

WATER TURNOVER IN ROADRUNNERS UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

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THIS study reports on the use of tritiated water (HTO) to determine total body water and the kinetics of the water pool in captive Roadrunners (*Geococcyx californianus*). The Roadrunner is an interesting subject for the study of water turnover, as it occurs in the most arid regions of North America (Grinnell, 1907), consumes primarily animal material (Bryant, 1916), will drink water in the field (Sutton, 1940), but apparently does not require it (Miller and Stebbins, 1964; Ohmart, field observ.). In addition, data on its water losses and requirements are available (Calder and Schmidt-Nielsen, 1967; Calder and Bentley, 1967; Calder, 1968a, 1968b). To our knowledge, this is the first reported attempt to use the HTO (tritiated water) technique to determine body water loss in nondomesticated or desert dwelling birds under two different environmental conditions.

METHODS

Three wild-trapped adult and three hand-reared immature Roadrunners obtained near Tucson, Arizona during July 1968 were taken to Davis, California in September 1968 and housed together in a large outdoor cage. Body water turnover was studied under two sets of conditions. In the first experiment, rates of water turnover were determined by following the loss of tritium activity administered intravenously on 10 January 1969. Blood samples were then taken on alternate days through 22 January 1969. The test birds were housed together in an outdoor cage measuring $3 \times 3 \times 2.3$ m. During the first test period, a total of 18.69 cm of precipitation was recorded and the maximal and minimal temperatures ranged from 16° to -4°C with a mean of the daily maxima and minima being 8°C . Water vapor pressure during the 13-day test ranged from 5.5 to 3.4 mm Hg with a mean of 4.45 at 8°C , which equals 55 per cent relative humidity.

In the second water kinetics experiment, the birds were housed together in a climatically-controlled, windowless chamber measuring $3.6 \times 2.7 \times 2.6$ m. The temperature was kept between 30° and 32°C . Relative humidity and temperature were monitored continually 13 cm above floor level on a Serdex hygro-thermograph (Bacharach Industrial Instrument Company). Preheated fresh air was delivered constantly into the chamber so that complete air replacement occurred every 3 minutes. We used 11 hours of light during the experiment because it approximated the natural photoperiod. An acclimation period of 15 days was allowed before starting the experiment. HTO was injected on 12 March 1969, and blood samples were obtained through 25 March 1969. During the experiment and the acclimation period, the water vapor pressure calculated at 31°C ranged from 2.0 to 9.43 mm Hg and average 5.72. At 31°C with 5.7 mm Hg, the relative humidity equals 17 per cent.

Drinking water was allowed *ad libitum* in the first experiment. The only water available in the second test was that in the diet of white mice.

Following the first water turnover experiment and at the beginning of the second experiment, an injection of 0.5 ml of a 0.9 per cent sterile saline solution containing 1.22 mci/ml of HTO was administered via the right or left brachial vein to each bird. Assuming that the body water pool size, as a per cent of body weight, did not change

appreciably under the two experimental conditions, we calculated total body water for the first test by multiplying the per cent body water of each bird in the second test times the mean of its initial and terminal weights in the first experiment. An approximation of daily water loss was made under this assumption for the first experiment.

Sampling and sample treatment were the same for both experiments, except that a zero sample was obtained prior to the initiation of the second experiment to correct for residual HTO from the first experiment. Approximately 3 to 4 hours following the HTO injection, a blood sample (0.5 to 1.0 ml) from each bird was drawn into a heparinized syringe via a brachial or medial tarsometatarsal vein. The whole blood was sealed in individual vials and frozen immediately following withdrawal. Sample treatment was the same as that described by Chapman and Black (1967).

Sex of the experimental birds was determined by laparotomy after both experiments were completed.

RESULTS

A linear relationship existed for each bird when loss of tritium activity was plotted semilogarithmically versus time. Individual regression lines for the 12 samples were checked for closeness of fit, and the correlation coefficient for each line was 0.98 or greater. The exponential loss of HTO from the body indicated a single pool undergoing simple dilution through time (Chapman and Black, 1967).

The six birds turned over a mean of 41.8 ml of water per day under moderate conditions, whereas under the simulated desert test, they reduced the mean loss to 26.2 ml per day (Table 1). Use of paired Student's *t* distribution yielded a highly significant difference ($P < 0.01$) between the $t \frac{1}{2}$ for the same individuals under the two different conditions. During the simulated desert test, fecal water showed a visible reduction, and we noted large amounts of salt encrustations around the external nares. No comparative measurements were conducted on fecal water reduction and salt encrustations did not appear around the external nares during the moderate test.

