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John A. Crawford

The effects of disking, food plantings, and wheat plantings on a population of California quail (Lophortyx californicus) were studied from fall 1976 to spring 1978 on the E.E. Wilson Wildlife Area, Oregon. Twelve 16.2-ha study sites were established: 3 study sites for each treatment and 3 control sites. Disked areas, food plantings, and wheat plantings averaged 2.4, 0.4, and 5.0 ha in size, respectively. Circular plots were used to determine percent cover of species and life forms of forbs and grasses, and line transects were used to determine percent cover of shrub species during all seasons. Relative numbers of quail were determined for all seasons with vehicular surveys and flush censuses. Calling quail counts and vehicular brood surveys provided additional indices to abundance during spring and summer. Quail were collected seasonally for food habits analyses.

Significantly ($P \leq 0.05$) more quail were observed on disked sites than other sites after disking in spring 1977 and significantly ($P \leq 0.05$) fewer quail were sighted on wheat planting sites in summer 1977. Significantly ($P \leq 0.05$) more chicks per adult were sighted on disked sites than on food planting or control sites in summer 1977. Although no other significant differences existed a trend was evident in which more quail were observed on disked sites. Fewest quail were observed on wheat plantings. Vegetation analyses and relative food preference indices revealed that quail responded positively to the increased production of preferred food species, consisting primarily of early successional forbs, on disked areas. Seemingly, disking is a viable technique for management of California quail in areas of advanced secondary succession.

Effects of Habitat Manipulations on California Quail in Western Oregon

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Associate Professor of Wildlife Ecology in charge of major

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Head of Department of Fisheries and Wildlife

Redacted for Privacy

Dean of Graduate School

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BACKGROUND AND RELEVANCE

California quail were native to interior valleys and foothills from Klamath Lake, Oregon south through California and Mexico and eastward to western Nevada (Grinnel et al. 1918). The popularity of the California quail as a game bird led to its successful introduction into many areas of the western United States, Hawaii, New Zealand, Chile (Bent 1932), and Germany (Peterson et al. 1967). California quail were introduced successfully into the Willamette Valley in 1870 (Gabrielson and Jewett 1940) and became the second most hunted upland game bird in Oregon (Oregon Wildlife Commission 1974). In 1976 hunters bagged approximately 40,000 California quail in the Willamette Valley (Oregon Wildlife Commission 1977).

Despite the importance of California quail as a game bird in the Willamette Valley, research on this species primarily was conducted in more arid portions of its range: southeastern Washington (Anthony 1969, 1970) and California (Emlen 1939, McMillan 1964, Raitt and Genelly 1964). Few researchers studied this species in mesic areas; Crawford (unpublished data) studied habitat preferences of California quail in the Willamette Valley, Barclay and Bergerud (1975) considered behavioral ecology and population dynamics on Vancouver Island, British Columbia, and Williams (1952, 1957, 1963, 1967) studied reproduction and ecology in New Zealand.

A variety of land-use and management practices affect quail populations. Crawford (1978) found that California quail on the

E.E. Wilson Wildlife Area in the Willamette Valley preferred habitat in early successional stages and recommended disking as a method to retard succession for enhancement of quail populations. On Vancouver Island, Barclay and Bergerud (1975) found more quail on disturbed areas supporting early seral stages than on wooded or shrubby areas. In California, Sumner (1935) and Emlen and Glading (1945) found that disking stimulated growth of natural quail foods. Seeding of native forbs on disked areas insured the growth of a food crop (Edminster 1954). Jackson (1969) contended that non-native food plantings lacked the climatic adaptations of native forbs and productive plantings were often destroyed by rodents or birds before quail could make use of them in winter. Contrariwise, Robel (1972) found that corn and sorghum food plantings probably increased winter survival of bobwhites (Colinus virginianus). Jackson (1969) recommended that several rows of crop grain remain unharvested for bobwhite. In eastern Washington, waste grain remaining after harvest was a valuable source of food for California quail (Anthony 1969), but Rosene (1969) noted that fall plowing of stubble fields rendered most grain unavailable to quail.

Densities of California quail in the Willamette Valley declined from a mean of 0.30 quail per ha from 1953 to 1968 to a mean of 0.13 quail per ha from 1969 to 1974 (Oregon Department of Fish & Wildlife 1950, 1953, 1958, 1961, 1963, 1966, 1969, 1974, 1976). On the E.E. Wilson Wildlife Area densities of quail declined gradually from a mean of 0.27 (1953 to 1961) to 0.03 quail per ha (1971 to 1976) (Oregon Department of Fish & Wildlife 1953, 1958, 1961, 1963, 1966, 1969, 1974, 1976, 1977). Because of declines of quail numbers in the Willamette Valley this research project was instituted to test the hypothesis that manipulation of succession by disking, food plantings, and wheat plantings would affect quail.

METHODS

Study Area

The study was conducted on the 648 ha E.E. Wilson Wildlife Area (Wilson WA), located on the site of a decommissioned military base (Figure 1). The Wilson WA was established in 1953 by provision of Public Law 537 (Oregon Department of Fish & Wildlife) as an upland game bird propagation and wildlife management area.

The Wilson WA is primarily mixed shrub and grassland with approximately 162 ha of cultivated fields, bird pens and buildings, and 14 ha of wooded sections. Soils are primarily Willamette and Amity (silt-loam), but approximately 20 percent of the area consisted of concrete foundations, asphalt roads, and graveled areas. Annual rainfall for the Wilson WA averaged 121 cm from 1966 to 1975 (U.S. Department of Commerce, Environmental Data Service, 1966-1975).

Notable past management procedures included construction of 10 gallinaceous guzzlers and extensive plantings of blackberry (*Rubus* spp.) snowberry (*Symphoricarpos* sp.), and multiflora rose (*Rosa multiflora*). During the 1950's, 24 food plantings were maintained but gradually the number was reduced to 11 (7.29 total ha) by 1977. Also during the 1950's area personnel burned numerous areas of approximately 4 ha each. An average of 14 4-ha blocks were burned in 1961, 1963, 1964, and 1967 (Donald Kirkpatrick, personal communication).

Study Sites

Twelve 16.2-ha study sites were established in September 1976 to evaluate the effects of disking, food plantings, and wheat plantings on

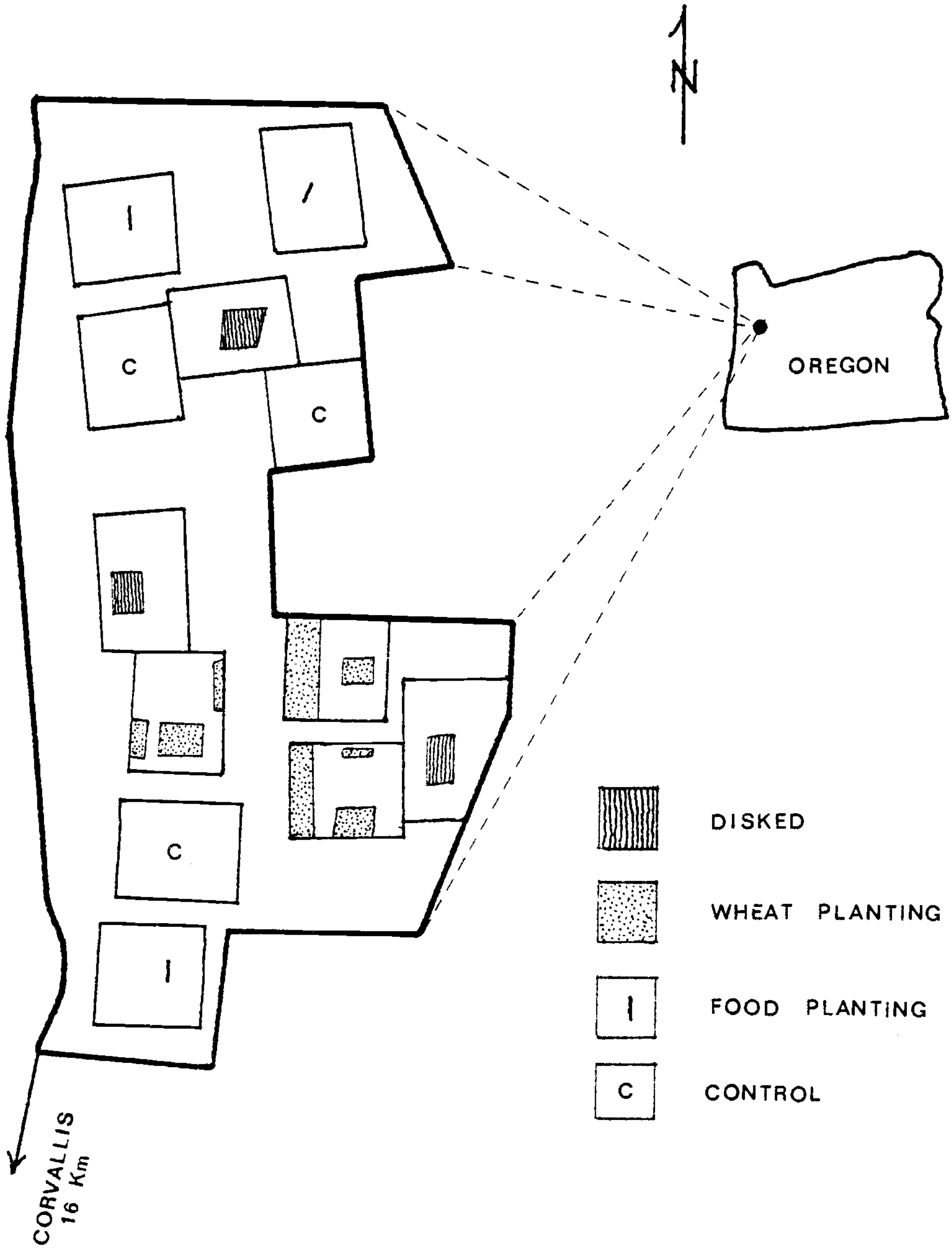

Figure 1. Location of study sites, E.E. Wilson Wildlife Area, Oregon.

quail. The experiment included 3 replications of each treatment and 3 control sites (Figure 1). Sampling began on all sites in October 1976 to provide pre-treatment vegetation and quail population data. Sampling seasons were defined as follows: fall = September to November, winter = December to February, spring = March to May, summer = June to August.

