WATER ECONOMY OF THE CALIFORNIA QUAIL AND ITS USE OF SEA WATER

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The California Quail, *Lophortyx californicus,* occurs widely in grasslands, brushlands, and woodlands from southern Oregon to southern Baja California, but it does not occupy high mountains or extreme desert areas. It is often found in marginal desert regions where water is frequently mineralized, on several offshore islands, and in areas adjacent to the sea. Therefore, the possibility exists that it may use saline waters for drinking. Consequently, quantitative information concerning the water requirements of the quail and its ability to obtain water from highly saline sources should allow a more precise understanding of the ways in which this highly successful species has been able to occupy areas of seasonal drought and high summer temperatures. Although extensive quantitative data are lacking, it is known that neither the California Quail (Sumner, 1935) nor the Gambel Quail, *Lophortyx gambelii* (Gullion, 1960), requires drinking water for survival or breeding as long as succulent vegetation is available.

Materials and Methods

Our observations were made on adult representatives of the widely distributed subspecies *L. c. brunnescens.* The 47 birds used were trapped in the Santa Monica Mountains on, or adjacent to, the UCLA campus between December 1958 and September 1959. The birds were housed in a windowless room on a 12-hour photoperiod (lights on from noon to midnight). Mixed bird seed with a water content varying between 9 and 10 per cent as determined by drying to a constant weight at 100° C was available at all times. The birds had free access to drinking solutions except during studies on water deprivation and minimum water requirements. Room temperatures varied between 18 and 26° C. Humidity was not controlled. Except during the tests of salinity discrimination the birds were housed individually in cages measuring 25 x 25 x 25 cm. The birds were weighed to the nearest tenth of a gram on Mondays, Wednesdays, and Fridays near the end of the dark period. The initial body weights used in our calculations are not the field weights, but the weights after three or four days of maintenance under laboratory conditions with food and distilled water freely available. In those cases in which experimental treatment resulted in significant changes in body weight and the birds were to be used again, they were given distilled water until their weights returned to the normal range and were stable for several days.

The water drunk was measured daily to the nearest 0.5 ml by the use of graduated cylinders equipped with "L"-shaped drinking tubes. The birds were trained to use the tubes by placing a watering cup nearby for several days. One drinking device was used to determine evaporation. Filtered sea water with a salinity of 31.5 parts per 1,000 was obtained from Marineland of the Pacific, Palos Verdes, California. The various dilutions of sea water were made by the addition of distilled water.

The tests for salinity discrimination were run on groups of birds in a cage measuring 37 x 45 x 60 cm. Four drinking devices were arranged around a ring stand at intervals of 90 degrees. The two solutions to be tested were put in alternate drinking devices. To minimize the use of clues other than taste, the ring stand was rotated 90° daily.

RESULTS

The California Quail shows some sexual dimorphism in weight. The mean body weight of the experimental population after acclimation to laboratory conditions was 138.9 g (males, 142.5; females, 135.3).

Dehydration. The changes in body weight of seven females and five males deprived of water but given mixed bird seed *ad libitum* were followed until death. None of the birds was able to maintain body weight. The mean loss was 1.6 ± 0.4 per cent of initial body weight per day, and in all except one case the decline in body weight was essentially linear. In general, the males survived longer and lost weight less rapidly than the females, but the relative weights at death of males and females were not significantly different (Table 1).

Distilled water. The consumption of distilled water by 20 quail tested individually for periods of from five to eight days averaged 5.2 ± 2.5 per cent of body weight per day (Figure 1). The quail

TABLE 1

RESPONSES OF FIVE MALE AND SEVEN FEMALE CALIFORNIA QUAIL TO WATER DEPRIVATION

	Males	*Females*
Days of survival		
Minimum	28	23
Maximum	48	37
Mean	40.6	28.1
Mean % initial wt. lost per day	1.3	1.8
Mean % initial wt. at death	48.4	51.9

showed a slight net gain in weight (Figure 2). The weight-relative water consumption of the females was slightly but insignificantly greater than that of the males (5.7 versus 4.3 per cent body weight per day).