An average of 28.7 g of mouse tissue was consumed by each bird per day in the simulated desert test. Water content of mouse tissue has been estimated to be 66% per cent (Schmidt-Nielsen, 1964). Thus each bird obtained an average of 19.1 ml preformed water per day. Mean water turnover per day (26.2 ml) slightly exceeded preformed water intake (19.1 ml). The deficit (7.1 ml) was supplied by the metabolic water produced in the digestion of the mouse tissue. The mean value of 7.1 ml compares closely with the 5.0 ml computation by Cade and Greenwald (1966) for a theoretical hawk.

DISCUSSION

The significant reduction in water loss in the same Roadrunners under the two experimental conditions indicates that the efficiency of the body water kinetics was related to the physiological state of the birds and the environmental conditions. Differences in rate of evaporative water loss in

TABLE 1
BODY WATER LOSS IN SIX ROADRUNNERS UNDER TWO DIFFERENT ENVIRONMENTAL CONDITIONS

Bird ¹ no.	Sex	<i>Ad libitum</i> drinking water and cool ambient temperatures ($\bar{x} = 8^{\circ}\text{C}$)				No drinking water and controlled ambient temperature ($30^{\circ}\text{--}32^{\circ}\text{C}$)					
		Initial wt.	Term. wt.	t $\frac{1}{2}$	Water loss ml/day	Initial wt.	Term. wt.	t $\frac{1}{2}$	Water loss ml/day	Total body water	Per cent body water
R-1	♂	352.9	333.0	4.53	38.26	323.2	327.1	5.69	28.06	230.33	71
R-2	♀	281.7	276.5	3.89	54.62	287.3	260.3	7.11	22.90	234.56	56
R-3	♂	339.5	334.0	3.88	45.98	328.8	340.3	6.33	27.82	233.78	66
Y-1	♀	294.5	255.0	4.02	36.93	258.2	279.4	5.10	26.54	195.01	65
Y-2	♂	296.9	290.0	3.07	39.20	284.2	287.1	5.63	26.00	211.03	55
Y-3	♂	269.8	246.0	4.05	35.95	246.8	255.0	5.19	26.44	195.37	72
Mean		305.8	289.0	3.91 ²	41.82	288.1	291.5	5.84 ²	26.24	216.67	64

¹ R denotes a wild captive adult, Y a hand-reared nestling.

² Highly significantly different ($P < 0.01$).

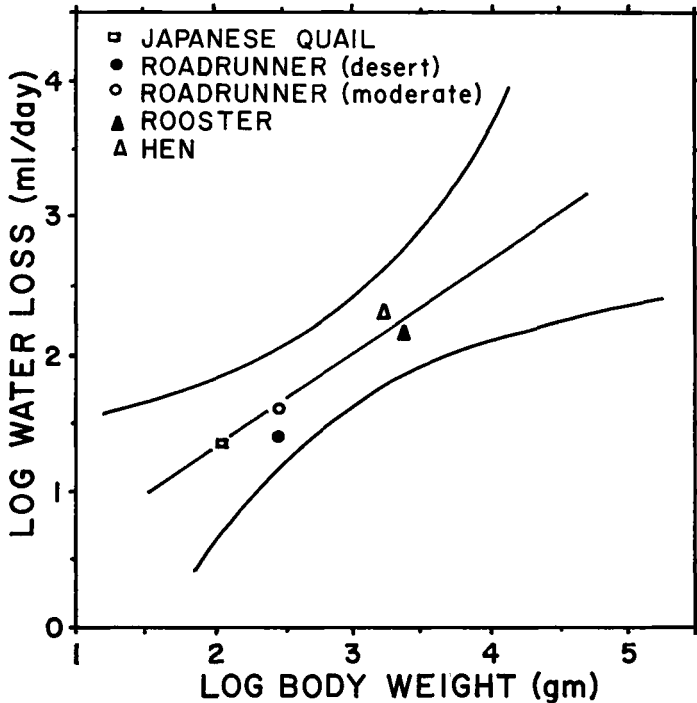


Figure 1. Relationship between log daily water loss and log body weight with 95 per cent confidence intervals among nonstressed avian forms. Roadrunners under simulated desert conditions were not included in these calculations. Data on fowl from Chapman and Black (1967) and Japanese Quail, *Coturnix japonica japonica*, Chapman and McFarland (MS). Method of presentation after Richmond et al. (1962).

