MUST DESERT CHUKARS (*ALECTORIS CHUKAR SINAICA*) DRINK WATER? WATER INFLUX AND BODY MASS CHANGES IN RESPONSE TO DIETARY WATER CONTENT

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ABSTRACT.—The Chukar subspecies *Alectoris chukar sinaica* inhabits the Negev desert, which is characterized by hot, dry summers, and little winter rainfall. Vegetation is dry and dormant during the summer and autumn; green, succulent vegetation is available following winter rain. We studied whether or not and under what dietary conditions Chukars require drinking water. Four groups of Chukars in an outdoor aviary received either a dry ration + water, a dry ration + green vegetation, a dry ration + green vegetation + water, or green vegetation only.

The birds offered only greens lost 15% of their body mass in the first 8 days and 2.9% over the next 6 days, while birds on the other three treatments maintained body mass. The birds receiving only greens had the highest total body water to body mass ratio and the highest water influx. We concluded that the Chukars receiving only green vegetation met their water requirements but not their maintenance energy requirements. Chukars fulfilled both their water and energy requirements on a dry ration + green vegetation (without drinking water); the green vegetation comprised approximately 60% of their total fresh matter intake, or 26% of their total dry matter intake. Our analysis suggests that wild desert Chukars do not require drinking water from early winter to late spring, when succulent forage is available, but probably need free water during summer and autumn, when the bulk of their diet is seeds.
Received 15 March 1983, accepted 8 July 1983.

BIRDS inhabiting deserts are often faced with hot, dry environmental conditions as well as sparse and unpredictable water and food supplies. Diurnal, granivorous birds are most vulnerable to these harsh conditions, especially those unable to fly great distances in search of water or food. In addition, seeds, their principal food during the hot summer, yield little preformed water at a time when their water requirements for thermoregulation are greatest. Although some small passerines are able to maintain body mass (m_b) when offered dry food without drinking water, most seed-eating birds must drink (Bartholomew and Cade 1963, Bartholomew 1972, Dawson 1976). Some primarily granivorous species can meet their water requirements by adding succulent vegetation and/or insects to their diet, however.

The desert subspecies of Chukar (*Alectoris chukar sinaica*) is a primarily granivorous, diurnal phasianid and is a permanent resident of the Negev desert, Israel (Nissani 1974). These birds inhabit areas where annual rainfall may be 90 mm or less and where surface water may be unavailable year round (H. Mendelssohn, G. Illani pers. comm.). Although Chukars have relatively low water influxes (Degen et al. 1982), previous reports have indicated that they depend on surface water when succulent forage is unavailable (Bump 1953, Christenson 1954, McLean 1955, Harper et al. 1958) and that they concentrate at open water sources during the summer (Alcorn and Richardson 1951, Christenson 1958, Alkon 1974).

We examined whether or not and under what conditions desert Chukars depend on the availability of drinking water. We measured the body mass of Chukars caged in an outdoor aviary during the summer and estimated their total body water, water influx, and food intake when offered a dry ration and/or green, succulent vegetation with and without drinking water.

MATERIALS AND METHODS

Experimental design.—The study was made during late summer at Sede Boqer (30°52′N, 34°46′E, 476 m above sea level) in the central Negev highlands, Israel. Chukars trapped near Sede Boqer were held in an outdoor aviary, which was partitioned into four similar cages (each 5 × 3 × 2.5 m) constructed of chicken wire. The cages shared a common rear wall and a sloping roof, which provided shade in parts of the cage throughout the day, either on the ground or on perches. Fresh tap water was available in open troughs as required by protocol. Floor material was gravel, and fine sand was provided to allow the birds to dust bathe. For at least 6 weeks before experimentation, all birds received a diet of a 1:1 mix of 15% protein chicken chow and whole sorghum seeds (dry ration) with occasional green vegetation. During the experiment, green vegetation (greens) consisted of both alfalfa seedlings (*Medicago sativa*) and 5- to 10-day old wheat seedlings. The former were freshly picked, while the latter were grown in styrofoam trays (30 × 60 cm).

Twenty-four adult Chukars of both sexes were weighed (initial m_b) and randomly separated into four groups. Each group was placed in a cage on one of the following dietary regimes for 14 days: Cage I—dry ration + water; Cage II—dry ration + greens; Cage III—dry ration + greens + water; Cage IV—greens. Food was available *ad libitum* throughout the day, and fresh food was placed in the cages between 1600 and 1700 daily. Old wheat trays were usually replaced with new trays, but on occasion it was necessary to use wheat from a previous day, which had regrown to some extent. Samples of all feed were dried at 70°C to constant mass for moisture determination. On day 11, birds offered only greens were visibly weak, and, consequently, they were given younger wheat seedlings with a larger amount of endosperm, i.e. a more digestible and concentrated source of energy, until the end of the experiment. Birds in other cages did not receive this food.

