WATER ECONOMY OF THE WHITE-CROWNED SPARROW AND ITS USE OF SALINE WATER

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The Gambel White-crowned Sparrow (*Zonotrichia leucophrys gambelii*) is a conspicuous winter visitant in California, occurring practically everywhere in the state below the snow level and east of the humid coast belt. Included in its winter range are the arid portions of southern California and adjacent regions (Grinnell and Miller, 1944). It is one of the most conspicuous winter-visitant sparrows in Joshua Tree National Monument, located in the transition between the Mojave Desert and the Colorado Desert in California (Miller and Stebbins, 1964). In addition Banks (1963) reports the occurrence of large flocks of White-crowned Sparrows (not subspecifically designated) on several of the desert islands in the Gulf of California during March and April 1962.

The physiology of photoperiodically influenced phenomena in the White-crowned Sparrow has been intensively investigated by Farner and his colleagues (for example, Farner, 1964); King (1964) has recently reported on its metabolism and body temperature, and Morton (1965) has analyzed its food intake and feeding periodicity. In spite of these many investigations and in spite of its frequent habitation of xeric situations in the winter, information on the water relations of the White-crowned Sparrow is fragmentary.

This investigation undertakes to examine the water economy of the White-crowned Sparrow in order to expand our knowledge of its general biology. Specifically, the study attempts to assess the ability of the White-crowned Sparrow to maintain water balance on the desert and to utilize saline water that may be present in desert springs and as sea water in portions of its winter range.

MATERIALS AND METHODS

The 39 Gambel White-crowned Sparrows employed in this investigation were captured between November 1963 and March 1964 near Claremont, Los Angeles County, California. They were confined in an outdoor aviary until needed for experimentation. During experimentation the birds were housed individually in cages measuring 10 × 10 × 10 inches in a windowless room on a 12-hour photoperiod (lights on from 0400 to 1600 hours). Each cage was equipped with an inverted graduated cylinder with an L-shaped drinking tube for measuring fluid intake. Except for studies of water deprivation and utilization of succulent food the birds had unrestricted access to drinking water. The birds were weighed to the nearest 0.1 g on alternate days at the beginning of the dark period. Water intake was measured daily to the nearest 0.5 ml. One drinking device was used as a control to measure evaporation.

It was found that the birds could not maintain normal body weight on a carbohydrate-rich diet of mixed bird seed. When provided in excess with chick-starter mash containing 20 per cent protein, the birds remained in excellent condition.

The investigation extended from April through July 1964, during which time the room temperature ranged from 20 to 24°C, and relative humidity fluctuated between 30 and 49 per cent. Filtered sea water with a salinity of 33 ppt was obtained from Marineland of the Pacific, Palos Verdes, California. The various drinking solutions were made by adding distilled water to sea water. Before making initial measurements each bird was allowed four to seven days of adjustment to laboratory conditions with food and tap water freely available. Unless otherwise specified all tests were run for seven days, and the birds were taken directly through the series of progressively more concentrated drinking solutions without intervening periods of fresh-water drinking.

The tests for salinity discrimination involved six birds in a cage measuring 17 × 24 × 30 inches. Four drinking devices were arranged at 90° intervals on a ring stand. The two solutions to be tested were put in alternate drinking devices, and the ring stand was rotated 90° daily to minimize the effect of clues other than taste.

To assess the importance of succulent food as a water source, five birds were deprived of drinking water and provided with either *Tenebrio* larvae (62 per cent water by weight) or fresh halved tomatoes (95.4 per cent water by weight), together with chick-starter mash (9.2 per cent water by weight).

RESULTS

Body weights. The mean body weights of birds in positive water balance increased throughout the experimental period. These birds weighed 26.9 g (12 birds), 30.3 g (12 birds), 31.2 g (12 birds), and 31.6 g (9 birds) on 1 April, 23 April, 26 May, and 3 July 1964, respectively. This weight gain is to be expected for birds kept in the spring on a 12-hour photoperiod, and is attributable to vernal premigratory fattening. This weight gain resembles that reported by King and Farner (1959) for captive male White-crowned Sparrows held in outdoor cages during the spring in Pullman, Washington.

