ADAPTATIONS SHOWN IN SELECTION OF FOOD BY GAMBEL QUAIL

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The Gambel Quail (*Lophortyx gambelii*) is resident in desert and semi-desert areas of Nevada, California, Arizona, New Mexico, and northern México. It exhibits several adaptations to these arid areas, one of the most significant being its ability to select green food in sufficient quantity to provide not only required nutrients but also adequate moisture (Hungerford, 1960). This ability to utilize the moisture from plants makes it possible for populations of quail to thrive in areas where no open water exists. In its seasonal changes in food selection, the Gambel Quail demonstrates an ability to adapt to a wide range of environmental conditions.

This paper presents information on the food selection of the Gambel Quail in southeastern Arizona and includes a discussion of the possible purposes of dietary changes. A total of 231 crops of adult quail were collected in connection with quail research conducted by the writer and other personnel of the Arizona Cooperative Wildlife Research Unit. Of the total number of crops of adult birds, some 36 spring crop samples, 104 summer samples, 19 fall samples, and 72 winter samples were analyzed. The majority of the birds were collected on three study areas, but all available crops of quail from known locations were used, including many from quail hunter-checking-stations and student collections.

Previously published reports on the foods of the Gambel Quail include the works of Judd (1905), Gorsuch (1934), and Campbell (1957). Martin, Zim, and Nelson (1951) summarized the year-round diet of the Gambel Quail. Their data were based on quail taken in many parts of the range of the species. In the present paper the seasonal diet is correlated with changes in quality of habitat, the availability of desired plants, and the quail's use of sources of drinking water.

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HABITATS INVESTIGATED

Gambel Quail in southern Arizona occupy areas of diverse vegetation, but their local habitats are similar in many ways. Climatically all of the areas are semi-desert and are characterized by high temperatures, low relative humidity, and high evaporation rates. The annual mean maximum temperature is above 80°F., and precipitation-evaporation ratios of 1:8 are common. Two distinct rainy periods alternate with dry periods (Smith, 1956). About 43 per cent of the annual precipitation falls in the period from July through September, and it comes from scattered thunderstorms; 35 per cent of the rainfall is deposited by more gentle, frontal-type storms which occur from November through February, and 22 per cent of the yearly total falls in small amounts in the remaining five months of the year. The greatest growth of vegetation follows the rains that occur

from November through February. There is no real winter period of food scarcity but rather an early summer and a late fall "squeeze period" due to seasonal drought.

The increase in precipitation at higher elevations was found to be one of the most significant environmental variables influencing sources of food in the three study areas near Tucson, Arizona. On a study area near the floor of the valley surrounding Tucson, an annual precipitation of approximately 11 inches was recorded. In this desert-shrub type are found saguaro cactus (*Carnegiea gigantea*), palo verde (*Cercidium microphyllum* and *C. floridum*), and bur-sage (*Franseria deltoidea*). Near the washes or arroyos grows velvet mesquite (*Prosopis juliflora* var. *velutina*), hackberry (*Celtis pallida*) and catclaw (*Acacia Greggii*). Many low, short-lived annual food plants are also produced if seasonal rainfall is adequate (Kearney and Peebles, 1951).

On the mesas and lower slopes of the desert mountain ranges the quail inhabit the desert grassland. The study area selected in the desert grassland ranges in elevation from 3000 to 3500 feet, and it has a yearly precipitation of about 13 inches. The desert grassland is actually dominated by shrubs including velvet mesquite, yucca (*Yucca elata*), burro-weed (*Aplopappus tenuisectus*) and cholla cacti (*Opuntia versicolor* and *O. fulgida*). But there is also considerable perennial grass (*Bouteloua*, *Aristida* and other genera), and annual or perennial forbs grow between the dominant shrubs.