Using tritiated water (TOH) in accordance with Degen et al. (1981), we estimated total body water (*TBW*) for all birds on day 8. The birds were weighed (to the nearest 0.1 g) and injected intramuscularly with 0.1 mCi/kg m_b of TOH in approximately 1 ml (weighed to 0.1 mg, assuming 1 ml weighs 1 g) sterile avian saline. After 45 to 60 min, to allow TOH equilibration with body fluids, birds were reweighed, and blood samples were taken from the basilic vein for *TBW* estimation (as TOH space). The mean of the two body masses, that is before TOH injection and after blood sampling, was used in subsequent calculations. Six days after injection, birds were weighed, and blood samples were collected to estimate water influx. We assumed that maintenance of constant body mass over the 6-day period, as in Cages I, II, and III, indicated constant TOH space. When body mass changed, as in Cage IV, we assumed the ratio of TOH space to body mass was constant and that changes were linear with time (Nagy and Costa 1980).

Serum samples of 0.05 ml were added to 5 ml Bray's solution and specific activity of tritium was measured in duplicate samples in a liquid scintillation counter (Packard Tri-Carb, model PLD). Counts were corrected for 6% dry matter content of the serum and for quenching, which was estimated by use of quenched standards (Packard).

Calculation of food intake.—The daily, dry-ration intake of birds in Cage I (dry ration + water) was calculated as:

$$D = \frac{m_b \times EE}{ME_D \times F_D}, \tag{1}$$

where D = fresh mass of dry ration (g); m_b = body mass (g); EE = existence energy (kJ/g m_b); ME_D = metabolizable energy of D (kJ/g dry matter); and F_D = fractional dry matter content of D.

Using the same dry ration, we had previously estimated that the daily existence energy of caged Chukars was 0.438 kJ/g m_b, and that 1 g of the dry matter had a metabolizable energy content of 13.8 kJ and yielded 0.5 g of metabolic water (Pinshow et al. 1983). F_D was 0.879 in the present study.

Greens (G) had a moisture content of 80.0%, and we assumed that 1 g of dry matter had a metabolizable energy content of 15.4 kJ and yielded 0.5 g of metabolic water (Hill 1964).

For birds in Cage II (dry ration + greens), the daily energy obtained from the dry ration was 13.8 (kJ/g) × 0.879 D (g) and from the greens was 15.4 (kJ/g) × 0.2 G (g). Therefore:

$$12.13\ D + 3.08\ G = m_b \times 0.438, \tag{2}$$

where G = fresh mass of greens (g).

Preformed water from the dry ration was 0.121 × D (g), and metabolic water was 0.5 × 0.879D (g), whereas for the greens these values were 0.8 × G (g) and 0.5 × 0.2G (g). Therefore:

$$0.56D + 0.9G = WI, \tag{3}$$

where WI = water influx (g).

Solving for D and G in equations (2) and (3), we calculated the dry ration and greens consumed by birds in this treatment.

Our casual observations indicated that the birds in Cage III (dry ration + greens + water) ate the same amounts of dry ration and greens as did the birds in Cage II (dry ration + greens). We therefore assumed that the difference between their water influxes was a result of water drunk.

The greens intake of the birds in Cage IV (greens only) was calculated as:

$$0.8G + 0.5 \times 0.2G = WI. \tag{4}$$

In all four cages, water obtained from food (preformed and metabolic) was calculated, and, in Cages I and III, water drunk was calculated as the difference between water influx and water from food.

Data analysis.—Upon comparison of initial body mass of the Chukars among the four cages, we found that the mean body mass of the birds in Cage IV was significantly different from those in the other three cages. Therefore, subsequent mass-specific statistical comparisons of *TBW* and water influx were made. Analysis of variance was used to test whether or not means were different among treatment diets. A level of $P < 0.05$ was chosen as significant, and means were separated by a Student Neuman-Keuls test (Steel and Torrie 1960).

RESULTS

The average minimum and maximum air temperatures in the aviary were 16.5°C and 35.9°C, respectively, and water vapor pressure varied between 17.8 and 20.8 mbars. Relative humidity varied from approximately 35% at midday to 95% between 0200 and 0600 over the same period (Meteorology Unit, Jacob Blaustein Institute for Desert Research). No rain fell during the study.

Birds fed mostly at first light. Feeding in late afternoon was observed on two occasions, when birds in Cage IV (greens only) were given younger wheat seedlings. All birds, except those receiving only greens, maintained their m_b throughout the experimental period. Birds given only greens lost 15% of their initial body mass after 8 days and a further 2.9% in the following 6 days (Table 1).