the same individuals under different states of dehydration have been reported in the Zebra Finch, *Taeniopygia castanotis* (Calder, 1964) and occur in Brewer's Sparrow, *Spizella breweri* (Dawson and Ohmart, research in progress). The salt-secreting nasal gland of the Roadrunner is capable of secreting sodium in concentrations (776 mEq/liter) about six times that of the renal system (130 mEq/liter; Ohmart, MS), and this would allow for greater conservation of water as would drying of the feces. Ohmart et al. (1970) have demonstrated from urographic studies that the mucosa of the rectum and ceca, as well as the cloaca, of the Roadrunner could be involved in water reabsorption.

Calder (1968a) has estimated that an adult Roadrunner in the field might lose as much as 135 ml of water in a day through respiration (105 ml) and defecation (30 ml). Although field water loss is unknown, the mean loss of 26.2 ml/day in this study suggests a much lower field value than that

estimated by Calder. More importantly, Calder's (1966) estimations were based on birds maintained in environmental conditions much more similar to our moderate test than the simulated desert conditions.

An equation that predicts water loss in nonpasserine birds has been calculated based on data in this study and in other studies (Figure 1). As additional data become available from other nonpasserine species, the slope (b) may be altered. The equation describing the relationship between evaporative water loss and body weight by Crawford and Lasiewski (1968) predicts that a nonpasserine bird weighing 1 kg will lose 24.3 ml/day. The 24.3 ml loss through respiration is about $\frac{1}{4}$ the total loss (104.7 ml/day) predicted by our equation. This does not appear unreasonable as the Crawford and Lasiewski (1968) equation was established on "resting" birds at ambient temperatures within or below their zones of thermal neutrality.

A correlation exists between daily body water loss and body weight in mean values for nonstressed avian forms (Figure 1). The coefficient of correlation (r) between the variables was 0.97. The regression equation is of the form:

$$\log Y = \log a + b \log W$$

(Y is body water loss in ml/day, W is body weight in g, and a and b are constants). The least squares regression line for daily body water loss in nonstressed birds ranging in weights from 100 to 2,500 g can be described by the equation:

$$\log \text{ml water lost/day} = 0.69 \log W - 0.05 \pm 0.129.$$

The \pm value is the standard error of the estimate.

Daily body water loss is not proportional to body weight. If it were, b would equal 1. The value of b indicates that relative to body weight, larger birds have a slower turnover of body water than smaller ones. This has been pointed out by other workers (Bartholomew and Dawson, 1953; Bartholomew and Cade, 1963).

A Bartlett's test for homogeneity of variance was conducted on the nonstressed avian water loss values in Figure 1 to determine if the log transformation procedure was the appropriate method of fitting the data to a regression line. Variance about each mean point was found to be nonhomogeneous, with variance in Y generally increasing for increasing values of W, indicating the transformation by logarithms to be valid; see Glass (1969) and Lasiewski and Dawson (1969) for a more complete discussion.

An equation for water loss in mammals was described by Richmond et al. (1962) and the regression coefficient (0.801) is higher than that we obtained for avian forms (0.690). The difference between the slopes is sig-

nificant ($P < 0.01$) and part of the disparity may be explained by the renal adaptations in voiding nitrogenous compounds in birds and mammals.

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SUMMARY

The rate of water turnover was studied in six captive Roadrunners by following the loss of injected tritiated water through time. The six birds were tested under two different environmental conditions. In the first experiment, they were exposed to moderate temperatures (\bar{x} of 8°C) and *ad libitum* water consumption. They replaced half of their body water ($t \frac{1}{2}$) in a mean period of 3.91 days. A highly significant increase ($P < 0.01$) in $t \frac{1}{2}$ (5.84 days) was noted when the same experimental birds were exposed to an ambient temperature controlled between 30° and 32°C and the only available water was that contained in their diet of white mice. Two adjustments occurred that permitted more efficient budgeting of water between the two experimental tests—a reduction of water in the feces and a marked increase in the elimination of salts through the nasal gland.

A regression equation has been established that predicts water loss values in nonstressed avian forms. The relationship between water turnover and body weight in birds and mammals was compared.

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