USE OF SODIUM CHLORIDE SOLUTIONS BY THE BREWER'S SPARROW AND TREE SPARROW

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SEVERAL studies of the ability of birds to use solutions of sodium chloride have been reported in recent years (Bartholomew and MacMillen, 1960; Cade and Dybas, 1962; Poulson and Bartholomew, 1962a, 1962b; Dawson et al., 1965; Smyth and Bartholomew, 1966; Willoughby, 1966). The majority of this research has dealt with distantly related granivorous inhabitants of desert or semiarid regions. No extensive studies have been made to examine a taxon containing a number of seedeating species that show a broad ecological divergence. The earlier studies of Poulson and Bartholomew (1962b) and Cade and Bartholomew (1959) on the Savannah Sparrow (*Passerculus sandwichensis*) approached this, but only 5 of the some 16 races were ever examined. This paper reports on two species in the genus *Spizella* and is the first in an attempt to examine all the species comprising this taxon. On completion we hope to have a clearer understanding of the use of sodium chloride solutions as an index of renal efficiency and added knowledge on the evolution of physiological systems.

The objectives of this study were to compare the ability to use sodium chloride solutions by two species of *Spizella* that occupy widely divergent habitats with respect to the availability of free water. Brewer's Sparrow (*S. breweri*), both on its wintering and breeding grounds, occupies areas often far removed from free water. The Tree Sparrow (*S. arborea*), on the other hand, occupies a much more mesic habitat where succulent plant material and/or free water are normally always available.

METHODS

BREWER'S SPARROW

The 60 Brewer's Sparrows used in the tests reported here were netted near Tucson, Arizona from January through March of 1966 and 1967 and were referable to nominate *S. b. breweri*. Measurements of *ad libitum* consumption of distilled water and NaCl solutions up through 0.45 M were made in late 1966 and early 1967. Tests on 0.5 and 0.55 M sodium chloride solutions and dehydration studies were completed after obtaining new test animals in 1967. Netted birds were held in outside aviaries for a week or longer before being placed in individual cages measuring 22 × 22 × 37 cm. The cages were housed in a windowless chamber in which the temperature was controlled between 20° and 21°C. The photoperiod extended from 12:00 to 24:00. The relative humidity during the experiments ranged from 20 to 70 per cent with the majority of the readings being near 70. The relative humidity remained between 32 and 42 per cent during the test in which the birds were maintained at 25°C with no fluid for drinking. All tests were conducted for 21 days except in the experiments with no water at 25°C and with the 0.45 M solution which lasted 14 and 17 days, respectively.

The use of "L" drinking tubes and placement were the same as described by Smyth and Bartholomew (1966). Test birds were given distilled water for 3 to 5 days between experiments. One drinking device was used to correct for evaporation. The body weight of the birds (to the nearest 0.1 g) and the fluid levels in the drinking devices (to the nearest 0.2 ml) were determined between 10:00 and 12:00 daily, just before the beginning of the daily photoperiod. Glass-distilled water was used as the distilled solution and as the solvent for all saline solutions. A commercial finch seed mixture combined with a commercial chick starter mash was supplied *ad libitum*. Chaff and excess seeds were allowed to accumulate on the cage bottoms to act as a secondary food source, an absorbant, and a soft base.

Data on the bird's activity and in moisture content of feces were obtained at the same time in the two groups and with procedures described by Smyth and Bartholomew (1966). Patterns of activity for the watered and unwatered groups (consisting of four birds each) were obtained continuously for 48 hours. The four birds comprising the unwatered group came from the sample of 12 after they had completed 21 days testing without water. The monitoring of defecation rate and moisture content of feces for the eight test birds occurred during the initial 2 hours of two consecutive photoperiods. Activity of unwatered birds maintained at an ambient temperature of 25°C was not monitored.

Tree Sparrow

Thirty Tree Sparrows obtained during early January 1968 at University Woods, 6 miles northeast of the University of Illinois, Champaign, Illinois, were tested under the same conditions imposed on the Brewer's Sparrows. Some experiments involving the two species were performed simultaneously.