Food patches, 0.4 ha in size, consisted of corn and sudan grass and were planted in late April 1976, 1977, and 1978. On 29 and 30 March 1977 and 1978, 3 2.4-ha areas were disked by Oregon Department of Fish & Wildlife personnel. Disks were set at depths from 7.6 to 15.2 cm as suggested by Jackson (1969) at close proximity to shrub cover to provide easy access for quail (Sumner 1935).

On wheat plantings, winter wheat was seeded in October 1976, fertilized with 16 (% Nitrogen) - 20 (% Phosphorus) - 10 (% Potassium) at the rate of approximately 40 kg per ha (Cominco American Company, personal communication) and treated with herbicide in May 1977. Crops were harvested in July and stubble fields were left fallow through the end of the study.

Quail Sampling

Vehicular transects were driven on established routes on roads of all study sites for 28 days of each season from winter 1976 to spring 1978 to provide an index to relative quail abundances. During the same seasons, two flush censuses were conducted with trained bird dogs on all portions of each study site to provide an additional index to relative quail abundance. Greatest emphasis was placed on results of vehicular transects because of the large number of replicates obtained from this technique. Data from vehicular transects were probably more uniformly affected by daily weather conditions than flush censuses as all study sites were censused daily with vehicular transects whereas only one or two sites were censused daily with flush censuses.

From late April through July 1977, one-half hour counts of calling quail were made from dawn until 2h past dawn and from 2h before dusk until dusk on all study sites to provide another index to relative quail numbers. Calls of crowing cocks and minimum numbers of calling quail were recorded. Weekly vehicular surveys of broods were driven from past dawn until 2h past dawn and from 1h before dusk until dusk on all roads on the Wilson WA for 12 weeks from June to September 1977.

Quail were collected by shooting each season for determination of diet from analysis of crop contents. Percent frequency and parts of the food item consumed were recorded for all food species or groups of food items. Incidence of fowl pox (Appendix I) and sex and age ratios (Appendix II) were also determined for samples of collected quail.

Vegetation Analysis

Vegetation analyses were conducted seasonally on brush-grassland portions of all study areas. Each replication was divided into a central core zone of 2.4 ha and an outer buffer zone of 13.8 ha. Disking was conducted over the entire 2.4-ha core zone of each disking study site. Food plantings averaged 0.4 ha and were located in core zones of food planting study sites. A mean of 5 ha (range = 3 to 6 ha) of the wheat planting sites was seeded to wheat; other study sites contained a mean of 1 ha (range = 0 to 2.6 ha) of wheat. Wheat plantings were scattered through core and buffer zones of study sites.

Percent cover for all shrub species was determined with the line intercept method (Canfield 1941) with 20 25-m transects on each study site. Five 0.092-m^2 circular plots were established at 5-m intervals on each transect for determination of grass and forb cover and percent bare ground. Percentages of cover of grasses and forbs were estimated for plant parts greater than 15 cm above ground (tall grass and tall forb) and for plant parts 15 cm or less above ground (short grass and short forb). Ten transects were randomly established at 50-m intervals in the core zone of each replication and 10 transects were randomly established at 100-m intervals in the buffer zone of each replication.

The effects of disking on the brush-grassland were determined by direct comparison of disked core zones and unmanipulated core zones of control sites. Vegetation data from core and buffer zones were weighted according to the relative percent area that each zone occupied to provide an overall vegetative description of each site. The vegetation data from core zones and the weighted data of the combined zones were used to compare vegetative parameters among treatments for each season and vegetative parameters within individual treatments through seasons.

Data Analysis

The experiment was arranged in a randomized block design. An F-test (Snedecor and Cochran 1967:299) was used to determine if differences in quail numbers existed among treatments. A Newman-Keuls test (Snedecor and Cochran 1967:273) was used to separate means and reveal which areas were significantly different from others. In addition, chi-squared analysis was used to determine differences in frequencies of observations among treatments.

Relative preference indices were computed for food items with the formula: $\text{preference} = \frac{\%\ \text{frequency in crop}}{\%\ \text{frequency in habitat}}$ (VanDyne and Heady 1965), whenever data were available for frequency of the food item in the habitat.

Stepwise multiple regression analysis (Neter and Wasserman 1974: 228) was used to determine the relationship between indices to quail abundance (dependent variables) and 23 vegetation parameters (independent variables). Vegetation parameters included 5 life forms (tall grass, tall forb, short grass, short forb, shrub) and 18 species or groups of species selected because of their importance as foods of quail (tall wild carrot *Daucus carota*, tall vetch *Vicia* spp., other tall forbs, short wild carrot, short vetch, nonvetch legumes, false dandelion Cichorieae, other forbs, apple (*Pyrus* spp.) or because of abundance on the area (tall fescue *Festuca* spp., other tall grasses, short fescue, other short grasses, ox-eye daisy *Chrysanthemum leucanthemum*, tansy ragwort *Senecio jacobaea*, blackberry *Rubus* spp., other shrubs, bare ground). Significance of correlations between vegetation parameters used in regression models and other vegetative parameters was determined with a *t*-test (Snedecor and Cochran 1967: 184).

Multivariate analysis of variance (Morrison 1967:170) was used to detect differences in vegetation among treatments and through seasons within treatments. The greatest characteristic root test (Morrison 1967:170) was used to evaluate test statistics. A test for additional information (Morrison 1967:170) was used to determine in which parameters differences existed.

RESULTS AND DISCUSSION

Quail Populations

Vehicular transects for winter 1976 indicated no significant differences between relative numbers of quail on sites (Table 1). Immediately after disking in spring 1977, significantly ($P \leq 0.05$) more quail were sighted on disked study sites than on other sites (Table 1). Food plantings, wheat plantings, and control sites were statistically similar to each other.

Covey dispersal and nesting activities probably accounted for decreased numbers of observations on vehicular transects during summer 1977. Significantly ($P \leq 0.05$) fewer quail were observed on wheat planting sites than on other sites. No statistical differences existed among disked, food planting, and control sites. Of the 3 treatments on which similar numbers of observations of adult birds were made (Table 2), disked sites yielded the significantly ($P \leq 0.05$) highest chick to adult ratio. Apparently the few birds which occupied the wheat planting sites also experienced good reproductive success.

Numbers of "cow" calls were positively correlated ($r = 0.72$, AM counts; $r = 0.67$, PM counts) to the estimated minimum number of calling quail. The estimated minimum number of calling quail was considered a more precise index of relative activity because of the great variation in number of cow calls given per quail (1 to 87). Rosene (1969) stated that numbers of bobwhites calling in summer provided a good index to the numbers of coveys sighted in the fall in the Southeast.

Initial examination of results of calling quail censuses suggested greater densities of quail on food plantings than on disked sites which

Table 1. Total numbers of California quail observed on seasonal transects on disked, food planting, wheat planting, and control sites, E.E. Wilson Wildlife Area, Oregon, from 1976 to 1978.

SEASON	DISKED	FOOD PLANTING	WHEAT PLANTING	CONTROL
Winter 1976[a]	28	91	0	44
Spring 1977[b]	220	66	22	24
Summer 1977[c]	67	37	10	21
Fall 1977[a]	106	52	22	44
Winter 1977[a]	15	24	0	11
Spring 1978[a]	15	23	2	7

[a]No significant difference among sites.

[b]Disked sites were significantly ($P \leq 0.01$) greater than all other sites.

[c]Wheat planting sites were significantly smaller ($P \leq 0.05$) than all other sites.

Table 2. Total numbers of adults and chicks and numbers of chicks per adult observed on brood surveys of California quail on disked, food planting, wheat planting, and control sites, E.E. Wilson Wildlife Area, Oregon, June to September 1977.

CATEGORY	DISKED	FOOD PLANTING	WHEAT PLANTING	CONTROL
Adults[a]	47	46	5	45
Chicks[a]	71	11	11	18
Chicks per adult[b]	1.5	0.2	2.2	0.4

[a]No significant differences among sites.

[b]Disked and wheat planting sites were significantly ($P \leq 0.05$) greater than other sites.

apparently supported greater densities than control or wheat planting sites (Table 3). However, Williams (1969) and Glading (1938) indicated that the majority of "cow" calls recorded after pair formation were elicited by unpaired males. Emlen (1939) stated that some unpaired males established small crowing territories near mated pairs while other unpaired males were transient. Consideration of this information and brood survey and vehicular transect data revealed that disked sites probably supported the greatest number of breeding pairs and food plantings supported the greatest number of unpaired males. Wheat plantings and control sites supported fewer numbers of quail.