Tap water. The consumption of tap water by 12 sparrows for seven days averaged 45.6 ± 3.5 per cent of body weight per day (fig. 1). During this period the birds gained an average of 0.5 ± 0.4 per cent of initial body weight per day (fig. 2).

Sea-water dilutions. The mean daily intake of serial dilutions of sea water increased directly with concentration within the range offered: 12.5 to 50 per cent sea water (fig. 2). Through 37.5 per cent sea water the mean daily consumption of each solution was significantly greater than that of the next less concentrated solution. The drinking of 25 per cent sea water by two groups of birds, one transferred directly from 12.5 per cent sea water and one from tap water, was essentially the same. Drinking of 50 per cent sea water was insignificantly greater than that of 37.5 per cent sea water, but was considerably more variable.

While being transferred from tap water to 12.5 per cent sea water and then to 25 per cent sea water, White-crowned Sparrows gained weight at about the same rate as on tap water; however, 11 birds taken directly from tap water to 25 per cent sea water were able only to maintain weight on this latter solution (fig. 2). On 37.5 and 50 per cent sea water the birds lost weight at the rates of 0.9 and 3.9 per cent of initial body weight per day, respectively. The losses in weight while drinking these latter two solutions were both significantly less than when water was withheld completely (fig. 2).

Water deprivation. Since Cade and Bartholomew (1959) found that prior drinking of maximally tolerable saline solutions enhanced the capacity of a salt-tolerant form of the Savannah Sparrow (*Passerculus sandwichensis*) to resist dehydration, two samples of well-hydrated White-crowned Sparrows were deprived of water until death. One sample was kept on tap water prior to water deprivation, while the other was hydrated first on 25 per cent sea water. The data for both samples are sum-

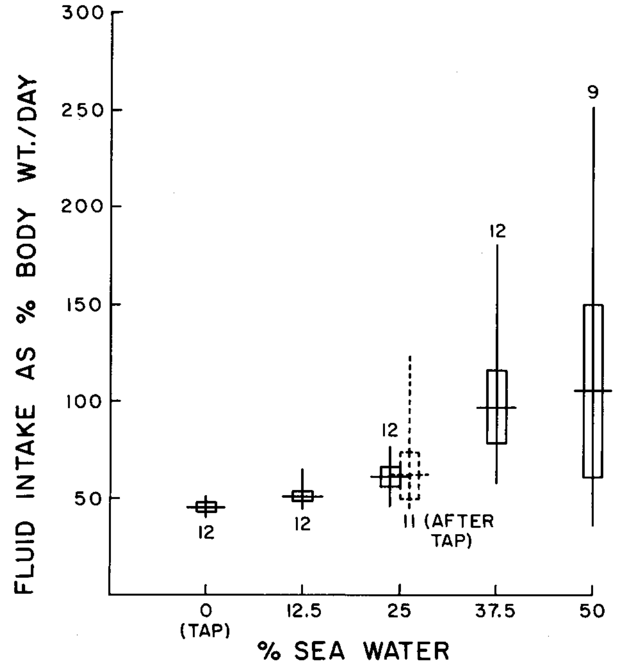

Figure 1. Consumption of tap water and various dilutions of sea water by White-crowned Sparrows. The solid-lined symbols represent drinking by birds that were taken directly through progressively more concentrated solutions. The dashed-lined symbol represents drinking by birds transferred directly from tap water. Vertical lines indicate ranges. Horizontal lines indicate means ($\overline{X}$). Rectangles inclose the interval $\overline{X} \pm 2$ SE. The numbers represent sample sizes. All tests were run for seven days except on 50 per cent sea water, which was run from five to seven days.

marized in figures 2 and 3, and demonstrate that both lost weight at nearly the same rate and survived about as long. Since there were no significant differences between the two water-deprivation samples in any of the parameters analyzed, the data for both samples are combined for comparative purposes in table 1.

Salinity discrimination. The data from the salinity discrimination tests are summarized in table 2, and show that in every instance the sparrows preferred the less concentrated of the two solutions offered. Of all the combinations of drinking solutions offered, only the preference between tap water and 12.5 per cent sea water was not significantly different.

