AN ECOLOGICAL RECONNAISSANCE OF THE PHEASANTS IN HAWAII

BY CHARLES W. SCHWARTZ AND ELIZABETH REEDER SCHWARTZ

INTRODUCTION

A PERUSAL of the technical literature dealing with the pheasant shows scant reference to the introduction of this avian exotic into the Hawaiian Islands or its success as the major game bird, and no mention of the factors related to its welfare in this archipelago. The ecology of the pheasant in this adopted range is reported herein as a contribution toward a better understanding of this game bird which now provides a favorite target for gunners on three continents. The study was conducted in the Hawaiian Islands from February, 1946, through July, 1947, as part of the upland game-bird survey, Project 1-R of the Federal Aid-Wildlife Program of the Board of Commissioners of Agriculture and Forestry of the Territory of Hawaii. All the major islands were surveyed except Kahoolawe, which was used as a bombing target under military jurisdiction, and Niihau which is privately-owned.

ACKNOWLEDGMENTS

Many individuals graciously contributed to the success of this study and we regret that only a few can be acknowledged here. We are indebted to Mr. Colin G. Lennox, President, Mr. Vernon E. Brock, Director, Division of Fish and Game, and other fellow employees of the Board of Commissioners of Agriculture and Forestry of the Territory of Hawaii for their assistance in numerous ways. The owners and operators of ranches and sugar cane and pineapple plantations gave us invaluable aid.

Assistance in the identification of some specimens was given by the following: MOLLUSCS—Dr. Montague Cooke, Jr., Bernice P. Bishop Museum; PLANTS—Mr. E. Y. Hosaka, University of Hawaii and Bernice P. Bishop Museum; Dr. Harold St. John, University of Hawaii, and Mr. Gunnar O. Fagerlund, formerly of Hawaii National Park; PARASITES—Dr. Joseph E. Alicata, University of Hawaii, Drs. E. W. Baker and E. W. Stafford, U. S. Department of Agriculture, and Mr. E. Ediger, U. S. Fish and Wildlife Service; INSECTS—Mr. C. E. Pemberton, Hawaiian Sugar Planters' Association Experiment Station.

Dr. Paul H. Baldwin, formerly of Hawaii National Park, donated the crops of 18 pheasants and Dr. Robert W. Hiatt, University of Hawaii, provided four additional crops.

We are indebted, also, to Dr. Harvey I. Fisher, formerly of the University of Hawaii but now with the University of Illinois, for a critical reading of this manuscript.

HISTORICAL BACKGROUND

From the time of their discovery by the English in 1778, the Hawaiian Islands have played host to untold introductions of plants and animals. One of these, the pheasant, has taken its place as an important member of the islands' exotic fauna and, of the limited species which became established, ranks with the very few considered assets. The pheasant's popularity arises largely from its sporting value, but its plumage is also highly prized for certain feathers used in the manufacture of hatbands, or *leis*, worn for so long as an island custom that they have become a trademark of Hawaii.

At present there are two pheasants and their hybrids established in the Hawaiian Islands. The Ring-necked Pheasant, *Phasianus torquatus torquatus* Gmelin, is the more common and widespread. It was first brought to Hawaii about 1865 (Caum, 1933) but until 1941 many subsequent liberations were made on all the major islands. While direct importations from the native range of the Ring-necked Pheasant in eastern China and northern Indo-China are believed to have occurred, most of the birds for liberation and breeding purposes were obtained from dealers in the United States where the ancestry of the stock included several subspecies. The rearing of pheasants for planting on the various islands was the major function of the Territorial Game Farm until it was disbanded following the Japanese attack on Pearl Harbor in 1941. Because of the questionably-pure racial heritage, it is doubtful if the Ring-necked Pheasant occurs as a "pure" species in Hawaii, but it will be referred to by this name here because of its similarity to pure stock of the Ring-necked Pheasant.