No significant statistical differences existed among sites during fall 1977 (Table 1). Although numbers of quail observed on disked areas during summer and fall 1977 were not significantly different from other sites, a consistent trend developed from spring through fall in which the most quail were observed on disked sites (Table 1).

Numbers of quail observed on study sites were statistically similar during winter 1977. Disked sites were low-lying, and winter rains caused accumulations of water on these areas which may have precluded use by quail. Copious rainfall during November and December 1977 and a November storm which deposited several inches of snow and ice probably resulted in high winter mortality of quail on the Wilson WA, as evidenced by decreases in indices from winter 1976-7 to winter 1977-8.

Significantly ($P \leq 0.05$) fewer quail were observed on vehicular transects in spring 1978 than in spring 1977. The population reduction was also reflected in flush censuses (Table 4) for the 2 years. No significant differences existed among study sites during spring 1978,

Table 3. Total numbers of calling birds and total numbers of "cow" calls recorded during calling quail counts of California quail on disked, food planting, wheat planting, and control study sites, E.E. Wilson Wildlife Area, Oregon, April to July 1977.

CATEGORY	FOOD PLANTING	DISKED	CONTROL	WHEAT PLANTING
Calling Birds AM	72[a]	42	24	14
Calling Birds PM	52	28	12	4
"Cow" Calls AM	1237	524	610	211
"Cow" Calls PM	561	210	34	9

[a]Lines connect counts which were not significantly ($P \leq 0.05$) different from each other.

and numbers of quail observed per site were similar to numbers of winter sightings. Either quail did not respond to disking or the population was so reduced in size that a response could not be detected.

Food Preferences

Although 100 crops were collected during 8 seasons (fall 1976 to summer 1978) relative preference indices of food items were computed only for the 6 seasons in which habitat data also were collected (winter 1976 to spring 1978).

Quail on the Wilson WA preferred forbs and consumed few grasses and shrubs throughout the year (Table 5). These findings were consistent with food habits studies in all parts of the range of the California quail (Anthony 1970, Williams 1952, Glading et al. 1940, Sumner 1935). Seeds and foliage of wild carrot and vetches were consumed with the greatest frequency of all food items. Highly preferred food items included seeds of sweetpea (*Lathyrus* spp.), foliage, flowers, pods and seeds of clovers (*Trifolium* spp.), pods and seeds of lotus (*Lotus* spp.), flowers and seeds of yellow and blue forget-me-not (*Myosotis bicolor*), and foliage, siliques, and seeds of bittercress (*Cardamine* spp.). Other important foods included foliage of sheep sorrel (*Rumex acetosella*), foliage of geraniums (*Geranium* spp.), seeds of teasel (*Dipsacus sylvestris*), leaves and buds of false dandelions (Tribe Cichorieae) and skin, pulp and seeds of apples. Pigweed (*Chenopodium* sp.), a volunteer in food plantings, was consumed readily.

Preference indices of grasses were based on occurrences of seeds in crops. Fragments of grass leaves (minor components of diet) could not be readily differentiated. Quail consumed seeds of bluegrass

Table 4. Total numbers[a] of California quail observed seasonally during flush censuses on disked, food planting, wheat planting and control study sites, E.E. Wilson Wildlife Area, Oregon, 1976 to 1978.

SEASON	DISKED	FOOD PLANTING	WHEAT PLANTING	CONTROL
Winter 1976[b]	31	49	1	5
Spring 1977[b]	18	48	5	9
Summer 1977[b]	14	28	0	5
Fall 1977[b]	25	0	0	13
Winter 1977[b]	18	0	0	0
Spring 1978[c]	6	9	0	2

[a]Combined morning and evening samples.

[b]No significant differences among sites.

[c]Food plantings and disked sites were significantly greater than wheat planting and control sites.

Table 5. Relative preference indices[a] of foods of California quail, E.E. Wilson Wildlife Area, Oregon, Winter 1976 to Spring 1978.

FOOD	WINTER 1976	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977	SPRING 1978
	n=14[b]	n=3	n=15	n=16	n=16	n=9
Polygonum sp.			7.0			
Rumex acetosella	3.5	16.8	11.0	8.3	14.7	18.7
Chenopodium album			7.0	31.0		
Cerastium spp.			40.0			
Cardamine spp.	7.0	20.0		6.0	10.1	29.7
Lathyrus spp.	21.0	33.0	7.0	50.0	81.0	33.0
Lupinus spp.		33.0	13.0			
Vicia spp.	1.8	1.9	1.2	1.1	1.7	1.5
Trifolium spp.	14.0	33.0	26.5		13.0	15.0
Lotus spp.			3.3	6.0		
Robinia psuedo-acacia		33.0	7.0			33.0
Cytisus scoparius		6.6		6.0		
Geranium spp.	7.0	33.5	2.3		3.8	11.3
Epilobium spp.						33.0
Anthriscus scandicina		33.0	13.0		19.0	
Daucus carota	4.0	3.1	1.6	2.0	3.6	3.0

Table 5. Continued.

FOOD	WINTER 1976	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977	SPRING 1978
	n=14[b]	n=3	n=15	n=16	n=16	n=9
Galium spp.	18.0					
Myosotis bicolor			7.3	3.0		
Dipsacus sylvestris	7.2	6.7	0.8	3.1	7.5	3.0
Tribe Cichorieae	1.7	16.8	21.8	4.2	10.5	
Cirsium spp.		1.5		2.4		
Pyrus spp.	15.5				7.6	
Rubus spp.				0.8		
Festuca spp.			0.2	0.9	0.3	
Holcus spp.	0.9		0.4			
Order Musci	0.2	0.5	0.4	0.1	0.1	0.6

[a]Relative preference index = $\frac{\text{\% frequency of food item in crop}}{\text{\% frequency of food item in habitat}}$.

[b]Number of crops in sample.

(*Poa* spp.) with moderate frequencies (Table 6) in spring and summer but a preference index could not be computed because of uncertainty of identification in the habitat analysis. Glading et al. (1940) believed bluegrass was the most preferred of the grasses on the San Joaquin Experimental Range in California. Fescue and velvetgrass (*Holcus* spp.) were generally avoided by quail (Table 5). Sudan grass grown in food patches was rarely consumed (Table 6). Similarly, wheat was found in very few crops (Table 6).

Quail consumed animal matter during all seasons (Table 6), but highest frequencies occurred during summer.

Vegetation Analyses

Vegetation of combined core and buffer zones exhibited similar growth patterns on all treatments through the course of the study (Figures 2, 3). Growth patterns of vegetation were also similar on core zones except on disked areas where grass and forb growth taller than 15 cm was diminished during summer 1977 (Figures 3, 4).

Pairwise comparisons revealed no significant differences in vegetation among sites during winter 1976.

Disking had little effect on combined core and buffer zones of disked study sites and no differences existed among treatments during spring, summer, and winter 1977. During fall 1977 and spring 1978 disked sites supported significantly ($P \leq 0.05$) less short grass than other sites. In addition, brush-grassland areas of cultivated sites supported more short grass than other sites (Figure 2).

During winter 1976 core zones of disking sites (before disking) had significantly ($P \leq 0.05$) less bare ground and shrub cover than other

Table 6. Frequency of food items in crops of California quail collected on E.E. Wilson Wildlife Area, Oregon, from fall 1976 through Summer 1978.

FOOD ITEM	FALL 1976	WINTER 1976-7	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977-8	SPRING 1978	SUMMER 1978
	n=18[a]	n=14	n=3	n=15	n=16	n=16	n=9	n=10
Polygonum spp.				7				
Rumex acetosella	22	14	67	33	25	44	56	50
Chenopodium album	6			7	31			
Cerastium spp.				40				
Spergularia spp.				27				
Cardamine spp.		7	100		6	81	89	10
Lathyrus spp.	7	21	33	7	50	81	33	10
Lupinus spp.			33	13				
Vicia spp.	33	86	100	67	69	81	78	80
Trifolium spp.		14	33	53		13	45	20
Lotus spp.	7	14		13	6		11	70
Robinia psuedo-acacia			33	7			33	
Cytisus scoparius	17		33		6			10
Geranium spp.		7	67	7		19	45	20
Hypericum perforatum								20

Table 6. Continued.

FOOD ITEM	FALL 1976	WINTER 1976-7	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977-8	SPRING 1978	SUMMER 1978
	n=18	n=14	n=3	n=15	n=16	n=16	n=9	n=10
Epilobium spp.							33	
Anthriscus scandicina	7		33	13		19		
Daucus carota	56	100	100	67	56	100	100	20
Plantago spp.	6							
Galium spp.		36						10
Myosotis bicolor				73	6			20
Dipsacus sylvestris	11	43	67	7	31	75	33	
Tribe Cichorieae	39	36	67	87	38	63	33	70
Cirsium spp.	6		33					
Sonchus spp.								10
Delphinium spp.							11	
Montia spp.							33	
Pyrus spp.	14	93				38		
Rubus spp.	33				44			40
Prunus spp.								20
Ribes spp.							11	

Table 6. Continued.