Arizona chaparral is the highest vegetation division having significant numbers of Gambel Quail. On the study area, 4100 to 4800 feet, approximately 19 inches of rain falls annually. This higher rainfall produces a denser vegetation and major populations of quail are limited either to the lower transitional edge or to the vicinity of clearings. Emory oak (*Quercus Emoryi*), Mexican blue oak (*Quercus oblongifolia*), hackberry (*Celtis* sp.) and skunkbush (*Rhus trilobata*) replace some perennial grasses and forbs.

METHODS AND TECHNIQUES

The basic procedure involved the collection and analysis of the crop contents of individual quail. Collection and preservation of the crops differed from standard methods. The crop and its contents were weighed before being preserved in formalin for later analysis. In the laboratory the contents were inspected in water, and green or succulent foods were identified. The contents were then suction-filtered and dried at 100°C. and re-weighed to determine the amount of moisture contained in the wild foods.

The volume of each individual food item was determined by water displacement, using small graduated cylinders. The dried materials were allowed to take up as much moisture as possible before the water displacement was measured. Volumes were recorded to the nearest 0.1 milliliter; identifiable items displacing less than this amount were recorded as a "trace." The number of individual seeds, flowers, leaflets or other items were counted and recorded. Grit was measured but not included in volume percentages, and gizzard contents were noted but not measured.

The percentages of volume and the frequency of occurrence of food items were determined by the method used by Korschegen (1958). In this procedure, the arithmetic means of the seasonal percentages of items were calculated to represent the frequency of consumption and the amount of major foods used by Gambel Quail in this area. A smaller number of crops was included in the volumetric analysis because many crops had several identifiable items but their individual volumes were not measurable. Crops with one-fourth or more of the total volume not identifiable or those containing bait from banding stations were excluded. For purposes of seasonal groupings, spring was considered to be February through April; summer, May through July; fall, August through October; and winter, November through January.

RESULTS

Members of the Leguminosae, ranging from small annual forbs (*Lotus, Lupinus* sp.) to shrubs (*Mimosa* sp.) and trees (*Prosopis* sp.), were found to be the more important food producers. This may be explained in part by the fact that legumes are comparatively abundant in the habitats of quail, but it also results from the fact that the leaves, flowers, and seeds of these plants are highly palatable to quail.

The dominant foods are listed in table 1. Filaree, saguaro, and *Carlowrightia* sp. are the only non-leguminous plants of major importance. As noted by Judd (1905) and by Gorsuch (1934), Gambel Quail are largely vegetarian. Ants, however, were consumed in high enough volume to be included also as a principal food item. One group of plants frequently dominated the diet at one season but was replaced in a following season by other plant foods. Insects commonly occurred in crops only during the summer months.

Low-growing annual and perennial forbs made up 56 per cent of the diet of quail in spring, 46.2 per cent in summer, 69.8 per cent in fall, and 44.7 per cent in winter. Shrubs,

TABLE 1

PRINCIPAL FOODS OF GAMBEL QUAIL IN ARIZONA EXPRESSED AS PERCENTAGE OF VOLUME CONSUMED AND FREQUENCY OF OCCURRENCE OF FOOD ITEM

Food item	Spring		Summer		Fall		Winter	
	Vol.	Occur.	Vol.	Occur.	Vol.	Occur.	Vol.	Occur
Deer-vetch (*Lotus* spp.)								
Seed	20	44	15	36	26	74	11	30
Leaves, flowers	1	3	1	7	4	5	1	1
Filaree (*Erodium cicutarium*)								
Seed	3	33	17	55	23	89	6	42
Leaves, flowers	5	8	1	4	9	42	6	5
Mesquite (*Prosopis juliflora*)								
Seed	4	22	4	14	4	5	4	12
Leaves, flowers	17	33	3	7	4	21	T[1]	12
Palo Verde (*Cercidium* spp.)								
Seed	....	....	T	2	....	....	T	3
Leaves, flowers	10	11	1	2	....	....	....	....
Lupine (*Lupinus* spp.)								
Seed	3	6	1	3	....	....	12	14
White-thorn (*Acacia constricta*); Catclaw (*A. Greggii*)								
Seed	1	28	T	7	4	14	7	32
Leaves, flowers	1	6	T	4	....	....	2	T
Mimosa (*Mimosa* spp.)								
Seed	T	5	1	4	4	5	4	T
Leaves, flowers	T	6	....	....	T	10	....	....
Saguaro (*Carnegiea gigantea*)								
Seed	T	T	4	2	....	....	....	....
Fruit	T	6	5	14	....	....	....	....
Ants (Formicidae)	T	11	6	57	1	16	1	8
Carlowrightia (*Carlowrightia arizonica*)								
Seed	T	3	2	12	....	....	2	7