The Green or Versicolor Pheasant, *Phasianus versicolor versicolor* Vieillot, which is believed to represent a single species in Hawaii, is less common and more restricted than the Ring-necked Pheasant. The Green Pheasant was liberated on all the major islands prior to 1900 (Caum, 1933), but subsequent plantings have been made directly from its native range on Hondo and Shikoku, Japan, from dealers in the United States, and from stock originating from these two sources which was reared at the Territorial Game Farm.

Birds possessing feather markings common to both these species occur in Hawaii, and these individuals are referred to herein as "hybrids." Unless specified otherwise, Ring-necked, Green, and hybrid pheasants will be discussed together in this paper.

Five birds showing some characteristics of the Mongolian Pheasant, *Phasianus colchicus mongolicus* J. H. Brandt, were seen or collected on Hawaii and Kauai during this survey and have been reported on Hawaii by Baldwin (1941 and MS). Such individuals probably represent hybridization between Ring-necked and Mongolian pheasants, since the latter subspecies was introduced onto these islands at various times after 1865 but no longer exists as pure stock (Caum, 1933).

Other pheasants have been brought into Hawaii on different occasions. The Silver Pheasant, *Gennaeus nycthemerus* (L.), and the Golden Pheasant, *Chrysolophus pictus* (L.), were first introduced about 1865 and 1870; in 1932 they were raised at the game farm and liberated on Oahu. The Copper Pheasant, *Syrmaticus soemmerringii* (Temminck), was planted on Oahu, Maui, and Kauai islands at various times between 1907 and 1914. The only recorded liberations of the Lady Amherst's Pheasant, *Chrysolophus amherstiae* (Leadbeater), were in 1932 on Oahu and 1933 on Hawaii. All these species failed to survive (Caum, 1933).

GEOGRAPHY

The major or windward Hawaiian Islands form the southeastern portion of the Hawaiian Archipelago and lie between 19 and 23 degrees north latitude at the northern border of the tropics. They have a combined land mass of 6,435 square miles and rise in places to a maximum height of 13,784 feet above sea level. These islands are of volcanic origin and much of their weathered surfaces possesses an extremely rugged topography. The leeward Hawaiian Islands, consisting of shoals and reefs totalling an area of only six square miles, are excluded from this discussion.

The climate of Hawaii is extremely equable, showing less than 8° F. difference in the mean temperature between the warmest and coolest months in an average year. However, above about 6,000 feet elevation, temperature fluctuations are somewhat greater. Because the temperature decreases approximately 1° F. with each 300-foot increase in elevation, concentric temperature belts are produced on each island. The climate is subtropical below 2,500 feet elevation, having an annual mean of about 75° F. Between 2,500 and 4,000 feet, it is more temperate and the annual mean is around 60° F. Frost is not infrequent at this highest elevation. From 4,000 to 7,000 feet, the mean temperature is approximately 50° F., decreasing to about 40° F. in a belt between 7,000 and 10,000 feet. Above 7,000 feet, the low summer temperatures limit good plant growth and almost no vegetation occurs above 10,000 feet (Ripperton and Hosaka, 1942). The

highest elevations in Hawaii are the summits of Mauna Loa and Mauna Kea which reach 13,680 and 13,784 feet, respectively. In winter, snow frequently blankets these peaks down to about 10,000 feet.

The northeastern trade winds, which are dominant throughout all seasons, provide rainfall for the greater parts of all islands. Maximum precipitation occurs between approximately 2,000 and 6,000 feet elevation on the windward sides, while little rain falls on leeward slopes or high mountain peaks. In lee sections most of the precipitation originates from irregularly-occurring southern and western frontal storms of a few days' duration. Throughout Hawaii, the annual rainfall varies from less than 10 inches on lee coasts to 450 inches or more in windward regions. Where the annual precipitation is less than 40 inches, conditions are semi-desert and long periods of drouth are common. In these sections the rainfall is generally torrential and it is not uncommon to have amounts nearing the total annual precipitation in a 24-hour period. Regions receiving from 40 to 60 inches annually have a more uniform distribution of rainfall throughout the year and conditions are favorable for continued plant growth and maturing of seeds. At approximately 60 inches annually, evaporation is equal to precipitation. The climate in areas receiving 60 inches or more of rainfall annually is characteristically damp and misty with little sunshine although heavy rains may occur (Territorial Planning Board, 1939; Ripperton and Hosaka, 1942; Stearns, 1946). Although comparative amounts of precipitation between regions are important, extreme variations occur from one month to another and hence the mean may have little ecological significance.