Body weights of individual Tree Sparrows typically fluctuated widely even in the absence of stressful conditions. The birds appeared healthy, but individuals were frequently noted to lose as high as 0.5 g a day for a week, then to reverse this trend and, within a couple of weeks, to stabilize at a weight above the initial level. Minimum daily water requirements were conducted for 60 days in hopes of eliminating this problem. These data were obtained by reducing the water ration to the smallest quantity at which each test bird could maintain body weight.

All tests on salt solutions were conducted for 21 days except for the one on 0.15 M which was terminated at day 19, and the 0.3 M test which was discontinued after losing eight birds by day 7.

To determine if they possessed salt-secreting nasal glands the culmens of each species were examined and the nares tasted of birds netted in the field. No specimens were dissected.

Mean weights with SD of test birds on the day before and on the terminal day for each experiment are presented in Table 2.

Results

Brewer's Sparrow

Fluid consumption.—When allowed *ad libitum* consumption of distilled water, the birds consumed an average of 32.2 per cent of their body weight daily. Fluid consumption on the 0.1 M solution decreased slightly below that of distilled water and concentrations between 0.2 and 0.4 M NaCl (Figure 1). No additional decrease was noted until the birds were placed on a 0.45 M solution. A new test group, i.e. one previously maintained

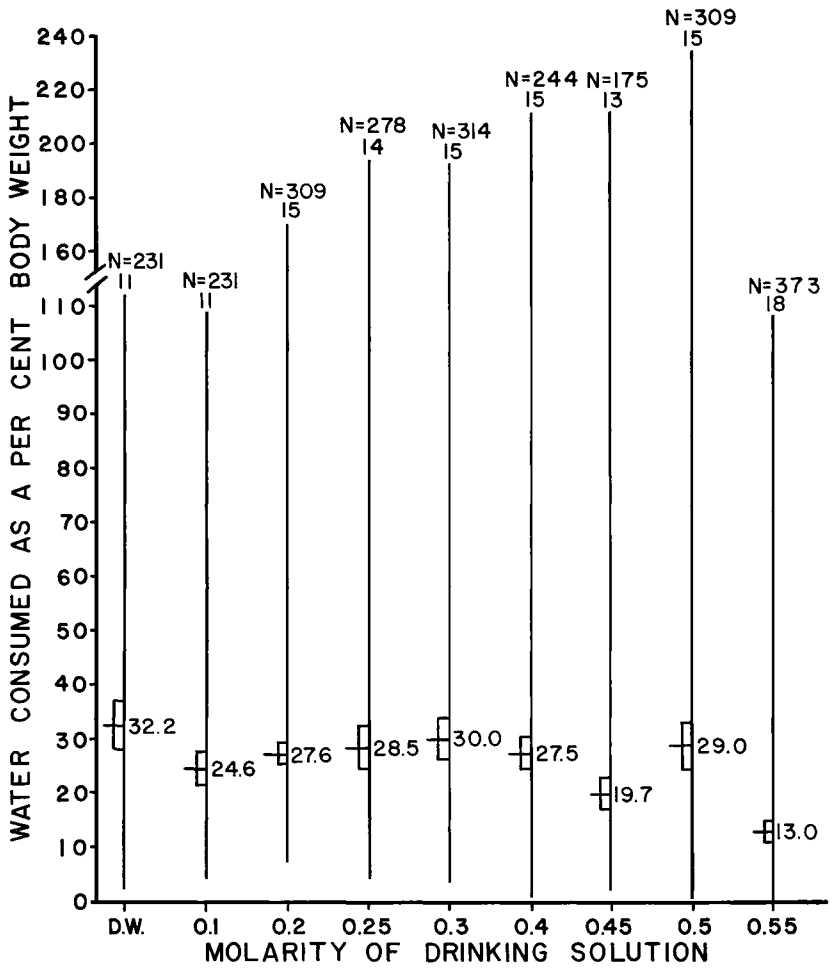

Figure 1. Relation between fluid consumption and solution concentration of sodium chloride in the Brewer's Sparrow. The horizontal bar is the mean, the rectangle is 2 SD of the mean, and the vertical bar is the range. The first number above the vertical bar is the number of test birds on the respective solution, the figure above that is the sample size, and the mean value is to the right of each horizontal bar. D. W. equals distilled water.

on distilled water, was placed on the 0.5 M concentration and an increase in fluid consumption was observed. Intake by this new group was reduced on the 0.55 M solution; four birds intermittently abstained from drinking the solution throughout the test period, but none completely abandoned intake of this saline fluid.