Minimum water requirements. By successively halving the previously determined *ad libitum* consumption of distilled water of each of 10 quail, we determined the daily water ration below which each bird was unable to maintain a constant body weight. The quail were kept on the minimum daily ration for periods of from seven to 14 days.

The mean minimum water consumption adequate for weight mainte-

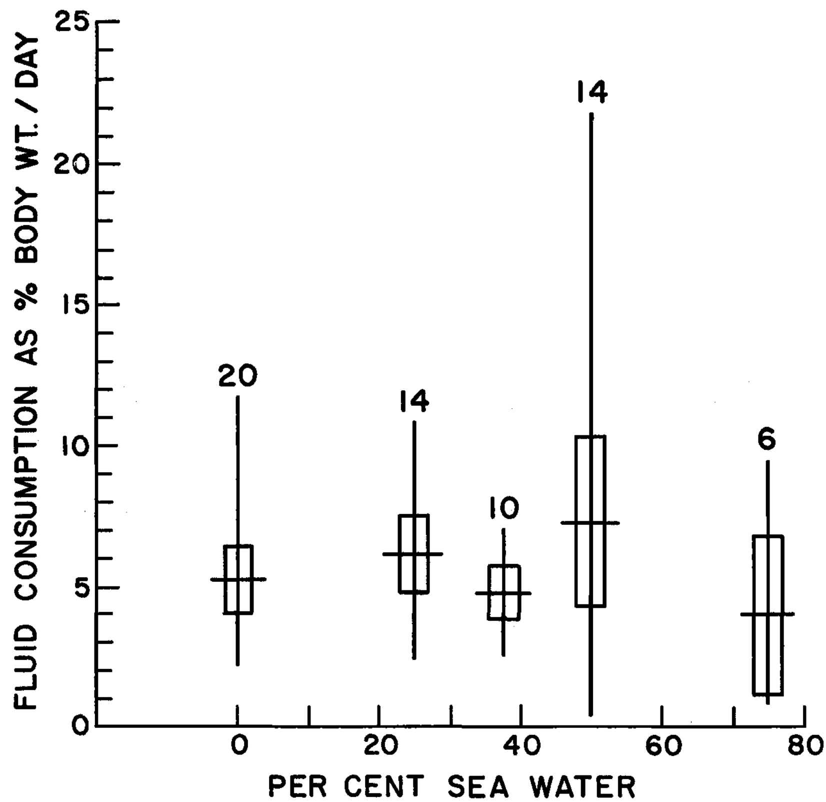

Figure 1. The relations of various dilutions of sea water to drinking by California Quail. The vertical lines indicate the range. The horizontal lines represent the means (M). The rectangles inclose the interval M — $2\sigma_M$ to M + $2\sigma_M$. The numbers indicate the size of the sample. Duration of tests: 25 per cent, 7 days; 37.5 per cent, 14 days; 50 per cent, 9-17 days; 75 per cent, 5 days.