The soils of Hawaii are derived almost entirely from lava and vary from loose volcanic ash to dense lava. Because of the geologic youth of the parent material and the rugged topography, only small areas of well developed soils occur. Those soils formed under heavy precipitation are generally acid and have a large content of organic matter and nitrogen, a decreased silica content, and small amount of available potassium and phosphorus. Their plant nutrients have been depleted by leaching. The converse applies to soils formed under low precipitation (Coulter, 1940).

Only seven per cent of the land of Hawaii is under cultivation. Of this, 78 per cent is in sugar cane, 16 per cent in pineapple, and the remaining 6 per cent in coffee, taro, fruit, nuts, cotton, and vegetable gardens. Only in rare localities does cultivation occur above 2,000 feet elevation. Forest reserve, amounting to 26 per cent of the land of Hawaii, consists of large tracts kept in forest, primarily the native ohia lehua, *Metrosideros collina*, and tree ferns, *Cibotium* sp., to pro-

vide a reservoir for continued surface run-off which is the main source of water for agricultural and civic development in the islands. Waste areas, comprising 32 per cent, are generally barren lava while pasture systems, constituting 29 per cent of the land area, vary from rocky expanses with extremely poor soil and only scattered forage species to generally open grassland with good sod coverage. Civic land and National Park comprise 4 and 2 per cent of the territory, respectively (Coulter, 1940).

The Hawaiian Islands had a unique vegetation in the native state. Of 1,200 plant species recorded, 85 per cent are endemic. After the discovery of the islands in 1778 and subsequent colonization, exotic plants were introduced both intentionally and accidentally until now over 2,000 such species are known. However, the distribution of both exotic and native species falls into a general pattern which is related to climatic conditions, soil, and land-use practices. Ripperton and Hosaka (1942) have proposed "Vegetation Zones of Hawaii" which correlate the essential features of the present environment on all islands with agricultural use. The distribution and relative abundance of game birds show a general agreement with these zones, but the degree of land use is further influential. These vegetation zones are used herein in the sense of game-range types and they form the basis of the management program developed for the game birds in Hawaii. In addition to their original description by Ripperton and Hosaka (1942) they are summarized and shown on a map in connection with a discussion of the California Quail in Hawaii (Schwartz and Schwartz, 1950: 8–9).

DISTRIBUTION

The distribution of pheasants on all islands surveyed is shown on maps in Schwartz and Schwartz (1949: opp. p. 28) and given by vegetation zone in Table 1 of this paper.

All suitable range for Ring-necked Pheasants on the various islands is occupied. In Hawaii this ubiquitous species ranges: (1) from sea level to 11,000 feet elevation; (2) from subtropical regions to those where freezing temperatures occur frequently; (3) where less than 10 inches of rain falls annually to places receiving 300 inches; (4) on recent soils (lava) to those soils with deep pockets of loam; (5) in forested and grassland regions, deserts, and other waste areas; (6) in pineapple fields, sugar-cane lands, small truck gardens, and corn acreages; and (7) in all types of topographic conditions. Its best populations are found, however, on soils of better fertility where the land use permits, in areas receiving between approximately 20 and 80