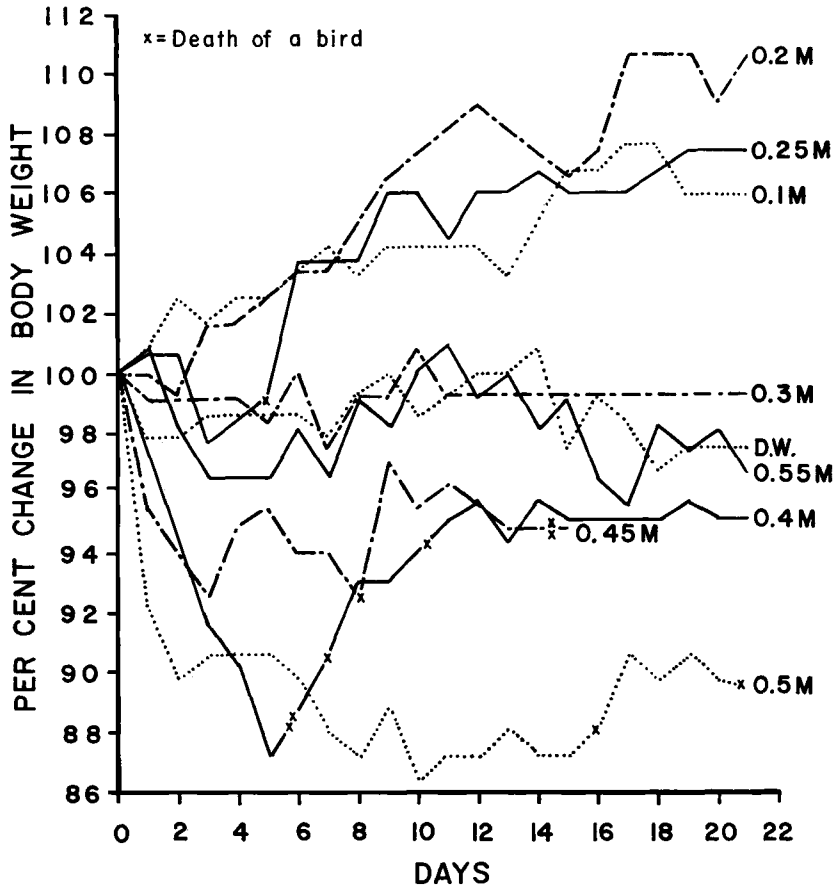

Figure 2. Mean body weights of Brewer's Sparrows (as per cent of initial weight) during *ad libitum* consumption of distilled water and varying molar concentrations of sodium chloride.

Brewer's Sparrows' weights varied greatly during and between some tests (Figure 2). The fluctuation in body weight and deaths with the 0.45 M solution prompted securing new test individuals for further experiments. Average body weight in the new test birds declined noticeably on the 0.5 M solution, but the subsequent test, following the break on distilled water, demonstrated the birds could process the 0.55 M solution and still maintain body weight. The nasal gland, if one exists, does not appear to secrete salt in Brewer's Sparrow.