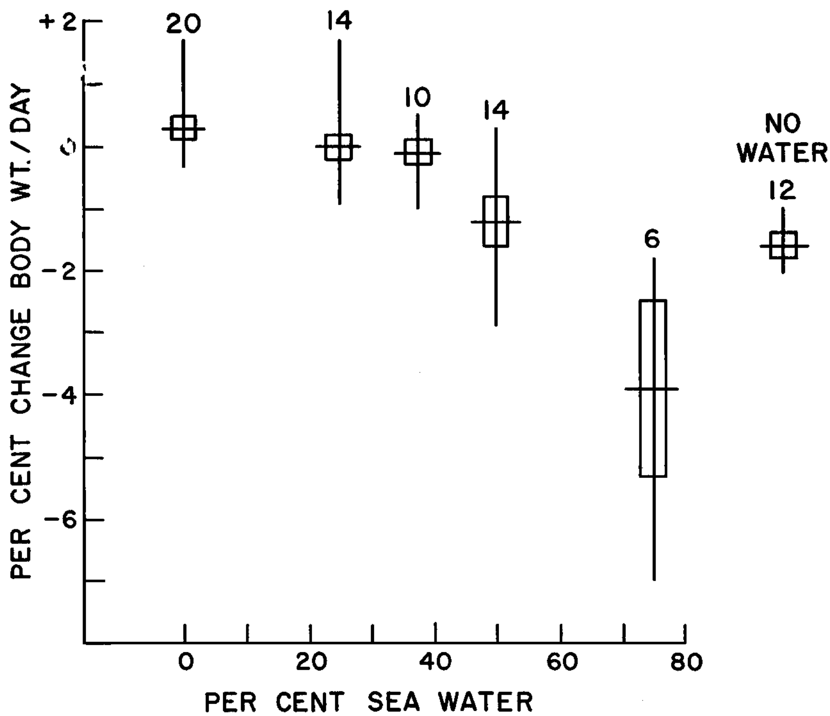

Figure 2. The effects of water deprivation and drinking of various dilutions of sea water on the body weight of California Quail. Symbols and duration of tests as in Figure 1.

nance was 1.8 per cent body weight per day (range 0.9 to 3.6). The females required slightly but insignificantly more water than the males (2.1 versus 1.4 per cent body weight per day).

Sea water. The mean consumptions of all dilutions of sea water tested (25, 37.5, 50, and 75 per cent) did not differ significantly from the consumption of distilled water. However, the performance of the birds offered 50 per cent sea water was extremely variable (Figure 1). Although water ingestion was relatively unaffected by salinity, the birds tended to lose weight when drinking the more saline solutions. The mean daily loss in body weight of birds drinking 50 per cent sea water was not significantly different from that of birds deprived of drinking water. The birds on a regimen of 75 per cent sea water lost more than twice as much weight per day as birds deprived of drinking water (Figure 2).

We undertook to test the relation of water deprivation to ability to process concentrations of sea water greater than 50 per cent. Ten quail were deprived of water for seven days and then offered 50 per cent sea water for seven days. Those individuals that gained weight while drinking 50 per cent sea water were then given distilled water until they regained all the weight they had lost during the period of water deprivation. They were then dehydrated again for seven days and offered 60 per cent sea water for seven days. This procedure was also used for 70 per cent sea water. Since the birds tested on 60 per cent and 70 per cent sea water were selected on the basis of their ability to process saline solutions, these experiments should indicate maximal abilities to obtain physiologically useful water from dilutions of sea water. Of the 10 birds tested, seven could use 50 per cent, four could use 60 per cent, and one could use 70 per cent sea water. No birds were able to maintain weight on concentrations of sea water exceeding 70 per cent. The birds that obtained physiologically useful water from the test dilutions of sea water drank much smaller quantities than those that lost weight on the same salinities (Table 2). The latter group lost weight essentially as rapidly as birds deprived of water.

TABLE 2

ABILITY OF CALIFORNIA QUAIL DEPRIVED OF WATER FOR SEVEN DAYS TO OBTAIN WATER FROM VARIOUS DILUTIONS OF SEA WATER

(Duration of Experiment, Seven Days. Weight Changes Are Expressed as Per Cent Initial Body Weight and Drinking Is Expressed as Per Cent of Body Weight Per Day.)

	Per cent sea water		
	50	*60*	*70*
Number of birds tested	10	7	4
Mean daily fluid consumption	16.5	17.2	12.4
Mean daily weight change	+ 0.6	– 0.1	– 1.2
Birds gaining weight			
Number	7	4	1
Mean daily fluid consumption	11.2	8.9	8.9
Mean daily weight change	+ 1.7	+ 1.1	0.0
Birds losing weight			
Number	3	3	3
Mean daily fluid consumption	29.0	28.3	13.6
Mean daily weight change	– 1.8	– 1.6	– 1.5

Use of succulent food. To obtain quantitative data on the use of succulent food as a water source by California Quail we deprived eight birds of water for six days and then supplemented their diet of dry grain with shredded cabbage that contained 90 to 92 per cent water by weight. Within four days all the birds regained the weight lost during six days of water deprivation. To extend the findings above, two freshly captured subadult California Quail were placed on a diet of dry grain and meal worms (*Tenebrio* larvae). During six days the female increased in weight from 107.6 to 129.7 g and the male increased from 101.3 to 125.1 g—gains of more than 3.5 per cent per day. It is obvious that either insects or succulent vegetation offer an adequate source of water for this species.