On day 8 of treatment, the total body water volumes (*TBW*) of the birds ranged from 64.4% of body mass for birds receiving dry ration + greens + water to 68.1% for birds receiving greens only (Table 1). Daily water influx between days 8 and 14 ranged from 50.2 ± 9.9 $ml \cdot kg^{-1} \cdot day^{-1}$ for birds receiving dry ration + greens to 103.1 ± 20.9 $ml \cdot kg^{-1} \cdot day^{-1}$ for birds receiving greens only. Differences in *TBW* and water influx among treatments were significant (Table 1).

It was calculated that the dry matter intake of the birds fed only greens was 22.6 g/kg m_b, 29% less than that of the other three treatments (Table 2). The birds on the dry ration + greens diet consumed 11.0 g dry ration and 15.8 g greens. Thus, greens comprised 60% of the total fresh matter intake or 26% of the total dry matter intake (Table 2).

DISCUSSION

Most seed-eating birds inhabiting deserts depend on drinking water in the absence of succulent vegetation and/or insects (Fisher et al. 1972, Bartholomew 1972, Dawson 1976), as the

TABLE 1. Body mass (m_b), total body water (*TBW*), and total water influx of Chukars on four treatment diets. (See text for details of diets.) *TBW* was calculated on day 8, and water influx was measured between days 8 and 14. Six Chukars were used in each treatment, and values are given as means ± SD. Values in the same column that are followed by different superscripts are significantly different from each other.

Cage	Diet	Body mass (g)			Total body water		Total water influx	
		Initial	Day 8	Day 14	(ml)	(% m_b)	(ml/day)	($ml \cdot kg^{-1} \cdot day^{-1}$)
I	Dry ration + water	428.2 ± 44.4	422.5 ± 42.7	418.3 ± 42.7	284.9 ± 67.6	67.6 ± 0.9[ac]	30.6 ± 5.8	72.4 ± 7.2[a]
II	Dry ration + greens	432.5 ± 31.0	436.0 ± 19.8	436.2 ± 19.3	285.4 ± 16.4	65.6 ± 1.8[ab]	21.9 ± 4.6	50.2 ± 9.9[b]
III	Dry ration + greens + water	402.8 ± 42.0	404.9 ± 43.3	405.0 ± 42.4	261.1 ± 36.8	64.4 ± 2.3[b]	24.1 ± 3.7	59.7 ± 8.8[ab]
IV	Greens	380.4 ± 39.3	323.4 ± 48.1	312.3 ± 34.0	220.5 ± 38.2	68.1 ± 1.9[c]	32.3 ± 5.4	103.1 ± 20.9[c]

TABLE 2. Calculated daily mean food and water intakes for Chukars on 4 different diets (see text for details of diet).

		Fresh mass intake (g)			Dry mass intake, DMI (g)				Water influx (ml)	
Cage	Diet	Dry ration	Greens	Total	Dry ration	Greens	Total	DMI/m_b (g/kg)	Drunk	Pre-formed + metabolic
I	Dry ration + water	15.1	—	15.1	13.3	—	13.3	31.6	22.1	8.5
II	Dry ration + greens	11.9	17.0	28.9	10.4	3.4	13.8	31.7	—	21.9
III	Dry ration + greens + water	11.0	15.8	26.8	9.7	3.2	12.9	31.7	3.8	20.3
IV	Greens	—	35.9	35.9	—	7.2	7.2	22.6	—	32.3

preformed and metabolic water obtained from dry food is insufficient to meet their water requirements. Many of these birds, however, do not have to drink when succulent, green vegetation is available in addition to the dry food. This is the case with a number of quail species such as California Quail (*Callipepla californica*; Bartholomew and MacMillen 1961), Gambel's Quail (*C. gambelii*; Gullion 1960), and Montezuma Quail (*Cyrtonyx montezumae*; Leopold and McCabe 1957).

We have observed Chukars drinking surface water in the summer months when their diet is principally dry seeds. In addition, we have shown that in the laboratory (Pinshow et al. 1983) and in the field (Degen et al. 1983) they must drink when dry food alone is available. When succulent vegetation is their principal food component, the water influx of Chukars can increase four-fold when compared to Chukars eating primarily seeds, but this may be accompanied by an initial decrease in body mass and body solids. In this situation, water influx clearly exceeds the birds' water requirements, while energy intake is below that required for maintenance (Alkon et al. 1982).