Water requirements.—It was found that the small (10–12 g) Brewer's Sparrows were capable of surviving during water deprivation on seeds

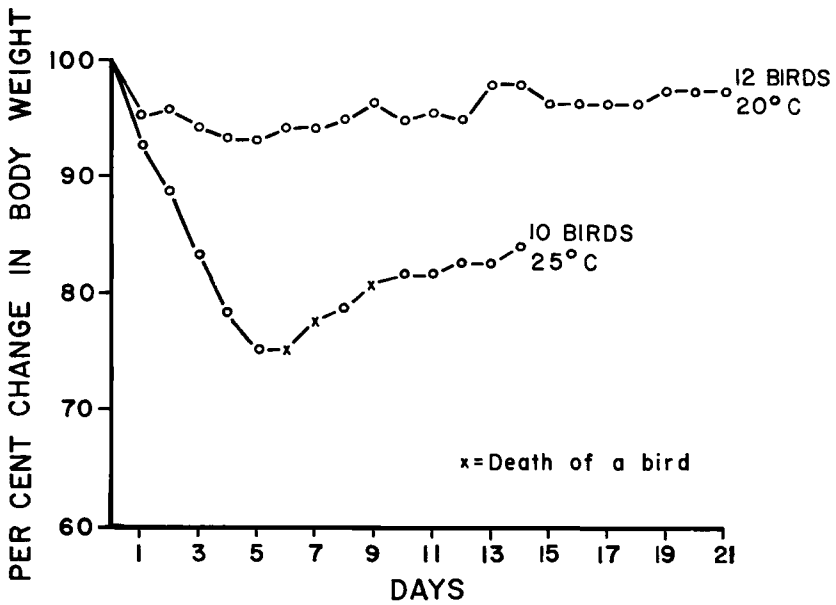

Figure 3. Mean body weights of Brewer's Sparrows (as per cent of initial weight) during water deprivation tests. Relative humidity was near 70 per cent at 20°C and 38 per cent at 25°C.

containing 7 per cent moisture (determined by drying them to constant weight at 100°C). For the 21-day test we used 12 freshly caught birds. The ambient temperature was maintained between 20° and 21°C, and the relative humidity ranged near 70 per cent (absolute humidity was 12.1 g/m^3). Mean weight declined slightly at the beginning of the test, but by day 13 this loss was almost fully regained; 8 of the 12 birds gained during the test and all showed subcutaneous fat deposits when the experiment was terminated.

A second test group of 10 birds was drawn from a holding cage that contained birds used both in sodium chloride and previous water deprivation experiments. This sample was held at 25°C and the relative humidity ranged from 32 to 42 per cent (absolute humidity equaling 7.4 to 9.7 g/m^3). The initial weight loss was more pronounced than observed during the test at a lower temperature and higher humidity (Figure 3). Three birds died during the experiment; the remaining seven had deposits of subcutaneous fat when autopsied on day 14. Only 2 of the 10 birds regained their initial body weight by the end of the 14-day test.

The difference in activity (perch hops) between watered and unwatered birds was significant at the 99 per cent level. Activity was monitored

TABLE 1

MEAN NUMBERS OF PERCH HOPS (± SD) PER HOUR[1] BY FOUR WATERED AND FOUR UNWATERED BREWER'S SPARROWS

	Lights on	Lights off
Watered	11.0 ± 2.0 (96)	32.9 ± 8.0 (74)
Unwatered	3.5 ± 1.2 (76)	1.7 ± 0.8 (62)

[1] Total number of hours sampled (N) in parentheses.

simultaneously on four watered and unwatered birds held at 20°C (Table 1).

Water content of excrement voided by birds supplied with fluid for drinking and by those deprived of it averaged 80 and 59 per cent respectively. These birds also differed in the frequency in which they voided excrement, the respective rates for watered and unwatered individuals averaging 6.1 and 2.5 droppings per hour.

TREE SPARROW

Fluid consumption.—At moderate temperatures and on a dry diet, the Tree Sparrows consumed an average of 29.6 per cent of their body weight of distilled water daily. On salt solutions the birds' mean fluid consumption increased with increasing salt concentrations (Figure 4). The test group on the 0.15 M solution initially lost weight, but more than recovered by the end of the test period (Figure 5). Five of the 12 birds died on the 0.2 M solution, but the remaining birds maintained their weight and two gained approximately a gram each. The test with 0.3 M was terminated at day 7 after all the birds showed a drastic loss of weight and 8 of the 12 birds starting the test had died. Occasionally high fluid consumption was recorded on concentrations of 0.15 M and less, but on the two more concentrated solutions large volume intakes were common. On the 0.3 M solution some individuals drank 50 ml/day.