[1] T = trace.

trees and cacti combined made up 37.1 per cent of the diet in spring, 30 per cent in summer, 18.2 per cent in fall, and 42.1 per cent in winter. Leaves and buds that could not be identified composed 5.5 per cent, 5.4 per cent, 6.4 per cent, and 4.1 per cent of the diet for the four seasons, and grasses made up 0.4 per cent, 2.0 per cent, 1.9 per cent, and 7.6 per cent of the diet for the four seasons. Animal foods, largely insects, occurred during the summer rainy season and made up 15.5 per cent of the summer diet but only 0.9 per cent of the spring diet, 1.7 per cent of the fall diet, and 1.1 per cent of the winter diet. These summaries together with the annual totals for each group are shown graphically in figure 1.

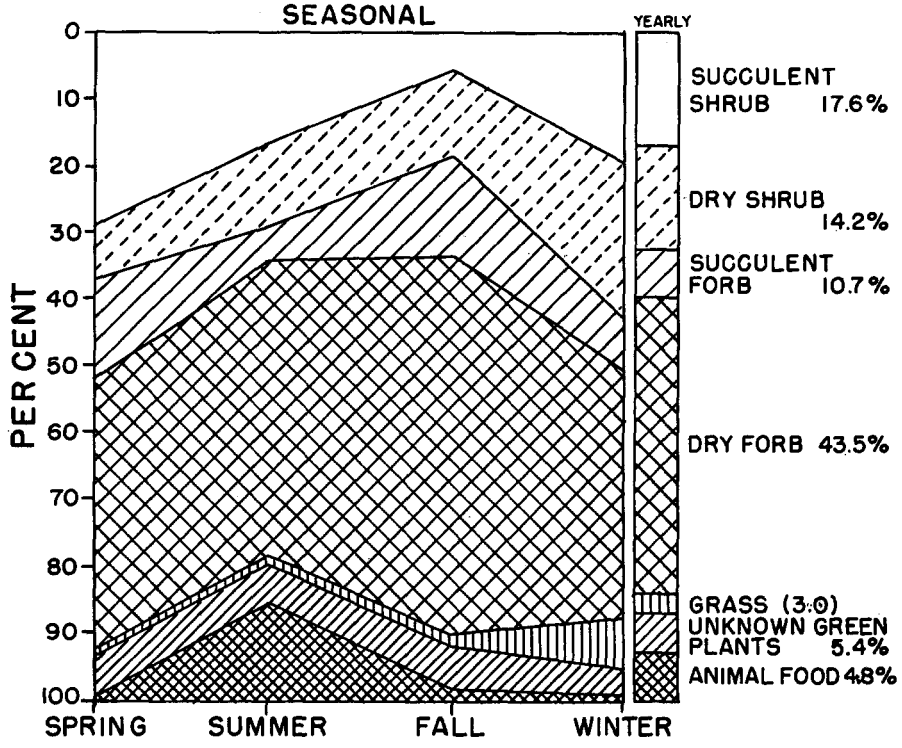

Fig. 1. Seasonal and yearly distribution of food consumed by Gambel Quail. Figures are based on volumetric analysis of 221 crops from 1953 to 1957.