Utilization of succulent food. Five White-crowned Sparrows kept on tap water for several days and then offered only succulent food as a water source were able to gain weight either on tomatoes or on *Tenebrio* larvae. After eight days on tomatoes the five birds weighed on the average 104.5 per cent of initial body weight; the mean weight of the birds after five days on *Tenebrio* larvae was 113.1 per cent of initial body weight.

DISCUSSION

As might be expected because of their preference for rather moderate environmental conditions, Gambel White-crowned Sparrows show no conspicuous physiological adaptations in their water relations. Their daily intake of tap water (45.6

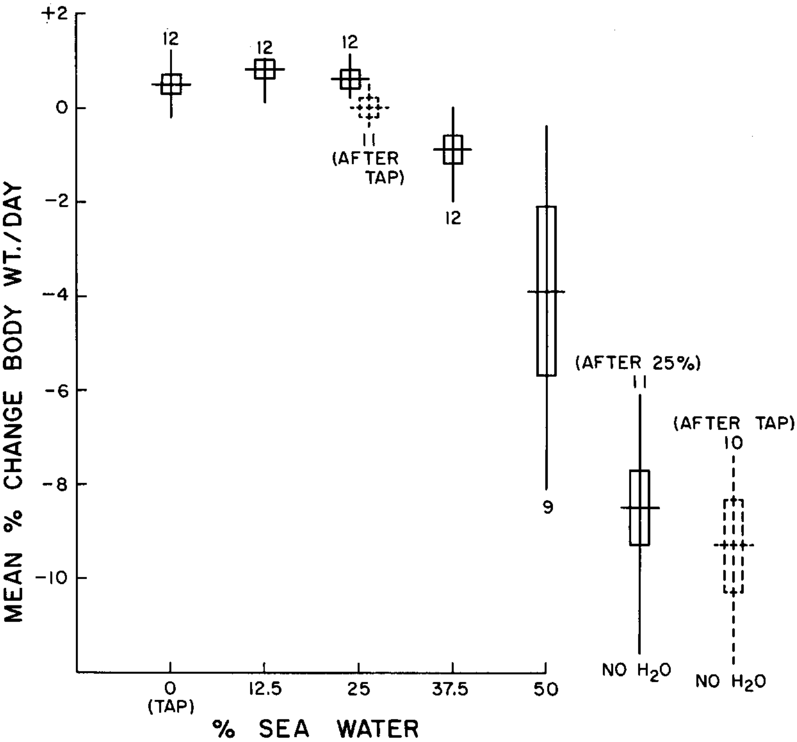

Figure 2. Effects of drinking tap water and various dilutions of sea water and of water deprivation on body weight in White-crowned Sparrows. Symbols as in figure 1.

per cent of body weight) is unusually great for birds of this size (27.1 g); the predicted daily intake would be 25 to 30 per cent of body weight (Bartholomew and Cade, 1964). The measurements of tap-water consumption were made 1 to 7 April 1964. Since all birds had been subjected to natural photoperiod followed by at least eight days of a 12-hour photoperiod just prior to and continuing through measurements, the measurement period could very likely have coincided with the onset of vernal *Zugunruhe* (see King and Farner, 1963). No attempt was made to detect *Zugunruhe,* but such nocturnal activity with related high rates of pulmocutaneous water loss might well explain the magnitude of the voluntary consumption of tap water, and of the ensuing sea-water solutions.

The ability of the White-crowned Sparrow to utilize saline solutions is very limited, and is similar to that of the Mourning Dove, *Zenaidura macroura* (Bartholomew and MacMillen, 1960). Like Mourning Doves, White-crowned Sparrows apparently are incapable of maintaining weight while drinking hypertonic saline solutions. The sparrows gain weight on 25 per cent sea water (approximately 270 milliosmoles) but lose weight on 37.5 per cent sea water (approximately 400 milliosmoles); although plasma osmotic pressure was not measured in White-crowned Sparrows it is assumed to be about the same as that of House Finches (*Carpodacus mexicanus*) and of Savannah Sparrows (*Passerculus sandwichensis brooksi*), that is, approximately 370 milliosmoles (Poulson and Bartholomew, 1962a, b). The only other