Minimum daily distilled water requirements of Tree Sparrows were found to vary from 1 to 3 ml with a mean intake for 12 birds being 2.2 ml. This mean value was 15 per cent of the test birds' weight.

Data on weight changes, fluid consumption, and sample size for the two species are presented in Table 2.

DISCUSSION

The wide ecological divergence of the Tree and Brewer's Sparrows makes it of interest to compare their sodium chloride metabolism and minimum daily water requirements. The Tree Sparrow is normally found in regions where free water or succulent material is available. Baum-

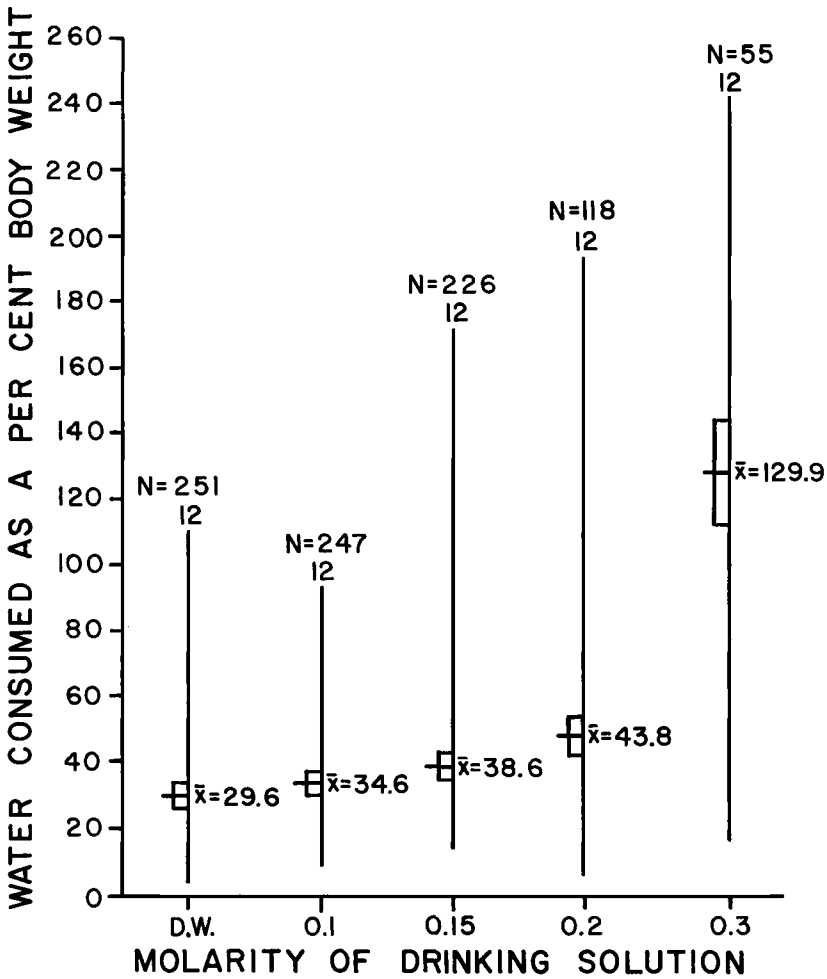

Figure 4. Relation between fluid consumption and solution concentration of sodium chloride in the Tree Sparrow. Symbols and value placement same as in Figure 1.

gartner (1968: 1158) reports "Water is as essential as food, and in winter when there are no open pools, I have frequently watched tree sparrows about my station swallowing snow." Antithetically the xerophylic Brewer's Sparrow breeds and winters primarily where free water is not available. Paine (1968: 1208) states "No other bird is more characteristic of the arid sage country of the Great Basin and Pacific slopes." Both species are essentially granivores, but extensive studies of their food habits show both may take animal material throughout the year (Kalmbach, 1914; Knappen, 1934; West, 1967; Baumgartner, 1968).