FOOD ITEM	FALL 1976	WINTER 1976-7	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977-8	SPRING 1978	SUMMER 1978
	n=18	n=14	n=3	n=15	n=16	n=16	n=9	n=10
Festuca spp.				13	56	19		60
Holcus spp.		7		7				
Bromus spp.		36		13	6	6		20
Poa spp.				53	6		45	10
Triticum aestivum	17				13			
Sorghum sudanense					25			10
Deschampsis spp.				7				
Arrhenatherum spp.								40
Class Musci	7	14		13	6	6	33	30
Order Pulmonata				13	6	6		10
Order Isopoda				20		6		10
Order Geophilomorpha						6		
Class Arachnida				27		6	11	10
Order Orthoptera				7	19			
Order Dermaptera	6			7				
Order Hemiptera		7						

Table 6. Continued.

FOOD ITEM	FALL 1976	WINTER 1976-7	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977-8	SPRING 1978	SUMMER 1978
	n=18	n=14	n=3	n=15	n=16	n=16	n=9	n=10
Order Homoptera			33	40	6		22	
Order Neuroptera				7				
Order Coleoptera	11			60	13	19	11	
Order Lepidoptera		7		7		25	11	
Order Diptera		7						
Order Hymenoptera	17			60	38	6	56	

[a]Number of crops in sample.

treatments. Control sites supported a significantly higher percentage of shrub cover and an intermediate percentage of bare ground (Figure 3).

Core zones of disked sites had significantly ($P \leq 0.05$) more bare ground than other sites in spring and summer 1977 and significantly more bare ground and a higher percentage ($P \leq 0.05$) of short forb cover in fall 1977 (Figures 3, 4). In winter 1977 disked sites supported a higher percentage ($P \leq 0.05$) of short forb cover. After disking in spring 1978, disked sites had a higher ($P \leq 0.05$) percentage of bare ground than other sites (Figure 3).

Crawford (1978) found that California quail on Wilson WA preferred study areas with large amounts of bare ground. Leopold (1977) stated that quail chicks fed in open areas to avoid contact with dew-covered vegetation. Chicks forced into wet vegetation often became chilled and died (Sumner 1935). The increased percentage of bare ground on the disked areas probably increased potential brooding area for quail and may, in part, have accounted for observed differences in productivity among treatments.

Effects of disking on abundances of food plants were varied. Wild carrot and vetch existed on core areas of disked sites in high frequencies prior to treatment (Figure 5). Although vetch did not respond well initially to disking, it persisted at relatively moderate frequencies through summer 1977 and later increased to frequencies significantly higher than other sites by fall ($P \leq 0.05$) and winter ($P \leq 0.01$) 1977. Wild carrot, which occurred in highest frequency ($P \leq 0.01$) on core zones of disked areas during winter 1976, responded positively to spring disking and by summer 1977 occurred on nearly 90 percent of the quadrats on disked areas. Sweetpea (Figure 5) did not intially

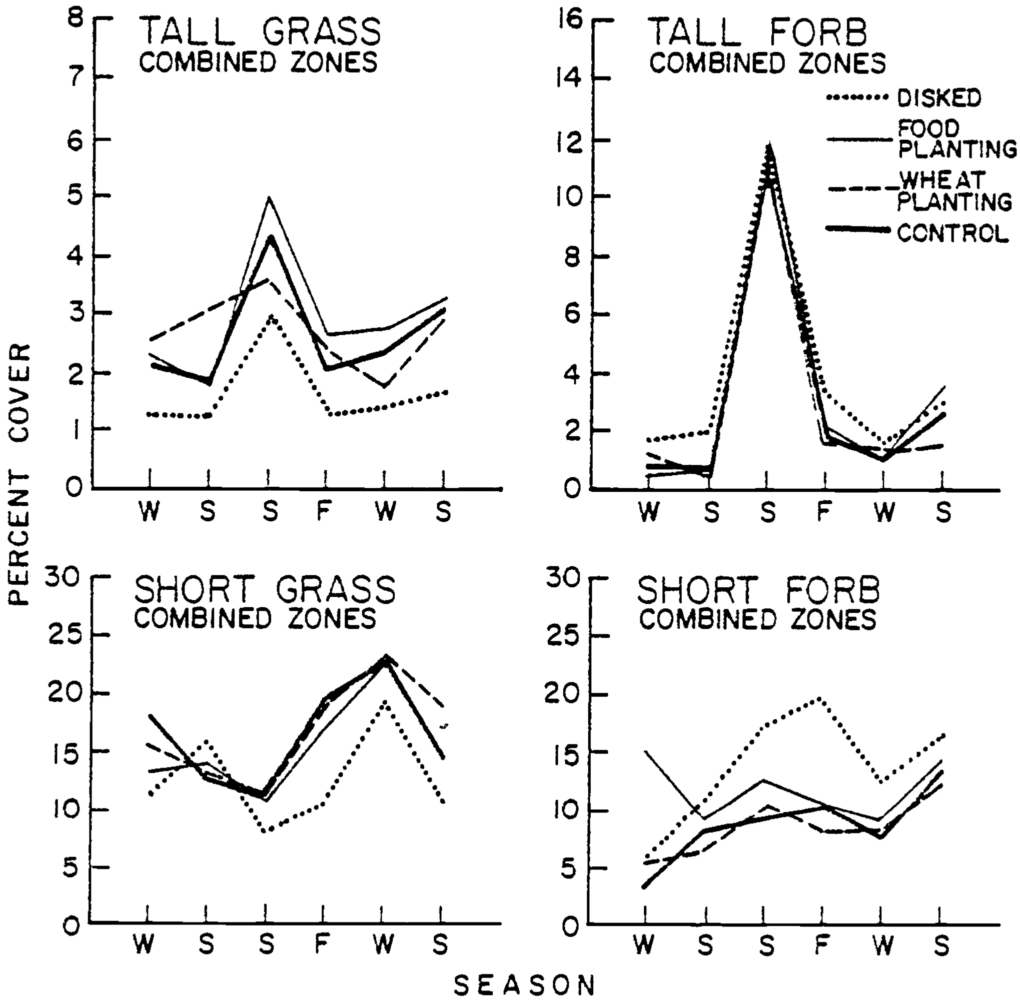

Figure 2. Percent cover of tall grass, tall forb, short grass, and short forb on combined zones of study sites, E.E. Wilson Wildlife Area, Oregon, from winter 1976 through spring 1978.

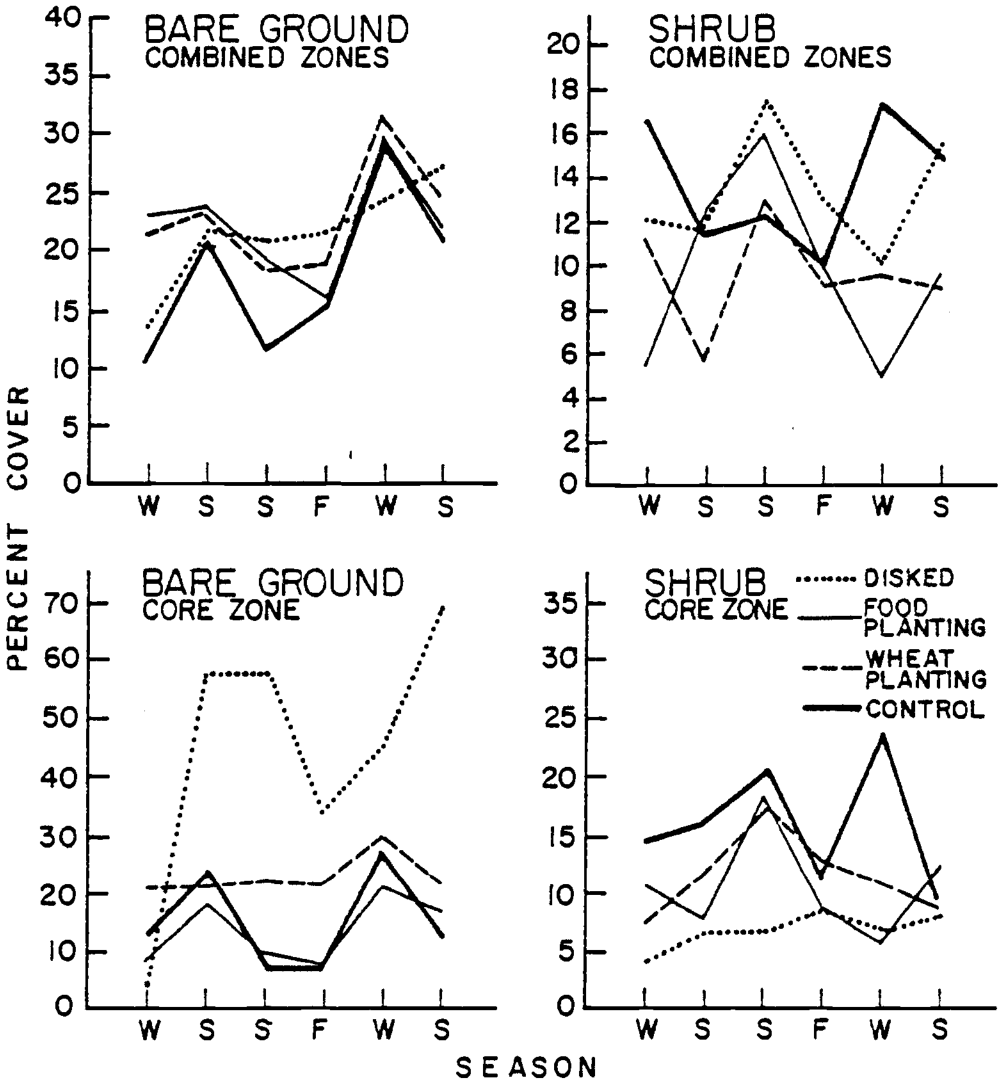

Figure 3. Percent cover of shrub and percent bare ground on combined zones of study sites and core zones of study sites on E.E. Wilson Wildlife Area, Oregon, from winter 1976 through spring 1978.