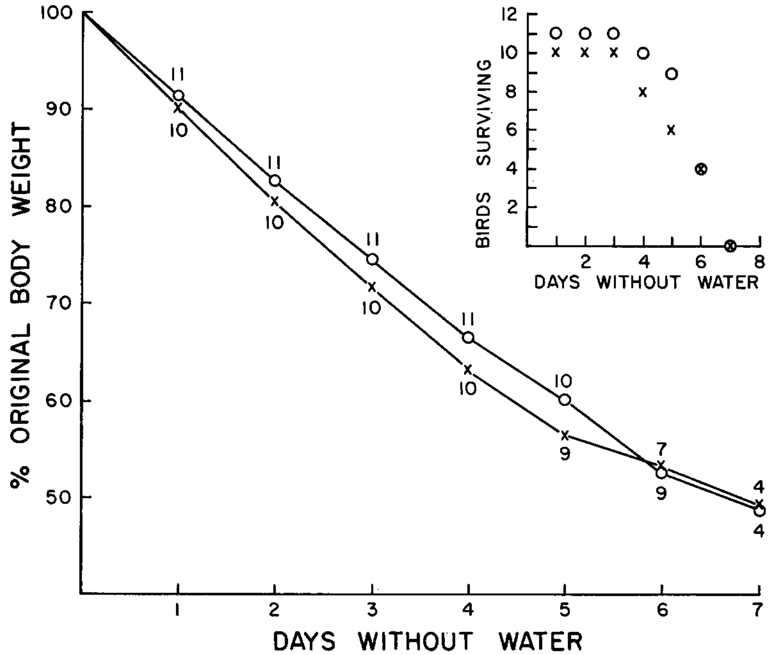

Figure 3. Effects of water deprivation on body weight and survival in White-crowned Sparrows. X represents birds deprived of water after having been hydrated on tap water; 0 represents birds deprived of water after hydration on 25 per cent sea water. The numerals represent the number of birds surviving on the previous day and either continuing to survive or dying on the day of the weight measurement.

data available on the utilization of saline water by *Zonotrichia leucophrys* are those of Oksche *et al.* (1963) who report that *Z. l. gambelii* from eastern Washington lost weight while drinking 0.3 to 0.5 M NaCl solutions, but maintained weight on solutions of 0.2 to 0.3 M NaCl. These latter two NaCl solutions are osmotically equivalent to about 36 and 55 per cent sea water, respectively. These differences in the ability of White-Crowned Sparrows to utilize osmotically equivalent concentrations of sea water and NaCl solutions are probably explicable in terms of a greater difficulty in handling the more complex ionic composition of the sea-water solutions. Although White-crowned Sparrows lost weight while drinking both 37.5 and 50 per cent sea water, these losses were less than when water was withheld completely (fig. 2), demonstrating that some physiologically useful water may be obtained from even hypertonic solutions.

White-crowned Sparrows are relatively intolerant of water deprivation, and die within a week when kept on a dry diet and in the absence of temperature stress (figs. 2 and 3). Their survival when deprived of water is probably even further curtailed by the noticeable decrease in food consumption after several days. The loss in body weight (8.9 per cent of initial body weight per day) during water deprivation in our birds kept on a 12-hour photoperiod compares favorably with the 12.4 to 13.7 per cent loss reported by Kawashima *et al.* (1964) for water-deprived birds from Pullman, Washington, exposed to 16 hours of light per day;

TABLE 1

COMPARISON OF WATER ECONOMIES OF WHITE-CROWNED SPARROWS AND MIGRATORY SAVANNAH SPARROWS

	Zonotrichia leucophrys	*Passerculus sandwichensis*[a]
Body weight	ca. 30 g	15–20 g
Water consumption		
Highest dilution of sea water on which body weight can usually be maintained	25%	50%
Mean daily ad-libitum consumption of tap or distilled water expressed as per cent body weight per day	45.6	28
Water deprivation		
Mean daily loss expressed as per cent initial body weight per day	8.9	<5.0
Mean per cent initial body weight at death	51.0	?
Mean days to death	6.0	?
Maximum days to death	7.0	>10

[a] From Cade and Bartholomew, 1959.

one would expect a greater daily loss for birds on a longer photoperiod, which would prolong the higher diurnal body temperatures and concomitant high pulmocutaneous water loss.