Salinity discrimination. The quail showed no significant preference for distilled water as compared with 25 per cent sea water, or for 12.5 per cent as compared with 25 per cent sea water (Table 3). They showed, however, a marked preference for 25 per cent as compared with 37.5 per cent sea water. Since California Quail can maintain weight without difficulty on salinities as high as 37.5 per cent sea water without significant changes in fluid ingestion, we assume that the preferences demonstrated above are a function of taste rather than physiological capacity.

TABLE 3

DISCRIMINATION BY CALIFORNIA QUAIL BETWEEN SOLUTIONS OF DIFFERENT SALINITIES

Test solutions	*Mean ml/bird/day*	*Length of test in days*	*No. birds*	*t*	*p*
Distilled water vs. 25 per cent sea water	3.7 / 3.4	6	9	0.41	> 0.1
12.5 per cent sea water vs. 25 per cent sea water	5.9 / 7.7	7	3	0.84	> 0.1
25 per cent sea water vs. 37.5 per cent sea water	10.3 / 3.2	7	8	7.97	< 0.01

DISCUSSION

Physiology. The California Quail, unlike the House Finch *(Carpodacus mexicanus)* (Bartholomew and Cade, 1958), the Savannah Sparrow *(Passerculus sandwichensis)* (Cade and Bartholomew, 1959), and the Mourning Dove *(Zenaidura macroura)* (Bartholomew and MacMillen, 1960), shows no significant change in fluid consumption with change in salinity. However, even though the amount they drink is independent of salinity, normally hydrated quail lose weight when drinking solutions more concentrated than 37.5 per cent sea water.

This weight loss is not necessarily caused by inability to process these salinities. Since these quail show a marked preference for solutions less concentrated than 25 per cent sea water and since they can easily survive for several weeks without drinking, they appear voluntarily to undergo dehydration rather than drink the 50 per cent sea water in quantities sufficient to maintain a positive water balance. If water is withheld so that the birds become moderately dehydrated and then are offered 50, 60, or 70 per cent sea water, they at once drink copiously, and some individuals regain the weight previously lost during the period of dehydration. With the restricted data available to us it is not possible to say whether or not dehydration induces a change in physiological capacity for processing saline water. However, even in the absence of direct measurements it appears that at least some California Quail can concentrate salts in the urine to a level well above that which could be expected in the serum; a few individuals maintained a positive water balance on 60 and on 70 per cent sea water. This is the equivalent of 0.3 to 0.35 M NaCl, which is about twice the osmotic pressure of the blood of the domestic chicken (Korr, 1939:177). The ability of California Quail to survive for a month or more on a dry diet without drinking is consistent with the observation (Bartholomew and Dawson, 1953) that in this species pulmocutaneous water loss is only slightly greater than metabolic water production. The capacity for prolonged survival on a dry diet appears also to be dependent on the fact that this species can tolerate a reduction in body weight of approximately 50 per cent during water denial. No other wild birds for which data are available have so great a tolerance of dehydration.

Ecology. The mean weight loss of California Quail on a dry diet without drinking water is about 1.6 per cent initial body weight per day, while the minimum water required for maintenance of body weight averages 1.8 per cent body weight per day. The rate of weight loss during dehydration is constant. It thus appears that these birds continue to eat normally in the absence of drinking water. Such a response should be of great utility for a bird living in an area of seasonal drought. The observations of Sumner (1935:192) indicate that California Quail do not visit water holes after the first autumnal rains, and, further, in the presence of green vegetation do not require drinking water even during the breeding season. Our laboratory data give a quantitative demonstration of the ease with which members of this species can satisfy their water needs by eating succulent food and insects. California Quail need obtain only a couple of grams of water per day from their food. Therefore, except during the most arid times of the year or during periods of unusually severe heat stress the securing of adequate supplies of water should present little difficulty.