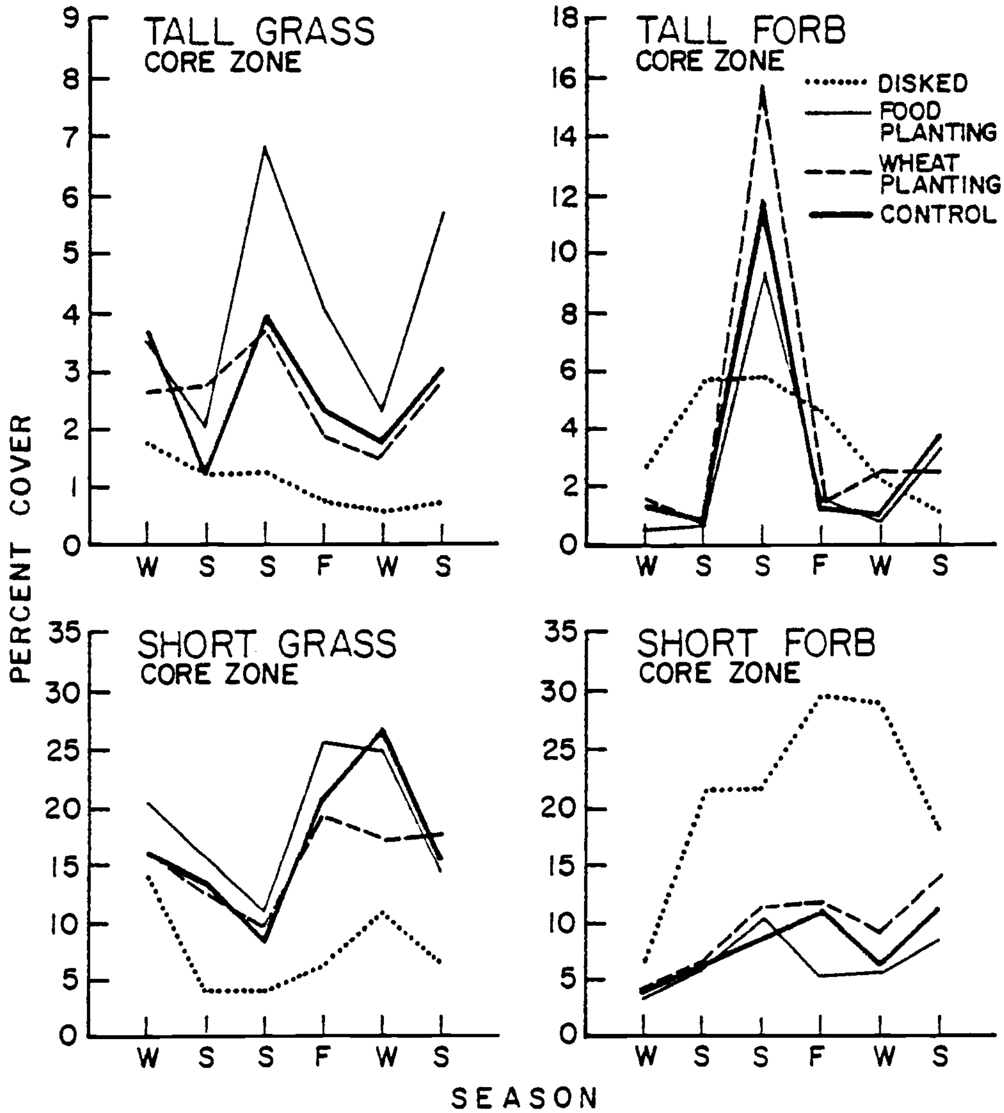

Figure 4. Percent cover of tall grass, tall forb, short grass and short forb on core zones of study sites, E.E. Wilson Wildlife Area, Oregon, from winter 1976 through spring 1978.

respond well to disking but increased by fall 1977 and maintained a low level of occurrence on disked areas. Core zones of food planting areas supported the highest frequencies of sweetpea but this was apparently unrelated to the food plantings. However, clovers, lotus, geranium, false dandelions, bittercress, and sheep sorrel, all important food items, responded positively to disking (Figures 5, 6, 7). Fescue (Figure 7) was detrimentally affected by disking and remained at relatively low levels on core zones of disked areas.

Quail-Vegetation Interaction

During winter 1976, quail densities were weakly related to percent cover of tall fescue ($R^2 = 0.35$). Percent cover of tall fescue was strongly correlated to percent cover of short fescue ($r = 0.86$).

Immediately after disking in spring 1977, quail densities were related to percent cover of tall forbs ($R^2 = 0.59$) which were highly correlated to short forbs (Table 7). Quail densities were also positively related to tansy ragwort and negatively related to false dandelions ($R^2 = 0.91$). Tansy ragwort was never found in quail crops but was probably not toxic to quail (Buckmaster et al. 1977). In addition, tansy ragwort seemingly lacked value as escape cover for quail. However, tansy ragwort was significantly and positively correlated to 4 important food groups: other tall forbs, nonvetch legumes, false dandelion, and other short forbs (Table 7). Although tansy ragwort apparently lacked attributes attractive to quail, its association with important food plants of quail may have accounted for the positive relationship to quail densities.

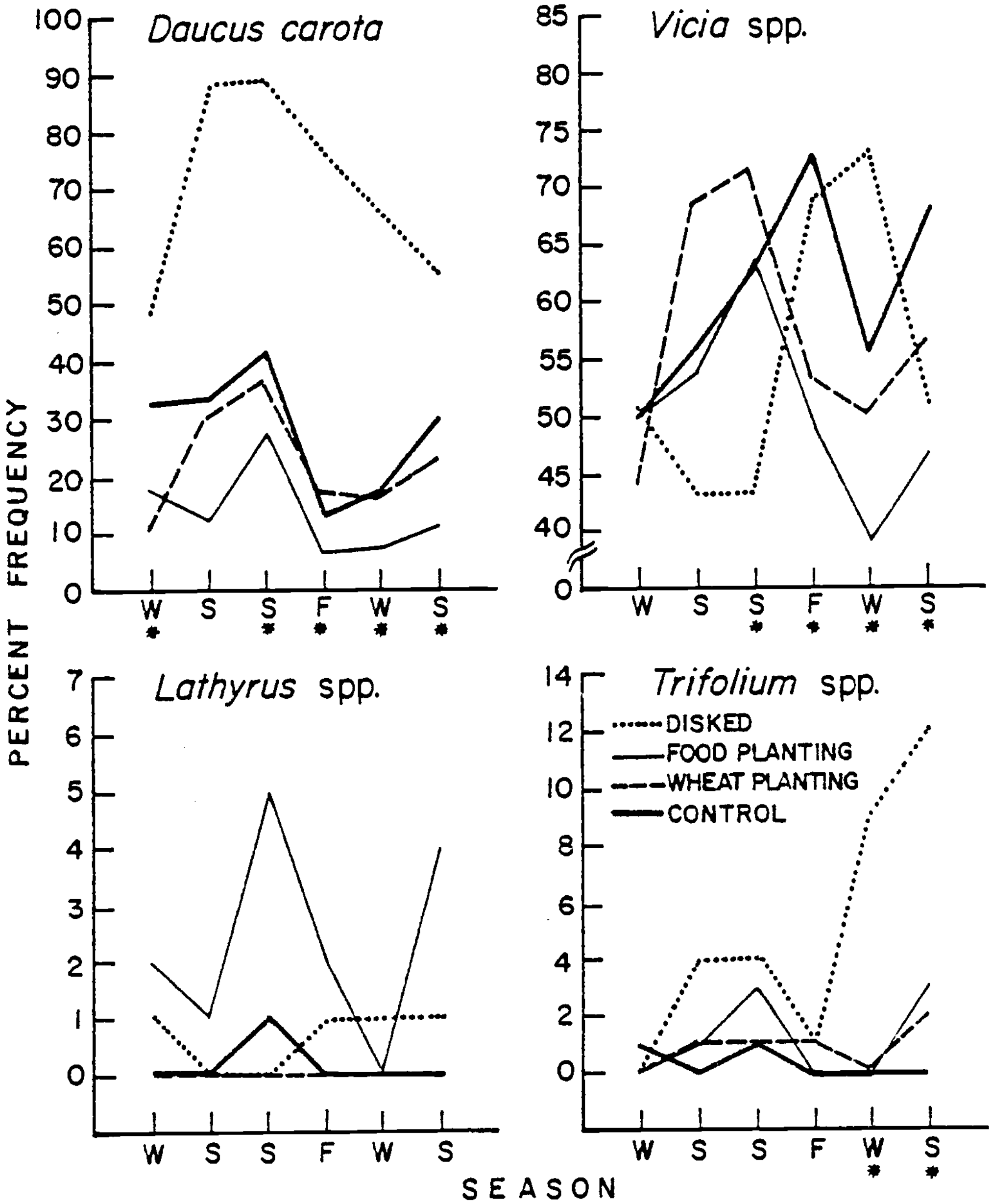

Figure 5. Percent frequency of wild carrot (Daucus carota), vetch (Vicia spp.), sweetpea (Lathyrus spp.), and clover (Trifolium spp.) on core zones of study sites, E.E. Wilson Wildlife Area, Oregon, from winter 1976 through spring 1978. Seasons in which disked sites were significantly ($P \leq 0.05$) different from other sites combined are denoted by asterisks.