TABLE 1

DISTRIBUTION BY VEGETATION ZONE OF PHEASANT RANGE IN HAWAII

	Hawaii	*Kauai*	*Lanai*	*Maui*	*Molokai*	*Oahu*	*Total*
Vegetation Zone A							
Square miles	249	23	72	121	64	67	596
Square miles occupied	73	23	72	108	64	28	368
Per cent zone occupied	29	100	100	89	100	42	62
Per cent total range	—	—	—	—	—	—	10
Vegetation Zone B							
Square miles	408	116	57	138	74	169	962
Square miles occupied	298	111	54	95	70	109	737
Per cent zone occupied	73	96	95	69	94	64	77
Per cent total range	—	—	—	—	—	—	20
Vegetation Zone C_1							
Square miles	194	88	10	54	46	146	538
Square miles occupied	126	85	9	45	40	127	432
Per cent zone occupied	65	96	90	83	87	87	80
Per cent total range	—	—	—	—	—	—	12
Vegetation Zone C_2							
Square miles	316	11	0	61	0	0	388
Square miles occupied	267	7	0	47	0	0	321
Per cent zone occupied	84	64	0	77	0	0	83
Per cent total range	—	—	—	—	—	—	9
Vegetation Zone D_1							
Square miles	464	113	2	97	32	110	818
Square miles occupied	367	113	0	73	12	83	648
Per cent zone occupied	79	100	0	75	37	75	79
Per cent total range	—	—	—	—	—	—	17
Vegetation Zone D_2							
Square miles	790	194	0	151	44	112	1,291
Square miles occupied	97	34	0	0	5	11	147
Per cent zone occupied	12	17	0	0	11	10	11
Per cent total range	—	—	—	—	—	—	4
Vegetation Zone D_3							
Square miles	353	10	0	23	0	0	386
Square miles occupied	297	10	0	23	0	0	330
Per cent zone occupied	84	100	0	100	0	0	85
Per cent total range	—	—	—	—	—	—	9
Vegetation Zone E_1							
Square miles	647	0	0	39	0	0	686
Square miles occupied	550	0	0	36	0	0	586
Per cent zone occupied	85	0	0	92	0	0	85
Per cent total range	—	—	—	—	—	—	16
Vegetation Zone E_2							
Square miles	503	0	0	44	0	0	547
Square miles occupied	94	0	0	29	0	0	123
Per cent zone occupied	19	0	0	66	0	0	22
Per cent total range	—	—	—	—	—	—	3
Vegetation Zone E_3							
Square miles	106	0	0	0	0	0	106
Square miles occupied	0	0	0	0	0	0	0
Per cent zone occupied	0	0	0	0	0	0	0
Per cent total range	—	—	—	—	—	—	0
TOTAL, *Vegetation Zones*							
Square miles	4,030	555	141	728	260	604	6,318
Square miles occupied	2,169	383	135	456	191	358	3,692
Per cent zone occupied	54	69	96	63	73	59	58
Per cent total range	59	10	4	12	5	10	

inches of rainfall annually, and in generally open cover interspersed with abundant forage species and with some form of available moisture. Areas of very heavy rainfall with associated dense rain forests, or extremely dry, barren areas at low elevations and on top of the highest mountain peaks are the only unoccupied portions of Hawaii.

According to military sources, no pheasants occur on Kahoolawe. Field observations on Niihau by Fisher (1951: 37) showed a population of Ring-necked Pheasants displaying a mixed ancestry. He described their abundance and distribution as follows: The lowlands have relatively few birds, except in the immediate vicinity of the waterholes. The open lava fields have almost none; the thickets of kiawe, *Prosopis chilensis*, present the best cover in the lowlands. The birds were abundant in the tall-grass cover on the east, south and west slopes of Kaeo, and in the indigo, *Indigofera suffruticosa*, vegetation one mile north of Kaeo. The grass and weeds of the plateau have by far the highest numbers.

The climatic conditions of the range of the Ring-necked Pheasant in Hawaii include extremes occupied by this species elsewhere in the world, except for the rigorous winters of the continents. However, the pheasant's range in Hawaii is unique in combining many variations within a small area. The high altitudes and heavy precipitation probably represent the greatest limits tolerated by this species anywhere.