California Quail prefer water of low salinity and will voluntarily undergo short periods of dehydration rather than drink adequate quantities of solutions more concentrated than 37.5 per cent sea water. Nevertheless, when they become sufficiently dehydrated, they will drink even 70 per cent sea water, from which at least some individuals can obtain adequate supplies of water. Thus, under conditions of severe drought or unusual heat stress saline springs and brackish water could be ecologically significant to the quail living on islands or in marginal desert areas. It appears highly probable that the quail on the offshore islands of California and northern Mexico utilize the abundant succulent vegetation rather than undiluted sea water; on a regimen of 75 per cent sea water captive individuals lose weight at a rate significantly greater than when water is withheld completely.

From a physiological aspect the California Quail is conspicuously better adjusted to water deprivation and to the drinking of saline water than is the Mourning Dove (Table 4). Nevertheless the California Quail is confined to brushlands and grasslands on the margins of the desert while the Mourning Dove ranges widely throughout the desert. This physiological paradox is at least partially explicable in behavioral terms. The doves are powerful fliers that can readily travel many miles to water while quail are weak fliers that are hardly more mobile than a medium-sized mammal. Hence, if this quail is to occupy even semidesert regions, it needs to be physiologically better

TABLE 4

COMPARISON OF WATER ECONOMIES OF THE MOURNING DOVE AND THE CALIFORNIA QUAIL

(The Data on *Zenaidura* Are from Bartholomew and MacMillen (1960).)

	Zenaidura	*Lophortyx*
Water deprivation		
Mean daily loss expressed as per cent initial body weight per day	4.8	1.6
Mean per cent initial body weight at death	63.3	50.4
Mean days of survival	7.3	33.3
Water consumption		
Highest concentration of sea water on which body weight can usually be maintained	25%	50%
Mean daily *ad libitum* consumption of distilled water expressed as per cent body weight per day	9.9	5.2

adapted to aridity than the dove, despite the fact that the dove successfully occupies the desert while the quail cannot.

ACKNOWLEDGMENTS

This study was aided in part by a contract between the Office of Naval Research, Department of the Navy, and the University of California, NONR 233 (61).

SUMMARY

On a dry diet captive California Quail showed a mean weight loss of 1.6 per cent of initial body weight per day. Mean length of survival without water was 28.1 days for females and 40.6 days for males. *Ad libitum* consumption of distilled water averaged 5.2 per cent body weight per day, and the minimum consumption of water on which body weight could be maintained averaged 1.8 per cent body weight per day.

Ad libitum drinking by normally hydrated birds of 25, 37.5, 50, and 75 per cent sea water did not differ significantly from that of distilled water, but birds drinking 50 and 75 per cent sea water lost weight. Daily weight loss of birds drinking 75 per cent sea water exceeded that of birds from which water was withheld completely.

After being deprived of water for a week, seven of 10 birds were able to maintain weight on 50 per cent sea water, four of 10 were able to maintain weight on 60 per cent sea water, and one bird was able to maintain weight on 70 per cent sea water.

Either succulent vegetation or insects offer an adequate water source for California Quail.

California Quail showed no significant preference for distilled water as compared with 12.5 and 25 per cent sea water, but chose 25 per cent sea water in preference to 37.5 per cent.

The low water requirements and the tolerance of dehydration of California Quail allow them to remain independent of surface water as long as green vegetation or insects can be found. Under conditions of severe drought or heat stress brackish or saline water may contribute to survival, but California Quail apparently cannot utilize the sea as a water source. Although they are not successful in deserts, California Quail have lower water requirements, greater tolerance of dehydration, and can utilize water of higher salinity than the Mourning Dove, which is a conspicuously successful desert species. This situation is probably related to the limited mobility of the quail, which precludes periodic visits to distant water sources.

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