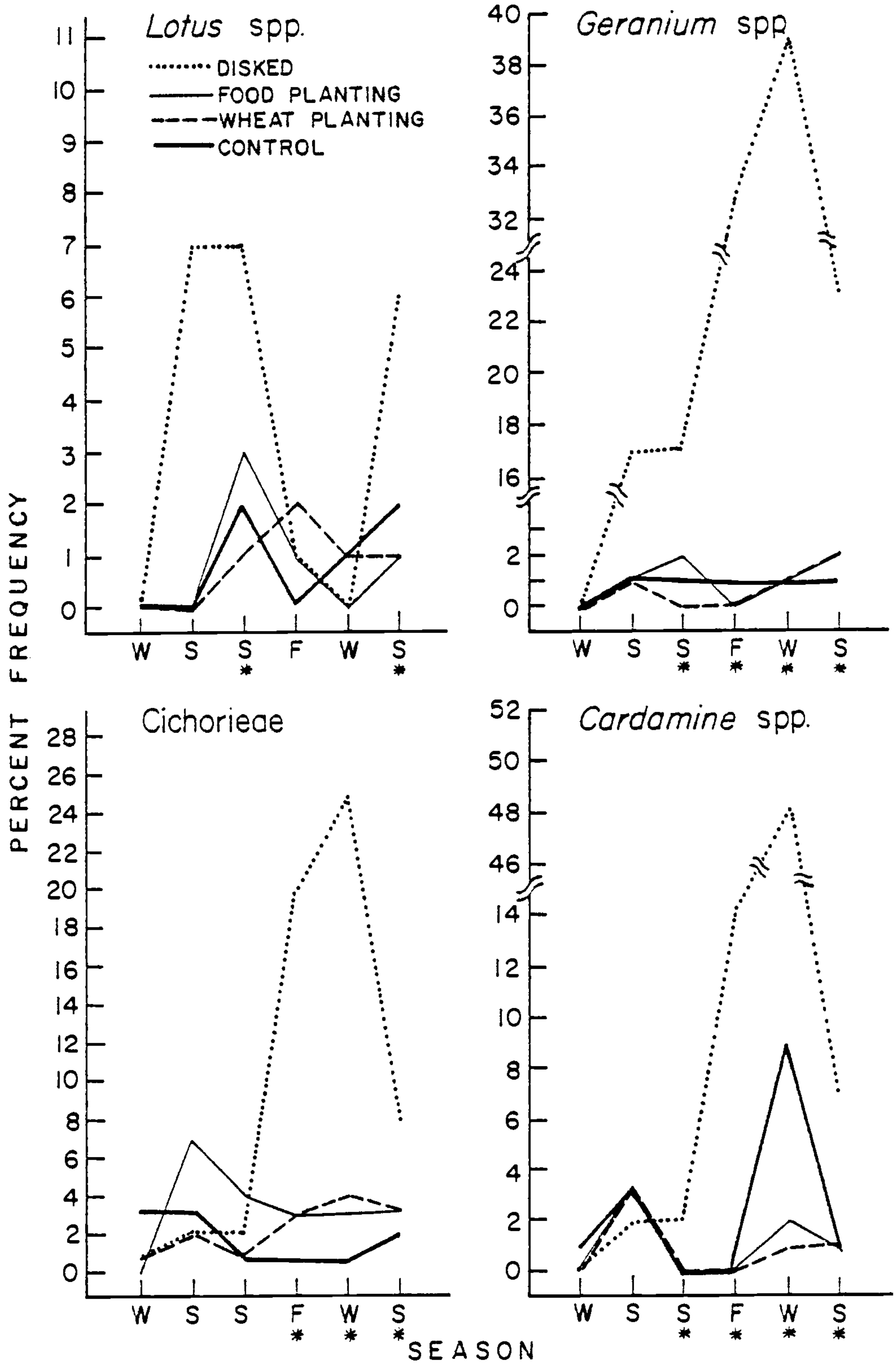

Figure 6. Percent frequency of Lotus (Lotus spp.), geranium (Geranium spp.), false dandelion (Cichorieae), and bittercress (Cardamine spp.) on core zones of study sites, E.E. Wilson Wildlife Area, Oregon, from winter 1976 through spring 1978. Seasons in which disked sites were significantly ($P \leq 0.05$) different from other sites combined are denoted by asterisks.

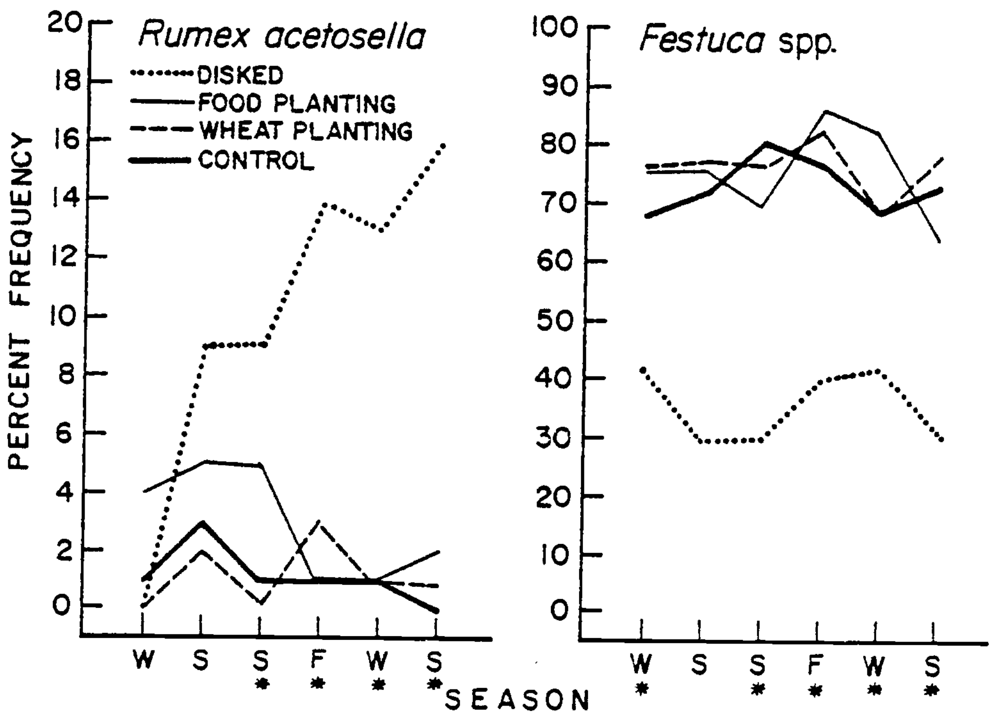

Figure 7. Percent frequency of sheep sorrel (Rumex acetosella) and fescue (Festuca spp.) on core zones of study sites, E.E. Wilson Wildlife Area, Oregon, from winter 1976 through spring 1978. Season in which disked sites were significantly ($P \leq 0.05$) different from other sites combined are denoted by asterisks.

Table 7. Significant ($P \leq 0.05$) intercorrelations among vegetation variables, E.E. Wilson Wildlife Area, Oregon, Spring 1977 to Spring 1978.

SEASON	ZONE OF STUDY SITE	VARIABLE IN MODEL	CORRELATED VARIABLE	r
Spring 1977	Core + Buffer	Tansy Ragwort	Other Tall Forbs	+0.71
		Tansy Ragwort	Non-vetch Legumes	+0.77
		Tansy Ragwort	False Dandelion	+0.74
		Tansy Ragwort	Other Short Forbs	+0.78
		False Dandelion	Short Fescue	-0.62
		Tall Forb	Short Forb	+0.81
	Core	Tansy Ragwort	Other Tall Forbs	+0.64
		Tansy Ragwort	Short Wild Carrot	+0.58
		Tansy Ragwort	Non-vetch Legumes	+0.67
		Tansy Ragwort	Other Short Forbs	+0.62
		Non-vetch Legumes	Other Short Forbs	+0.71
		Non-vetch Legumes	Bare Ground	+0.88
		Non-vetch Legumes	Short Wild Carrot	+0.70
		Non-vetch Legumes	Short Fescue	-0.73
		Non-vetch Legumes	Tall Fescue	-0.72
Summer 1977	Core	Tall Forb	Non-vetch Legumes	-0.59
		Tall Vetch	Tall Fescue	+0.61
		Tall Vetch	Short Fescue	+0.79

Table 7. Continued.