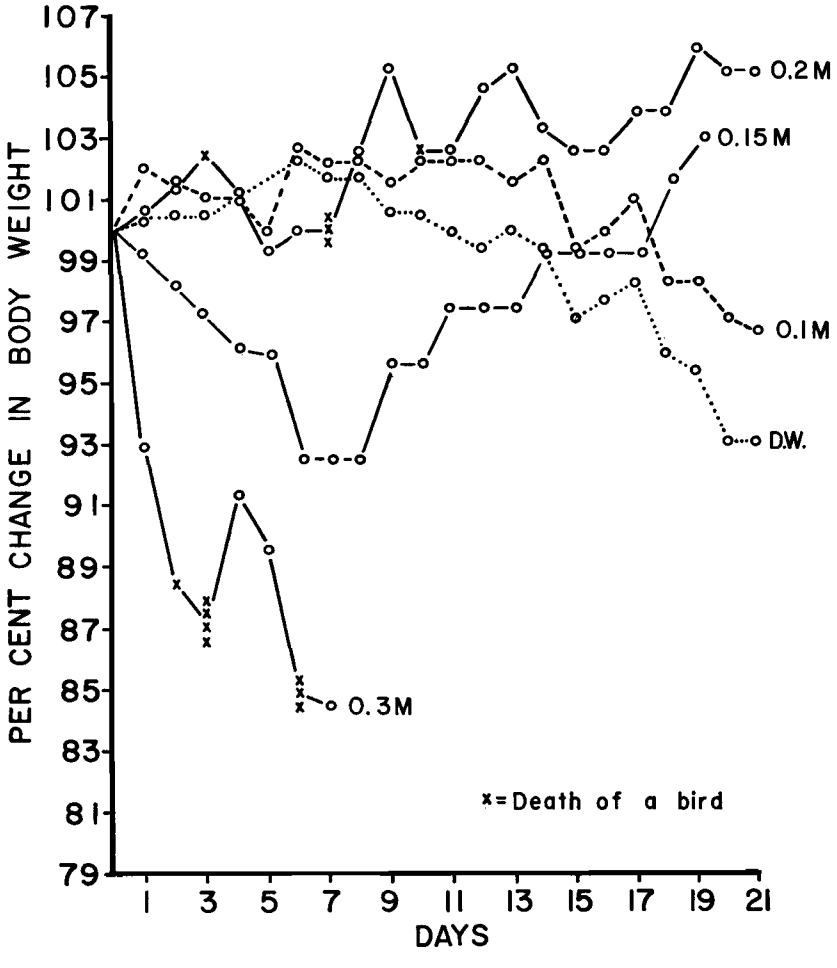

Figure 5. Mean body weights of Tree Sparrow (as per cent of initial weight) during *ad libitum* consumption of distilled water and varying molar concentrations of sodium chloride.

Tree Sparrows were found able to maintain body weight on solutions only as concentrated as 0.15 M sodium chloride. Stronger solutions produced an increased fluid consumption, a copious cloacal voidance, a loss in body weight, and death in some birds. In this respect the Tree Sparrow is more like the Mourning Dove, *Zenaidura macroura* (Bartholomew and MacMillen, 1960), Ground Dove, *Columbina passerina* (Willoughby, 1966), Red Crossbill, *Loxia curvirostra* (Dawson et al., 1965), and Green-tailed Towhee, *Chlorura chlorura* (Smith and Ohmart, 1969).