The Green Pheasant is concentrated only on the windward slopes of Mauna Kea and Mauna Loa on Hawaii. Ring-necked and hybrid pheasants are also found in this area, but the population ratio is approximately 3 Green to 1 Ring-necked to 1 hybrid. Additional range occupied by Green Pheasants occurs adjacent to these areas of concentration and in isolated sites on other islands where this species was introduced. The composition of the pheasant population in such ranges is approximately 1 Green to 2 Ring-necked to 2 hybrid. Hybrids become more numerous toward the periphery of each species' concentration.

While Green Pheasants are found in all extreme elevations where Ring-necked Pheasants occur, their best range lies between approximately 4,000 and 7,000 feet elevation in vegetation zones D_3 and E_1. This area is primarily open koa, *Acacia Koa*, forest with interspersed grassy meadows containing mixed herbaceous growth. The surface here is gently sloping and the soils are better than in other portions occupied by Green Pheasants. The climate is cool and moist with an annual mean of about 50° F. Maximum rainfall is 125 inches at lower elevations and 20 inches at higher altitudes but, even in areas of

little precipitation, mists of several days' duration characterize the prevailing weather. Open grasslands, sugar cane areas, and dense forests are less productive habitats for the Green Pheasant.

Beebe (1936) described the Green Pheasant as a native of the lowlands in Japan. According to him, these birds seldom reach any great height on the ranges and mountains of the interior but seem to prefer the vicinity of cultivated fields along the coast.

The Green Pheasant is apparently decreasing in Hawaii through hybridization, and its restricted distribution and fewer numbers favor the Ring-necked Pheasant. Much of the present preferred range of the Green Pheasant is developing into open grassland through prevention of tree reproduction by heavy grazing of feral and controlled livestock. While some new range is being created by grazing in denser forests, the range of the Green Pheasant will probably always be less than that of the Ring-necked Pheasant in Hawaii.

From all indications, both Ring-necked and Green pheasants tend to remain in the same vicinity throughout the year. In areas subjected to prolonged drouth we have found that birds may move to regions where water or succulence is available, and in extremely high elevations during colder months they tend to move down to about 8,000 feet elevation.

POPULATIONS

A population of 70,000 pheasants was estimated for 3,700 square miles of range in the major Hawaiian Islands. Population densities vary from less than 10 to 100 birds per square mile. Estimates of populations for 1946–1947 are given by vegetation zone in Table 2. Average densities have not been computed because they do not show the span or frequency of densities within a given range and are of little value in range evaluation.

Evaluation of vegetation zones for pheasant productivity on the basis of size of population, area occupied, and amount of range with high densities shows four general groups: (1) zones B, C_2, D_1, and E_1 rank highest in all three respects; (2) zones D_2 and E_2 rate lowest, and zone A, although having more occupied range, has low densities and a low population; (3) zones C_1 and D_3 are intermediate; and (4) zone E_3 is unoccupied.

Two methods were utilized to estimate the pheasant population. A count of crowing males was taken during the height of the breeding season on Hawaii, Kauai, and Oahu. Our method was developed independently but is similar to the crowing-count pheasant census described by Kimball (1949). This count was converted into a census