SEASON	ZONE OF STUDY SITE	VARIABLE IN MODEL	CORRELATED VARIABLE	r
		Tall Vetch	Short Vetch	+0.58
		Tall Vetch	Short Wild Carrot	-0.73
		Tall Vetch	Other Short Forbs	-0.61
		Tall Vetch	Short Grass	+0.62
		Tall Vetch	Bare Ground	-0.66
		Tall Vetch	Short Forbs	-0.65
		Other Shrub	Blackberry	+0.68
Fall 1977	Core + Buffer	False Dandelion	Short Vetch	-0.63
		Bare Ground	Blackberry	+0.61
	Core	Tansy Ragwort	Tall Wild Carrot	+0.80
		Tansy Ragwort	False Dandelion	+0.84
		Tansy Ragwort	Short Fescue	-0.69
		Tansy Ragwort	Other High Forbs	+0.64
		Tansy Ragwort	Bare Ground	+0.68
Winter 1977	Core + Buffer	Other Short Grass	Tall Fescue	-0.60
		Other Short Grass	Tall Vetch	-0.65
		Other Short Grass	Short Fescue	-0.60
Spring 1978	Core + Buffer	Tall Fescue	Short Fescue	+0.79

Table 7. Continued.

SEASON	ZONE OF STUDY SITE	VARIABLE IN MODEL	CORRELATED VARIABLE	r
		Tall Fescue	Nonvetch Legumes	-0.60
		Ox-eye Daisy	Short Wild Carrot	+0.65
		Ox-eye Daisy	False Dandelion	+0.84

Quail densities also were related positively to percentages of cover of tansy ragwort and nonvetch legumes on core zones ($R^2 = 0.80$). Tansy ragwort was positively correlated to other high forbs, short wild carrot, nonvetch legumes, and other short forbs (Table 7). Nonvetch legumes, important food species (Table 5), were positively correlated to other short forbs, short wild carrot, bare ground, and negatively correlated to short fescue and tall fescue (Table 7).

During summer 1977, quail densities were negatively related to short grass ($R^2 = 0.43$). On the core zones, quail densities were negatively related to tall forbs ($R^2 = 0.34$) and negatively related to tall vetch and other shrubs ($R^2 = 0.71$). Tall forbs were negatively correlated to nonvetch legumes and tall vetch was negatively correlated to false dandelion, short forbs, other short forbs, and bare ground and positively correlated to short vetch, tall fescue and short fescue (Table 7). Although vetches were a major food item during summer (Table 5), they were abundant on all treatments (Table 8), and readily available for use by quail. Tall vetch, particularly V. villosa, often grew as thick mats in dense stands of fescue (hence, significant correlation to fescue) and apparently created a vegetative barrier to quail during summer. Quail seemingly preferred more open areas with less tall cover and more low forbs.

Densities of quail during fall 1977 were positively related to false dandelions and bare ground ($R^2 = 0.79$). Foods of quail were probably most abundant during fall and may not have acted as a limiting factor to quail distribution. However, false dandelions were among the least abundant of the important food items of the fall period (Table 8). Quail densities were positively related ($R^2 = 0.44$) to tansy ragwort on

Table 8. Mean percent frequency of food items on study sites, E.E. Wilson Wildlife Area, Oregon, from Winter 1976 through Spring 1978.

FOOD ITEM	WINTER 1976-7	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977-8	SPRING 1978
Polygonum spp.	0	0	0	0	0	0
Rumex acetosella	4	4	3	3	3	3
Chenopodium album	0	0	1	0	0	0
Cerastium spp.	0	0	1	0	-[a]	-
Cardamine spp.	1	5	1	1	8	3
Lathyrus spp.	1	1	1	1	1	1
Lupinus spp.	0	0	1	0	-	-
Vicia spp.	48	53	58	61	49	53
Trifolium spp.	1	1	2	1	1	3
Lotus spp.	0	1	4	1	1	2
Robinia psuedo-acacia	-	-	1	-	-	-
Cytisus scoparius	-	5	4	-	-	5
Geranium spp.	0	2	3	3	5	4
Epilobium spp.	-	-	-	-	-	-
Anthriscus scandicina	0	0	1	0	1	1
Daucus carota	25	32	42	28	28	33
Galium spp.	2	-	-	-	-	-

Table 8. Continued.

FOOD ITEM	WINTER 1976-7	SPRING 1977	SUMMER 1977	FALL 1977	WINTER 1977-8	SPRING 1978
Myosotis bicolor	0	-	10	2	2	15
Dipsacus sylvestris	6	10	9	10	10	11
Tribe Cichorieae	3	4	4	9	6	6
Cirsium spp.	-	22	-	16	-	20
Pyrus spp.	6	-	-	5	5	-
Rubus spp.	-	-	51	55	-	-
Festuca spp.	55	64	57	62	64	56
Holcus spp.	8	0	17	-	15	-
Order Musci	63	69	35	52	69	55

[a]Percent frequency was not computed.

the core zones. Tansy ragwort was positively correlated to food groups and bare ground and negatively related to short fescue (Table 7).

During the decline of quail numbers in winter 1977, quail densities were positively related to other short grass and ox-eye daisy (R^2 = 0.64). Other short grasses were negatively correlated to tall fescue, short fescue, and tall vetch (Table 7). Ox-eye daisy, which was never found in quail crops and apparently provided little cover, was not significantly correlated to any other variable.

Densities of quail in spring 1978 were negatively related to tall fescue and positively related to ox-eye daisy (R^2 = 0.58). Tall fescue was positively correlated to low fescue and negatively correlated to nonvetch legumes (Table 7). Ox-eye daisy was positively correlated to short wild carrot and false dandelion (Table 7), important food items.

Generally, quail responded positively to forbs and negatively to grasses throughout the study. Dense stands of grasses inhibited the growth of several important food species. Similarly, Leopold (1977) stated that thick stands of woody vegetation prevented the growth of important quail foods. Francis (1970) and McMillan (1964) found that California quail production was highest in years of high forb production. In addition, years of low chick production were often years in which grasses dominated the habitat and forbs were sparse (Leopold 1977).

Wild carrot and vetch rarely were related significantly to quail distribution despite their importance as staple food items of quail. However, wild carrot and vetch occurred at high frequencies in the habitat throughout the year (Table 8) and probably never acted as limiting factors to quail. Other important foods which occurred at lower frequencies apparently affected distribution and productivity of quail.

Quail numbers were not significantly correlated to the percentages of study sites planted to wheat for any season during the study.

Disking, food plantings, and wheat plantings affected quail quite differently. Disking benefited quail by stimulating growth of preferred foods and creating open areas which were favored brooding habitat. During 1977 quail spent more time and produced more chicks on disked sites than on other sites. Although quail infrequently consumed the sudan grass grown in food plantings, they readily ate forbs which grew incidental to the planted crop. Quail were more numerous on food planting sites than on wheat planting or control sites; however, quail on food planting sites experienced the poorest reproductive success. Fewer chicks and adults were sighted on wheat planting sites than control sites throughout the study. Apparently wheat plantings constituted poorer habitat for California quail than other sites investigated in the study.

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APPENDIX I

AVIAN POX IN CALIFORNIA QUAIL FROM OREGON

J.A. Crawford, and R.M. Oates, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon 97331, USA.

D.H. Helfer, School of Veterinary Medicine, Oregon State University, Corvallis, Oregon 97331, USA.

Abstract

California quail (Lophortyx californicus) from several locations in Oregon were examined seasonally between fall 1975 and summer 1978 for avian pox. Pox lesions were present on 66 of 256 (26%) birds from the E.E. Wilson Wildlife Area. None of the remaining 41 birds from other areas was infected. Rates of infection of males and females were equal; juveniles had a slightly, but not significantly, higher prevalence of pox than did adults.

Introduction

Avian pox, a disease common to domestic gallinaceous birds, was reported to occur in wild populations of bobwhite (Colinus virginianus) (Stoddard 1932) and Gambel's quail (Lophortyx gambelii) (Blankenship et al. 1966), but not in other species of North American quail. Incidental to a study on the factors affecting California quail (L. californicus) populations in western Oregon (Crawford 1978) was the discovery of avian pox in this species. Consequently, the prevalence of avian pox in California quail from several locations in Oregon was examined between 1975 and 1978.

Materials and Methods

The study was conducted primarily on the E.E. Wilson Wildlife Area, a state-operated refuge and game farm, located 16 km north of Corvallis, Benton County, Oregon. Quail were collected seasonally by trapping or shooting from fall 1975 through summer 1978, except for spring and summer 1976. Birds, trapped during one season and recaptured or shot during a subsequent season, were treated as separate observations. Recaptures within a season were not included in the analysis. A total of 256 quail (283 observations) from the E.E. Wilson Wildlife Area was examined. Additionally, 20 quail were shot in Benton (9), Linn (2), Polk (1), and Yamhill (8) Counties and 21 quail were shot in Morrow (16) and Umatilla (5) Counties between spring 1975 and winter 1977-78.

Most cases of avian pox were diagnosed in the field by gross examination; however, quail with epidermal lesions of a questionable nature were submitted to the Oregon State University Veterinary Diagnostic Laboratory for examination. Lesions from infected birds were fixed in 10% buffered formalin for 24 hours, sectioned at 5 μm, and stained with hematoxylin-eosin for histopathological evaluation. Where indicated, bacteriologic cultures were made.