TABLE 2

WEIGHTS AND FLUID CONSUMPTION FOR BREWER'S AND TREE SPARROWS WHILE DRINKING VARIOUS SOLUTIONS AND DURING DEHYDRATION[1]

Fluid (M/NaCl)	Brewer's Sparrow weights		Tree Sparrow weights		Brewer's Sparrow fluid		Tree Sparrow fluid	
	Initial	Terminal	Initial	Terminal	Intake	SD	Intake	SD
Distilled H_2O	12.3	12.0	17.4	16.2	32.2	2.1	29.6	3.6
	(11)	(11)	(12)	(12)	(231)		(251)	
0.1	11.8	12.5	18.1	17.5	24.6	1.5	34.6	3.1
	(11)	(11)	(12)	(12)	(231)		(247)	
0.15	—	—	15.8	16.2	—	—	38.6	3.3
			(12)	(12)			(226)	
0.2	12.2	13.5	15.2	16.0	27.6	1.1	43.8	3.8
	(15)	(14)	(12)	(7)	(309)		(118)	
0.25	13.3	14.3	—	—	28.5	1.9	—	—
	(14)	(13)			(278)			
0.3	14.3	14.2	17.4	14.7	30.0	1.9	129.9	7.1
	(15)	(15)	(12)	(4)	(314)		(55)	
0.4	14.3	13.6	—	—	27.5	1.4	—	—
	(15)	(11)			(244)			
0.45	13.4	12.8	—	—	19.7	1.5	—	—
	(13)	(10)			(175)			
0.5	11.8	10.5	—	—	29.0	2.1	—	—
	(15)	(13)			(309)			
0.55	11.3	11.0	—	—	13.0	0.97	—	—
	(18)	(18)			(373)			
No fluid 20°C	12.0	11.7	—	—	—	—	—	—
	(12)	(12)						
No fluid 25°C	12.6	10.5	—	—	—	—	—	—
	(10)	(7)						

[1] N is given in parentheses.

The approximated minimum daily water requirement value of 15 per cent of the body weight slightly exceeds the 10 per cent figure reported for the House Finch (*Carpodacus mexicanus*) by Poulson and Bartholomew (1962a). Laboratory findings on the Tree Sparrow support the field observations of Baumgartner (1968) with respect to water requirements. The species' need for a substantial daily intake of water plus its inability to process electrolyte solutions much greater than 0.2 M sodium chloride must limit its movements away from water sources.

The *ad libitum* drinking pattern our Tree Sparrows exhibited agrees closely with Bartholomew and Cade's (1963) pattern A. Fluid consumption increased markedly with increasing salinity until the birds were inundating their system with a more concentrated solution than they were capable of utilizing. Despite the large amounts of fluid the Tree Sparrows consumed on a 0.3 M solution, weight loss was dramatic and death occurred.

Brewer's Sparrows maintained body weight on the most concentrated solution offered to them. Their weight loss on the 0.4 and 0.45 M concentrations was thought to result primarily from the length of time the birds were in captivity combined with experimental stress. Weight loss was also observed in the experimental birds on the 0.5 M solution, but these were new birds not experienced in drinking salt solutions. The same group, plus three new birds, did not inundate their systems with the 0.55 M solution during the 21-day test and their weight loss was not appreciable.

Apparently the Brewer's Sparrows previously on salt solutions profited from the experience and did not initially inundate their systems with the more concentrated new solutions when they were offered them. The new test birds placed on the 0.5 M salt solution showed a mean weight loss of 13 per cent of initial weight and consumed an average of 29 per cent of their body weight in fluids. These same birds, after a few days rest, survived the 21-day test on the 0.55 M salt solution with only slight fluctuations in weight and consumed 13 per cent of their body weight.

Brewer's Sparrow compares more closely with the Black-throated Sparrow, *Amphispiza bilineata* (Smyth and Bartholomew, 1966) and the Savannah Sparrow (Poulson and Bartholomew, 1962b) in its ability to utilize strong salt concentrations. The maximum solution concentration on which Brewer's Sparrow can maintain weight was not determined. Unfortunately data on electrolyte concentrations in urine and serum are lacking in Brewer's Sparrow for further comparisons.