TABLE 2

POPULATIONS OF PHEASANTS IN HAWAII BY VEGETATION ZONE

	Total population	*Distribution of density classes in birds per square mile*							
		1–10		*11–25*		*26–50*		*51–100*	
		Miles	*Per cent*	*Miles*	*Per cent*	*Miles*	*Per cent*	*Miles*	*Per cent*
Vegetation Zone—A									
Hawaii	670	68	93	5	7				
Kauai	460			23	100				
Lanai	430	70	97	2	3				
Maui	1,160	51	47	57	53				
Molokai	640	64	100						
Oahu	400	23	82			5	18		
Total	3,760	276	75	87	24	5	1		
Per cent population	5								
Vegetation Zone—B									
Hawaii	4,430	201	68	57	19	28	9	12	4
Kauai	2,890	19	17	50	45	36	33	6	5
Lanai	890	21	39	13	24	20	37		
Maui	1,540	8	8	87	92				
Molokai	870	51	73	14	20	5	7		
Oahu	2,000	32	29	59	54	18	17		
Total	12,620	332	45	280	38	107	15	18	2
Per cent population	18								
Vegetation Zone—C_1									
Hawaii	1,240	113	90			13	10		
Kauai	2,610	10	12	8	9	67	79		
Lanai	130	5	56	1	11	3	33		
Maui	1,130	4	9	10	22	31	69		
Molokai	580	30	75	2	5	8	20		
Oahu	2,720	6	5	103	81	18	14		
Total	8,410	168	39	124	29	140	32		
Per cent population	12								
Vegetation Zone—C_2									
Hawaii	8,060	122	46	69	26	43	16	33	12
Kauai	150	6	86	1	14				
Lanai	0								
Maui	2,230			6	12	41	88		
Molokai	0								
Oahu	0								
Total	10,440	128	40	76	24	84	26	33	10
Per cent population	15								
Vegetation Zone—D_1									
Hawaii	1,910	366	100			1	trace		
Kauai	4,620	7	6	21	19	66	58	19	17
Lanai	0								
Maui	2,160	19	26	1	1	53	73		
Molokai	230	3	25	4	33	5	42		
Oahu	1,820			66	80	17	20		
Total	10,740	395	61	92	14	142	22	19	3
Per cent population	15								
Vegetation Zone—D_2									
Hawaii	1,520	43	44	37	38	17	18		
Kauai	610			30	88	4	12		

TABLE 2—(*continued*)

	Total population	Distribution of density classes in birds per square mile							
		1–10		11–25		26–50		51–100	
		Miles	Per cent	Miles	Per cent	Miles	Per cent	Miles	Per cent
Veget. Zone—D_2 (cont.)									
Lanai	0								
Maui	0								
Molokai	90	1	20	3	60	1	20		
Oahu	220			11	100				
Total	2,440	44	30	81	55	22	15		
Per cent population	4								
Vegetation Zone—D_3									
Hawaii	4,910	157	53	74	25	66	22		
Kauai	200			8	80	2	20		
Lanai	0								
Maui	1,250					20	87	3	13
Molokai	0								
Oahu	0								
Total	6,360	157	47	82	25	88	27	3	1
Per cent population	9								
Vegetation Zone—E_1									
Hawaii	10,870	271	49	136	25	112	20	31	6
Kauai	0								
Lanai	0								
Maui	1,670			7	19	29	81		
Molokai	0								
Oahu	0								
Total	12,540	271	46	143	25	141	24	31	5
Per cent population	18								
Vegetation Zone—E_2									
Hawaii	1,580	46	49	39	41	9	10		
Kauai	0								
Lanai	0								
Maui	1,450					29	100		
Molokai	0								
Oahu	0								
Total	3,030	46	37	39	32	38	31		
Per cent population	4								

	Total population	Per cent total population	Distribution of density classes in birds per square mile							
			1–10		11–25		26–50		51–100	
			Miles	Per cent	Miles	Per cent	Miles	Per cent	Miles	Per cent
All Zones—Total										
Hawaii	35,190	50	1,387	64	417	19	289	13	76	4
Kauai	11,540	17	42	11	141	37	175	46	25	6
Lanai	1,450	2	96	71	16	12	23	17		
Maui	12,590	18	82	18	168	37	203	44	3	1
Molokai	2,410	3	149	78	23	12	19	10		
Oahu	7,160	10	61	17	239	67	58	16		
Total	70,340		1,817	49	1,004	27	767	21	104	3

figure by using the sex ratio obtained from sight observations in the same area in early morning or evening. The islands of Maui, Lanai, and Molokai were censused following the height of the breeding season by strip counts made with and without dogs, and on foot and horseback. The limitations of these methods are realized, but our estimates agree closely with those of informed observers in the areas.