The only other closely related bird that generally corresponds in habit and habitat with the White-crowned Sparrow and for which comparative data are available is the migratory Savannah Sparrow (Cade and Bartholomew, 1959). The White-crowned Sparrow is far less efficient in every respect in its water relations than is the Savannah Sparrow (table 1). The more economical water relations of the migratory races of the Savannah Sparrow may be an adaptation to their frequent occurrences in coastal salt marshes and alkaline desert sinks; Savannah Sparrows that are permanent residents of salt marshes are even more economical.

TABLE 2

DISCRIMINATION BY WHITE-CROWNED SPARROWS BETWEEN VARIOUS DRINKING SOLUTIONS

Drinking solutions	ml fluid consumed/day			No. birds	No. days
	$\bar{X} - 2$ SE	$\bar{X}$	$\bar{X} + 2$ SE		
Tap water vs.	37.5	61.8	86.1	6	7
12.5 per cent sea water	26.4	36.3	46.2		
Tap water vs.	75.9	85.5	95.0	6	7
25 per cent sea water	9.5	13.6	17.6		
Tap water vs.	65.4	74.2	83.1	6	6
37.5 per cent sea water	4.5	8.1	11.8		
12.5 per cent sea water vs.	71.0	77.7	84.4	6	8
25 per cent sea water	11.1	16.4	21.7		
12.5 per cent sea water vs.	78.0	86.5	95.1	6	7
37.5 per cent sea water	3.3	5.2	7.1		
25 per cent sea water vs.	93.6	101.5	109.4	6	7
37.5 per cent sea water	1.3	2.0	2.7		

The weight-response and drinking data for 25 per cent sea water suggest the possibility of limited acclimatization to a more saline drinking solution by prior experience with one of lower salinity (figs. 1 and 2). Those birds transferred directly from tap water to 25 per cent sea water drank the same amount of 25 per cent sea water as those transferred from 12.5 per cent. Yet those transferred from tap water were able only to maintain weight on the 25 per cent solution, while those transferred from 12.5 per cent gained weight significantly. However, it is doubtful that this slight acclimatization could be of survival significance. Water-deprived birds previously given tap water or 25 per cent sea water lost weight at about the same rate and survived equally long (figs. 2 and 3).

In terms of habitation of semidesert and desert situations we must conclude that Gambel White-crowned Sparrows show no conspicuous adaptations in their water economy. Their occurrence on the desert is restricted to the winter period of minimal heat stress and maximal precipitation, during which time their water needs can be readily met at water holes and by eating succulent vegetation and insects. They seem to be geared to the continual availability of a hypotonic water source, and the only conceivable role hypertonic water might serve is to prolong survival for a few days in times of severe stress or when migratory routes pass through desert or coastal areas where no fresh water is available. Thus the White-crowned Sparrow is one of the apparently many coincidental "desert birds" that owe their existences, as it was so aptly suggested by Miller (1963), to several inherently avian preadaptations in physiology.

SUMMARY

Gambel White-crowned Sparrows captured on their winter range in southern California have unusually high voluntary water intake; this increases directly with concentration up through dilutions of 50 per cent sea water. They can maintain or gain weight on hypotonic drinking solutions (tap water, 12.5 and 25 per cent sea water), but lose weight on hypertonic solutions (37.5 and 50 per cent sea water).

When offered choices of drinking solutions, White-crowned Sparrows invariably prefer the least concentrated; the only solutions between which they could not discriminate were tap water and 12.5 per cent sea water.

White-crowned Sparrows lose weight at the rate of about 9 per cent of initial body weight per day when deprived of water, and survive for a maximum of seven days.

There appear to be no unique physiological adaptations that equip White-crowned Sparrows for existence in arid regions. Instead, they rely upon ordinary avian capacities and occupy desert areas only during the winter when sufficient water and succulent food are more readily available.

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