The capacity of Brewer's Sparrow to exist on a diet of dry seeds equals that reported for the Zebra Finch, *Taeniopygia castanotis* (Calder, 1964; Cade et al., 1965), the Savannah Sparrow (Cade and Bartholomew, 1959), the Scaly-feathered Finch, *Sporopipes squamifrons* (Cade, 1965), the

Black-throated Sparrow (Smyth and Bartholomew, 1966), the Cut-throat Finch, *Amadina fasciata* (Edmonds, 1968) and domesticated stock of the Budgerigar, *Melopsittacus undulatus* (Cade and Dybas, 1962). The unwatered Brewer's Sparrows made at least three adjustments: 1) a significant reduction in activity, 2) reduction of fecal water content, and 3) possible reduction of food intake (indicated by decrease in defecation rate). Where it was determined in the above species, only the Black-throated Sparrow did not reduce its activity during water deprivation tests (Smyth and Bartholomew, 1966).

It has been demonstrated that the smaller the bird, the greater is its weight-relative evaporative water loss (Bartholomew and Cade, 1963). Thus the size of Brewer's Sparrow (10–12 g) coupled with its capacity to exist on a diet of seeds makes it an intriguing candidate for studies dealing with evaporative water loss and metabolic rate, and such studies are now in progress.

Data presented on the capacity of Brewer's Sparrows to exist only on a diet of dry seeds (Figure 3) suggest that absolute humidity has an important bearing on this capability. Studies with more refined controls and measurements of temperature, humidity and pulmocutaneous water loss are presently being conducted.

Data on weight changes of Brewer's Sparrows (Figure 2) are skewed because the test birds underwent fat deposition during part of the experiment. Testing was from distilled water to 0.45 M sodium chloride in chronological order, and from the 0.1 M solution throughout the 0.25 M solution, the birds' subcutaneous fat was seen to be increasing. Body weight stabilized throughout the 0.3 M test and began to fluctuate and decline in the 0.4 and 0.45 M experiments. Freshly-trapped birds for further experimentation the following winter confirmed suspicions that factors other than high salt concentrations contributed to the weight loss and deaths on the 0.4 and 0.45 M solutions.

Field and laboratory data combined yield a clearer understanding of how Brewer's Sparrow may satisfy its daily nutritional and water requirements. Contents of 46 stomachs of this species taken during the hotter months of May through July contained better than 75 per cent insect material (Kalmbach, 1914). We suspect Brewer's Sparrow satisfies its daily water requirement from food intake; this assumption agrees with findings for the Black-throated Sparrow (Smyth and Bartholomew, 1966) and more detailed foraging results reported for the Rufous-winged Sparrow, *Aimophila carpalis* (Ohmart, 1969). If Bartholomew and Cade (1963: 518) are correct in stating "Most, if not all land birds must rely on their kidneys for salt excretion" (in the absence of a salt-secreting gland), then the small Brewer's Sparrow, with a low daily water requirement coupled

with an efficient renal system, has adjusted both behaviorally and physiologically to its xeric environment. In the Tree Sparrow no specialized means for water conservation beyond the normal terrestrial requirements appear to have evolved, reflecting a greater water availability in the habitat.

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SUMMARY

Brewer's Sparrows consumed 32.2 per cent of their body weight when allowed *ad libitum* consumption of distilled water. Fluid intake remained about the same through 0.1 to 0.5 M concentrations of sodium chloride. A decrease in consumption was observed on the 0.55 M solution, but the 18 test birds maintained their body weight. Twelve birds at 20°C and 70 per cent relative humidity survived the 21-day test solely on a diet of seeds. Weight loss was rapid initially, but most birds regained their weight by the end of the experiment. At 25°C and about 38 per cent relative humidity, 7 of 10 birds survived 14 days without free water. The unwatered birds at 20°C reduced their activity significantly, curtailed water loss in the feces, and apparently reduced their food intake.

Tree Sparrows drank 29.6 per cent of their body weight daily when allowed *ad libitum* consumption of distilled water. Fluid intake increased on progressively stronger sodium chloride solutions. They were unable to maintain body weight on solutions stronger than 0.15 M sodium chloride. Mean minimum daily water requirements were 15 per cent of the body weight.

Selection pressure for water conservation has apparently been low in the habitat occupied by the Tree Sparrow, but the congeneric Brewer's Sparrow has evolved efficient systems to conserve water. Their low water requirements and ability to maintain body weight on salinities equaling sea water are unusual among land birds.

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