Chi-squared analysis is (Snedecor and Cochran 1967) was used to test for differences in rates of infection between adults and juveniles and between males and females. Results from shooting and trapping were analyzed separately. Age ratios of birds which were shot during summer were excluded from calculations because only adult birds were collected.

Results and Discussion

Sixty-six of 256 (26%) different individuals from the E.E. Wilson Wildlife Area and none of 41 birds from other areas were infected with avian pox. Results from the sample of birds shot on the E.E. Wilson Wildlife Area indicated a prevalence of 14%, whereas 34% of trapped birds were infected (Table A). Seemingly, the prevalence of pox was unrelated to sex ($P \geq 0.75$) or age ($P \geq 0.10$) of the birds. Nevertheless, a trend which indicated a higher proportion of juveniles among infected birds was apparent. Seasonal prevalence of infection varied from 0 to 50% (Table A). Infection was lowest during summer which coincided with the driest part of the year in western Oregon.

All infected birds possessed lesions on the feet or tarsi. Additionally, a lesion on the epidermis of the tibiotarsus was found on one bird and another individual had a lesion near the left eye. No evidence of wet pox involving the mouth or upper respiratory tract was found in any of the 4 birds examined. In bobwhites, Stoddard (1932) found that lesions usually occurred on legs. Contrastingly, Blankenship, Reed, and Irby (1966) observed pox lesions only on the heads of Gambel's quail.

Microscopic examination of the lesions revealed a proliferative process involving the stratified squamous epithlium characterized by ballooning of individual epithelial cells which contained large eosinophilic intracytoplasmic inclusion bodies (Bollinger bodies). Associated with this condition were superficial necrotic debris and, in the dermis, varying degrees of inflammatory response characterized by edema and leukocytic infiltration. _Staphyloccus aureus_, probably

Table A. Prevalence of pox in California quail, E.E. Wilson Wildlife Area, Oregon, 1975-1978.

SEASON	COLLECTION METHOD	NUMBER EXAMINED	NUMBER WITH POX	(%)
Fall 1975	Shot	20	0	(0)
Winter 1975-76	Trapped	10	2	(20)
Fall 1976	Shot	23	0	(0)
Winter 1976-77	Trapped	32	10	(31)
Spring 1977	Shot	6	2	(33)
Spring 1977	Trapped	33	13	(39)
Summer 1977	Shot	15	2	(13)
Summer 1977	Trapped	6	1	(17)
Fall 1977	Shot	21	3	(14)
Fall 1977	Trapped	38	18	(47)
Winter 1977-78	Shot	16	8	(50)
Winter 1977-78	Trapped	23	8	(35)
Spring 1978	Shot	9	2	(22)
Spring 1978	Trapped	7	0	(0)
Summer 1978	Shot	10	0	(0)

reflecting secondary invasion, was isolated from lesions on 2 quail.

Fowl pox was detected on the heads and feet of gray partridges (Perdix perdix) imported to the E.E. Wilson Wildlife Area in 1956 (T.P. Kistner, personal communication). Personnel of the Oregon Department of Fish and Wildlife conducted serological tests for pox in pheasants and partridges annually until the 1970's; no infected birds were found (D. Kirkpatrick, personal communication). However, incidental to trapping for quail, fowl pox was discovered in 1 of 5 female ring-necked pheasants (Phasianus colchicus) captured during April 1978.

Previous documentation of avian pox in game farm birds on the E.E. Wilson Wildlife Area, the relatively high prevalence of pox among California quail on that area, and the absence of infected birds from other locations tend to indicate a relationship between pox in quail and game-farming activities.

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APPENDIX II

POPULATION CHARACTERISTICS

Trapping of quail was conducted for 28 days each season from winter 1976 through spring 1978. The walk-in style traps, 56 cm x 56 cm x 18 cm in size and constructed of welded wire, were baited with small grains. Sex and age were determined for all quail and hatching dates for juveniles were estimated from growth characteristics of primary flight feathers (Raitt 1961).

Shooting and trapping yielded significantly different results for sex and age ratios in several instances. Although no differences existed between sex ratios of quail obtained from shooting and trapping samples for individual seasons, a significantly ($P \leq 0.01$) higher percentage of females were trapped than were shot in the combined sample of all seasons. A significantly ($P \leq 0.05$) higher percentage of juveniles were trapped than were shot during winter 1976, fall 1977, and winter 1977. In addition, significantly ($P \leq 0.01$) more juveniles were trapped than were shot in the combined sample of all seasons. Leopold (1977) believed both trapping and shooting provided representative samples of population characteristics of California quail. Likewise, Stoddard (1932) indicated that similar sex ratios of bobwhites were obtained by shooting and trapping and Campbell et al. (1973) believed that similar age ratios of scaled quail were obtained from shooting and trapping samples.

The apparent inconsistencies between the results of the present study and those of Leopold, Stoddard and Campbell et al., may have reflected differences in sampling techniques or data analysis.

Assuming that sampling procedures (which were similar for all studies) could not be adequately compared, methods of analyses were examined. Campbell combined 9 years of data, weighted according to annual sample size, to obtain mean percentages of juveniles for shooting and trapping samples. If the assumption of adequacy of annual sample size was accepted, the annual figures for percent juveniles should not be weighted for computation of the means. Chi-squared analysis with unweighted means of 9 years of samples revealed a significantly ($P \leq 0.01$) higher percentage of juvenile quail in the shooting samples. Stoddard's data, when analyzed in the same manner, revealed that significantly ($P \leq 0.025$) fewer females occurred in the trapping sample than in the harvest sample.

Intensive pressure on a brush-bound covey by dogs and collectors probably provided little opportunity for the display of sex or age differential behavior. The comparatively calm conditions of a trap site probably provided opportunities for expression of differential behavior in this study. In the present investigation juvenile and female quail were probably more susceptible to being trapped than shot.

Crawford (1978) documented a predominance of females (Table B) in fall and winter shooting and trapping samples, respectively. Fall 1976 collection also revealed a majority of females. Females predominated in shooting samples through winter 1976 and in trapping samples through spring 1977. Sample sizes of spring 1977 shooting sample and summer 1977 trapping sample were considered inadequate for meaningful analysis. After spring 1977 the sex ratio favored males for the remainder of the study (Table B).

As both shooting and trapping samples indicated that juvenile

Table B. Sex and age ratios of California quail shot and trapped on the E.E. Wilson Wildlife Area, Oregon, 1975 - 1978.

SEASON	SHOOTING			TRAPPING		
	Sex Ratio (M:F)	Age Ratio (A:J)	n	Sex Ratio (M:F)	Age Ratio (A:J)	n
Fall 1975[a]	40:60	25:75	20	-	-	-
Winter 1975-6[a]	-	-	-	40:60	20:80	10
Spring 1976	-	-	-	-	-	-
Summer 1976	-	-	-	-	-	-
Fall 1976	43:57	30:70	23	-	-	-
Winter 1976-7	43:57	36:64	14	41:59	13:87	32, 30[b]
Spring 1977	83:17	33:67	6	48:52	27:73	33
Summer 1977	53:47	20:80	15	33:67	33:67	3
Fall 1977	67:33	38:62	21	55:45	16:84	38
Winter 1977-8	75:25	69:31	16	65:35	39:61	23
Spring 1978	56:44	22:78	9	71:29	43:57	7
Summer 1978	60:40	30:70	10	-	-	-

Table B. Continued.

SEASON	SHOOTING			TRAPPING		
	Sex Ratio (M:F)	Age Ratio (A:J)	n	Sex Ratio (M:F)	Age Ratio (A:J)	n
Fall 1978	57:43	36:64	14	-	-	-
Winter 1978-9[c]	-	-	-	50:50	50:50	8
Spring 1979[c]	-	-	-	58:42	32:62	37

[a]Data from Crawford (1978).

[b]Age was not determined for 2 quail.

[c]Data from Crawford (personal communication).

females predominated fall and winter populations in 1975 and 1976, it was likely that juvenile females experienced higher survival rates than juvenile males during these periods. Although males consistently constitute the majority in wild populations of California quail (Emlen 1940, Raitt and Genelly 1964, Leopold 1977) several studies revealed predominances of females in the juvenile segment of the fall populations (Emlen 1940, Raitt and Genelly 1964, Yadon 1954, Williams 1957). Williams (1957) found that prior to 13 weeks of age male quail suffered greater mortality than females. Subsequently, mortality rates of females increased and males predominated by winter. Raitt and Genelly (1964) found that the high proportion of females persisted through winter. In each study cited adult males outnumbered adult females to the extent that the combination of age groups resulted in an overall predominance of males. In the present investigation, the paucity of adults in most samples may have resulted in an inaccurate representation of adult sex ratios therefore yielding a predominance of females when the 2 age groups were combined.

Mean recruitment rate for fall populations of quail on E.E. Wilson Wildlife Area (1975-1978) was 68 percent juveniles. This rate compared favorably with recruitment rates in other areas of the range of the species: southern California--59 percent juveniles (McMillan in Leopold 1977), Sacramento Valley--67 percent juveniles, Vancouver Island--77 percent juveniles (Barclay and Bergerud 1964). The quail population presently on the E.E. Wilson Wildlife Area existed at a lower density than any of the 3 previously mentioned populations. Apparently the low-density of the population on the E.E. Wilson Wildlife Area was not a result of low productivity.