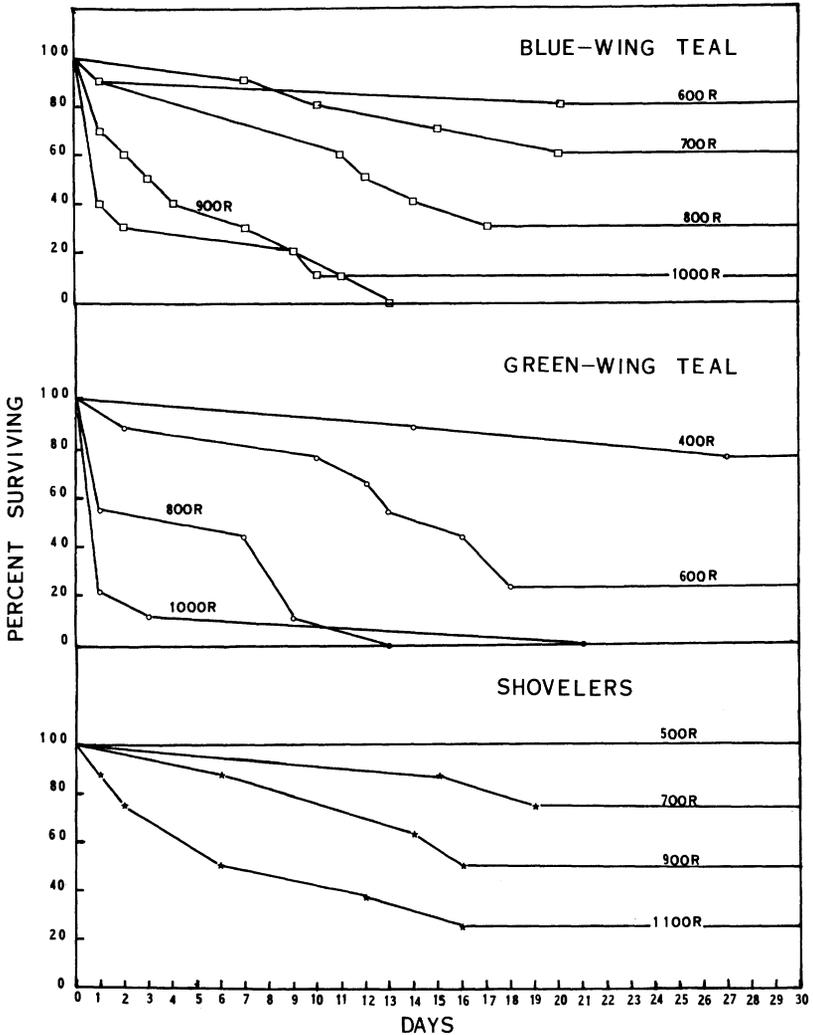


FIG. 2. Percentage of survival after irradiation for three species of ducks. Sample sizes for control and experimental groups were ten for Blue-winged Teal, nine for Green-winged Teal, and eight for Shovelers. No deaths occurred in the control groups.

TABLE I  
HEMOGLOBIN VALUES FOR INDIVIDUALS THAT SURVIVED  
IRRADIATION AT DOSES SHOWN AND WERE  
SACRIFICED AT 30-DAY POSTIRRADIATION

<i>Shoveler</i> hemoglobin (gm %)	Dose (R)	<i>Blue-winged Teal</i> hemoglobin (gm %)	Dose (R)
16.6	1100	13.0	1000
12.7	1100	15.3	800
13.7	900	14.9	800
2.1	900	12.5	800
15.7	900	14.7	700
10.4	900	13.7	700
14.2	700	12.8	700
15.3	700	14.9	600
15.5	700	14.1	600
14.1	500	10.2	600
11.3	500		
13.3	500		

Twelve Shovelers and ten Blue-winged Teal lived until they were sacrificed for more detailed examination at 34 days and 39 days after irradiation, respectively. Blood from all twenty-two of these birds started to hemolyze in ethylenediamine-tetraacetate about 1 hour after drawing. After refrigeration overnight every bottle showed complete hemolysis of the red blood cells. Hemoglobin values (determined by spectrophometric analysis, 4) for these birds are shown in Table I. Magath and Higgins (5) presented a range of 12.9 to 18.2 for tame Mallard ducks (*Anas platyrhynchos platyrhynchos*). Seven of our individuals fell outside this range, perhaps indicating slightly lower hemoglobin values for the irradiated birds.

Staphylococci were isolated from liver culture from three Blue-winged Teal which died 7, 9, and 67 days after receiving 1600, 1600, and 800 R, respectively, and from one Blue-winged Teal in the control group which died 32 days after "sham" irradiation. The birds dying on days 7 and 9 had no visible signs of infection and probably died from hemorrhage, whereas the 67-day and control birds had swollen, green livers typically encountered in certain bacteremic diseases. The specific etiologic agent, *Staphylococcus aureus*, was cultured from the viscera of the latter birds.

#### DISCUSSION

The observed differences in radiation resistance of these three species may represent real specific variability, but they could have been caused by a number of other factors. The experiments are not strictly comparable, since there were differences

in the sex and age of the groups used, experiments were not all carried out at the same time of year, the birds in one group were wing-clipped, and the same size of pen was not used in all cases.

Our results suggest that the Shoveler is the most radiation-resistant species ( $LD_{50(30)}$ , 894 R), but the birds used in our experiments were adults well adapted to captivity and human disturbance. The Blue-winged Teal had been in captivity for a shorter period, and perhaps the lower lethal dose (715 R) reflects the greater stress of captive conditions. The Green-winged Teal test was carried out in spring (the other species were tested in fall); the birds were kept in small pens and were feather-clipped, so it is very likely that these birds were under additional stress, perhaps sufficient to account for the  $LD_{50(30)}$  of 485 R.

In addition to these variables related to the experimental conditions, specific body-size differences could be involved in radiation resistance. The Shoveler is the largest species, the Green-winged Teal the smallest. Also, there are specific differences in the adaptability of these species to captivity; the Shoveler and Blue-winged Teal settle down quickly and become tame, but Green-winged Teal always remain nervous and extremely timid in captivity.

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