Compared to the Ring-necked Pheasant, crowing of the Green Pheasant is distinctly higher and shriller, as first pointed out by Beebe (1936); the crow of the hybrid tends to resemble that of the species which its plumage portrays. However, the relative abundance of these three types was based upon sight observation rather than on auditory means because the listener could not always distinguish the fine demarcation in the crowing of these different birds.

FOODS

The crops and gizzards of 191 pheasants taken from the nine occupied vegetation zones formed the basis for this food study. Identification of food items was done in the field and, although the time thus spent limited the size of the sample, the on-the-spot analysis provided valuable information for concurrent range evaluation and permitted a sufficiently accurate picture of foods in the better pheasant ranges. The food items were separated, identified, dried, measured volumetrically in cubic centimeters, totalled for respective vegetation zones by aggregate volume, and recorded as to frequency of occurrence. In order to provide a measure of food plants in the range, the various foods were assigned to three arbitrary classes—classes 1, 2, and 3—on the basis of volumes in crops by vegetation zone. It was found that the foods of pheasants were related to the plant distribution and availability by vegetation zone, rather than to any seasonal occurrence, because of the little variation in the growing season in most of Hawaii.

Table 3 gives the annual foods, by food class, of pheasants in all vegetation zones of Hawaii. A total of 152 foods was utilized; 97 were plant species and 55 animal items. The wide variety of foods which the pheasant eats illustrates the adaptability of this bird to the different habitat conditions in Hawaii.

Class 1 foods include all species which occurred as more than six per cent of the crop volume in any vegetation zone. In this class there are 23 plant species and 5 insects. Class 2 foods, including 15 plant species and 9 animal items, occurred as 1 to 6 per cent of crop volumes. These two classes are important because of their volumes in the diet.

TABLE 3

FOODS OF PHEASANTS IN ALL VEGETATION ZONES BY FOOD CLASS[1]

Species	*Food class by vegetation zone*								
	A	*B*	C_1	C_2	D_1	D_2	D_3	E_1	E_2
PLANTS									
Acacia Koa							2	3	
Anagallis arvensis				3	3				
Ananas comosus		1							
Basidiomycete (unid.)								3	
Bidens pilosa		2							
Bromus catharticus		3		1				3	1
Capsicum frutescens					3				
Carex wahuensis								2	
Cassia bicapsularis	G	G							
Cassia Leschenaultiana		3	G		3				
Chenopodium ambrosioides				2					
Chenopodium oahuense				3					
Cirsium vulgare				1				2	
Colocasia esculenta					2				
Coprosma ernodeoides var. *typica*								G	
Coprosma montana var. *typica*							G		
Coprosma rhyncocarpa							G	G	
Crotolaria mucronata					3				
Cynodon Dactylon		3							
Desmodium canum					2				
Desmodium tortuosum				2					
Desmodium uncinatum		G		3					
Dianella sandwicensis							1		
Diospyros ferrea		3							
Dodonaea viscosa		G		3			3	G	G
Eleusine indica		3							
Emilia sonchifolia					3				
Eragrostis grandis								G	
Erigeron albidus		3							
Eugenia Cumini			1		1				
Euphorbia geniculata					3				
Euphorbia hirta				3				3	
Euphorbia hypericifolia	3				3				
Fragaria grandiflora		3							
Galinsoga parviflora		1		3					
Geranium carolinianum var. *australe*				3			3	3	
Geranium cuneatum var. *hypoleucum*				3					
Holcus lanatus							3		
Hypochaeris radicata		3		1			1	1	
Indigofera suffruticosa		G		G					
Ipomoea Batatas		1							
Korthalsella sp.							3		
Lantana Camara	1	G	1		3				
Lepidium auriculatum								3	1
Leucaena glauca	G	G	G					G	
Linum usitatissimum								3	
Lolium multiflorum				3				2	
Lythrum maritimum							3		
Medicago hispida		G							
Medicago lupulina				G	3			3	
Melilotus indica							G		
Merremia aegyptia	G	G							