Unusual items occurring in the crops of quail included snails, bone fragments, insect eggs, and rodent droppings. Although the rodent droppings may have been mistaken by the birds for seeds, there is a distinct possibility that they may have been taken intentionally. Rodent droppings were found in small amounts at all seasons, but they represented almost one-half of one per cent by volume of the winter and spring diet. This consumption of rodent droppings was concluded to have a nutritional significance, and the birds may use them as a source of vitamin B_{12}.

Forb seeds (43.5 per cent), shrub seeds (14.2 per cent) and grass seed (3.0 per cent) together accounted for 60.7 per cent of the yearly diet. Dry seeds, therefore, provided the greatest quantity of food in comparison with the other major food classes. Such seeds provided the most concentrated source of nutrients, and this type of food is always

available. All of the other major food types utilized had a much higher moisture content and were thought to be selected primarily for their moisture content. In order to determine the moisture content of the foods consumed, most of the crops were oven dried. They were then moistened and allowed to rehydrate before measuring their volume displacement, but the measured volume of green material was considered to be less than the actual volume because of the error introduced by this procedure. In spite of this error, a high frequency and percentage of volume was recorded for succulent foods. For the entire spring collection period, the ratio of the volume of dry foods to the volume of succulent foods was 50:50. Crops of quail taken in the spring often contained little but the blossoms of palo verde, yucca, or mesquite. Spring forbs produced considerable food of this type and were important at this season.

TABLE 2

MORE IMPORTANT FOODS OF GAMBEL QUAIL FROM NOVEMBER THROUGH JULY BY PER CENT OF VOLUME CONSUMED AND FREQUENCY OF OCCURRENCE IN A SAMPLE OF 202 CROPS

Food item	Plant part	Per cent of volume	Per cent frequency
Deer vetch (*Lotus humistratus*	seeds	15	36
and *L. tomentellus*)	leaves, flowers	8	4
Filaree (*Erodium cicutarium*)	seeds	9	43
	leaves, flowers	4	6
Lupine (*Lupinus* sp.)	seeds	5	7
Miscellaneous forb leaves		4	19
Mesquite (*Prosopis juliflora*)	seeds	4	16
	leaves, flowers		
	buds	7	14
Unknown leaf material		5	10
Palo Verde (*Cercidium* sp.)	seeds	T[1]	2
	leaves, flowers	3	4
Saguaro (*Carnegiea gigantea*)	fruit	2	6
	seeds	1	1
Ants (Formicidae)		2	25
Tansy-mustard (*Descurania obtusa*)	seeds	2	4
White-thorn (*Acacia constricta*)	seeds	2	6
	leaves, flowers	1	3
Condalia (*Condalia* spp.)	seeds	T	2
	leaves, fruit	2	5
Mistletoe (*Phoradendron* sp.)	fruit, seeds	2	2
Beetles (Coleoptera)		1	11
Carlowrightia (*Carlowrightia arizonica*)	seeds	1	7
Catclaw (*Acacia Greggii*)	seeds	1	6
	leaves, flowers	T	1
Mimosa (*Mimosa biuncifera*)	seeds	1	5
	leaves, flowers	T	1
Panic grass (*Panicum* sp.)	seeds	1	5
Skunkbush (*Rhus trilobata*)	fruit, seeds	1	4
Jojoba bush (*Simmondsia chinensis*)	seeds	1	2
Desert-plume (*Stanleya pinnata*)	seeds	1	2
Indigo bush (*Dalea Parryi*)	seeds	1	2
Milo maize (*Sorghum vulgare*)	seeds	1	1
Ocotillo (*Fouquieria splendens*)	seeds, flowers	1	2

[1] T = trace.

Saguaro fruit was a principal constituent of the summer diet in the desert-shrub zone. Insects were a fairly important food in summer, and fruit of the prickly pear was a common food at all elevations in late summer. The ratio of volumes of dry foods to succulent foods in all summer samples was 58:42.

The fall ratio of volumes of dry foods to succulent foods was 69:29, and the winter ratio was 67:33. Little flower, fruit, or new leaf material was available normally at these seasons.