This study showed that Chukars faced with an abrupt shift to only greens from a diet of dry ration + greens + water increased their water influx substantially, but their energy intake for maintenance was insufficient. In addition, the birds fed only greens had the largest *TBW* to body-mass ratio, indicating that they had the lowest body-solid and, presumably, lipid content to body-mass ratio. Chukars maintained body mass on a dry diet supplemented by greens, however. We calculated that if greens that are 80% water (26% of the total dry matter content) comprise some 60% or more of their fresh food, then Chukars can obtain sufficient water to maintain their water balance.

Chukars fed only greens had the highest water influx, a consequence of the high water content of the greens. The water influx of these birds was lower, however, than that of free-living Chukars feeding mainly on green vegetation during the winter (Alkon et al. 1982). The fractional moisture content (0.80) of the greens during this summer study was lower than that of the winter green vegetation that Chukars eat in the wild (unpubl. data), and this could explain the difference in water influx. Birds that received a dry ration + water had a higher water influx than the two groups that received a dry ration + greens (Cages II and III). This is a possible result of the higher protein and electrolyte contents of the former diet, necessitating more water for nitrogenous and electrolyte waste excretion (McNabb et al. 1972).

Ecological implications.—The Negev highlands are characterized by hot, dry summers with 250–300 biologically "dry" days per year (UNESCO 1963). Annual precipitation averages 90 mm, with all rain falling during the winter months. Temperatures are highest in August, with a daily mean of 25.3°C, and are lowest in January, with a daily mean of 9.7°C (Desert Meteorology Unit, Jacob Blaustein Institute for Desert Research).

The onset of germination and the growth of annual and perennial plants are linked to the timing of winter rains. The major period of plant growth is in winter and early spring, i.e. usually from mid-January to mid-April, and most herbaceous vegetation is dry and dormant

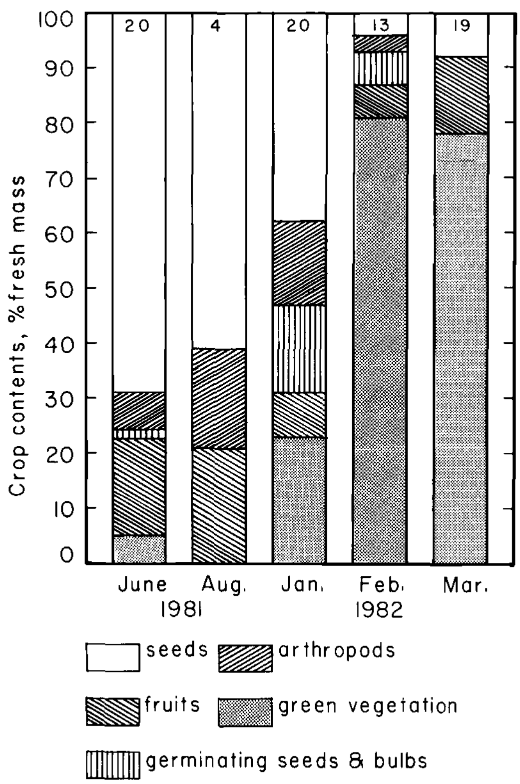

Fig. 1. Fresh matter components of Chukar crop contents during summer (June, August), winter (January, February) and spring (March). Crop contents were separated into items of high (green vegetation, germinating seeds and bulbs, fruits, and arthropods) and low (seeds) moisture content. The number of crops analyzed each season is given at the top of each column.

by mid-May. Large variations in primary production, especially of annual plants, are characteristics of the study region (Evenari 1981).

In a separate study (P. U. Alkon et al. MS), the crops of 76 Chukars, collected during different seasons, were examined for food types and quantities. Crop contents were categorized into items with high (green vegetation, sprouting seeds, fruits, and arthropods) and low (seeds) moisture content. In general, the ratio of high- to low-moisture-content food (Fig. 1) followed the seasonal availability of green vegetation. It is apparent that captive Chukars can fulfill their water requirements if approximately 60% of their fresh-matter intake is green vegetation. If we assume that the ratio of water to dry matter intake is the same in caged and free-living birds, then free-living Chukars may be independent of drinking water from early winter to sometime in late spring. During the summer and autumn, however, when seeds form the bulk of their diet and vegetation is dry, Chukars must drink. Because Chukars have been observed in areas where surface water is unavailable in the summer and autumn (H. Mendelssohn, G. Illani pers. comm.), we assume that either these birds have access to succulent vegetation all year, or they migrate periodically to surface water.

Acknowledgements

We thank Philip U. Alkon for helpful comments on the manuscript. The study was done in the Lady Edith Wolfson Laboratory for Environmental Physiology and was supported by United States-Israel Binational Science Foundation grants 2496/81 and 2911/82. Berry Pinshow is a Bat-Sheva de Rothschild Fellow.

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