The extremes of moisture content of the material in the crops analyzed ranged from less than 15 per cent to more than 88 per cent depending upon the season and upon the distance of the quail from open water.

Any animal's choice of food is influenced by the differences in abundance of the various foods available to it in its habitat. A comparison of the frequency of occurrence of a plant in a given habitat with the frequency of occurrence of that plant in the diet should serve as a measure of preference. The amount of ground cover composed of individual plant species was determined on each study area by line-intercept transects. Forbs as a class made up a low (7.7) per cent of the average ground cover, but they made up a large part (54.2 per cent) of the average crop contents. The birds showed a high preference for filaree; it comprised 8.3 per cent of the diets of the birds collected in the spring, but it composed only one per cent of the spring ground cover. Although only traces of this forb were recorded in the fall and winter ground cover measurements, 36.8 and 4.2 per cent, respectively, of succulent parts of filaree were recorded in crops of quail during these seasons.

The ratio of spring abundance to spring use of filaree was found to be 1:8. Other narrow ratios indicating preferred plants were *Lotus* spp., 1:100; *Lupinus* spp., 1:20; *Descurania* sp., 1:25; and *Dalea* sp., 1:6. Reverse ratios recorded for *Amaranthus* sp. (36:1) and *Euphorbia* spp. (11:1) indicate but slight use of these relatively abundant plants. These indices are a measure of the importance of the plant in the diet, but they are a measure especially of the succulent parts consumed.

DISCUSSION

Southern Arizona is noted for its spring and summer "desert bloom." In years of adequate, well-timed rainfall there is a startling change in quail habitats as an abundance of flowering, seed-producing annuals appear. For relatively short periods later in the year, trees, shrubs and cacti bear succulent berries and fruits. However, between these times of abundance, Gambel Quail must use their ability to find suitable food in a marginal habitat. Changes in habitat quality for Gambel Quail in Arizona are as extreme as the changes from fall abundance to winter snow in habitats of more northern game birds.

Water availability is a major factor governing the foods selected by Gambel Quail. Quail ranging away from open water exhibit thirst as well as hunger in selecting their food. Green or succulent foods were found to compose an especially large share of the diet of the birds living under these conditions. A flexibility in selection of foods is apparently required in order to get adequate nutrients and sufficient moisture during hot, dry periods.

Water sources constructed for Gambel Quail may concentrate these birds in limited areas beyond the capacity of some ranges to provide sufficient foods during stress periods. Certainly plant food sources should be abundant where such watering sites are constructed. The abundance of certain plant foods or plant types for Gambel Quail should also be considered in classifying or evaluating ranges of quail.

Several of the cacti, for example, are of greater importance than is indicated by the food selection figures. Pickly pear, cholla, and barrel cacti provide large, succulent seed-filled fruits during the drier parts of the summer season. Several shrubs, including the hackberries and species of *Condalia*, produce succulent berries, provide needed shade, and furnish roosting cover at all elevations in the range of the Gambel Quail in southern Arizona. Saguaro cactus is limited to the lower desert-shrub areas, but its large fruits usually ripen during the hottest and driest periods prior to the advent of summer rains.

Annual plants which respond to seasonal rainfall in both the highest and the lowest elevations improve food conditions considerably for the quail as long as they remain green. At the higher elevations annuals may respond earlier and produce more seed and foliage, but they are by nature short-lived and thus offer little advantage to quail ranging at higher elevations.

SUMMARY

Crops of 231 adult Gambel Quail from three major vegetation types in southeastern Arizona were analyzed to determine the more important seasonal food items. Special procedures were used to measure and record the moisture contained in foods. Food selection was correlated with elevation of ranges, rainfall periodicity, and abundance of spring plant cover.

Although largely graminiferous, these birds have a variable seasonal diet and sufficient succulent foods are taken to maintain body moisture. Food preference should be considered in quail management in evaluating range quality and in locating watering devices.

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