TABLE 3—(*continued*)

Species	*Food class by vegetation zone*								
	A	*B*	C_1	C_2	D_1	D_2	D_3	E_1	E_2
PLANTS—(*continued*)									
Mimosa pudica			3		1				
Myoporum sandwicense							G	3	
Myrica Faya							1		
Nicandra Physalodes		3							
Opuntia megacantha		3		3					
Osteomeles anthyllidifolia		G							
Oxalis corniculata		2		3	3		G	2	
Oxalis Martiana			1		2				
Paspalum Urvillei		3			3		3		
Passiflora edulis					1		2		
Pellaea ternifolia								G	
Physalis peruviana								3	
Poa pratensis							3		
Prosopis chilensis	1	3							
Psidium Guajava		G	G		1				
Richardia brasiliensis					3				
Rubus hawaiensis							G	G	
Rubus rosaefolius					G	G	3	2	
Rumex acetosella							G	2	
Rumex crispus							G		
Scaevola procera		G					2		
Setaria geniculata		3					3		
Siegesbeckia orientalis					1				
Silene gallica				3				3	
Solanum nodiflorum	1	1			1		3	2	
Solanum Pseudo-Capsicum								sight	
Sonchus oleraceus	3	2		3	3			2	2
Sophora chrysophylla								3	
Sporobolus capensis		3		1	2		3	3	
Sporobolus indicus							3		
Stellaria media							3	3	
Styphelia Tameiameiae		G						1	
Tephrosia purpurea		3							
Trifolium repens		2		1	3		1	2	G
Tritonia crocosmaefolia					2				
Tropaeolum majus							1		
Vaccinium reticulatum								3	
Verbena litoralis							G	3	
Verbesina encelioides	3								
Vicia sativa				3	3			3	
Vigna marina					3				
Waltheria americana		3							
Wikstroemia phillyraefolia		1		1					
Xanthium saccharatum					3				
Zea mays		3		2	2				
ANIMALS									
Agriolimax sp.								3	
Agrotis ypsilon		2		2			2	1	1
Antonina graminis				3					
Aphodius lividus	1			3	3			3	
Arachnida (unid.)		3		3				3	
Atractomorpha ambigua		3			1				
Blapstinus dilitatus	2	3		2	3			3	
Blattidae (unid.)					3				
Bradybaena similaris				3					

TABLE 3—(*continued*)

Species	*Food class*[1] *by vegetation zone*								
	A	*B*	C_1	C_2	D_1	D_2	D_3	E_1	E_2
ANIMALS—(*continued*)									
Bruchus prosopis					3				
Carpophilus hemipterus		3							
Chaetogaedia monticola								3	
Chrysomia megacephala				G					
Cirphis unipuncta				G				2	
Coelophora inaequalis		3						3	
Coleoptera (unid.)	G	3		G			3	G	
Conoderus exsul		3		3	3	G		3	
Conocephalus saltator				3	2	1			
Copris incertus prociduus					3				
Curculionidae (unid.)								G	
Cutilia soror		3							
Diploptera dytiscoides		G	1	3					
Diptera (unid.)	3			3				G	
Elateridae (unid.)								G	
Epitragus diremptus	3								
Euborellia annulipes		2		3	3			G	
Fulgoridae (unid.)		3							
Gastropoda (unid.)				3					
Geotomus pygmaeus				3					
Gonocephalum seriatum		3			3			3	
Graptostethus manilensis	2							3	
Hemiptera (unid.)		3							
Homoptera (unid.)								G	
Insecta (unid.)				G				3	
Lepidoptera (unid.)	G			3			G	3	
Listroderes obliquus								G	
Megacerus alternatus	2								
Nysius coenosulus		G		3				3	
Oechalia pacifica							3		
Onthophagus insensus				2				3	
Orthoptera (unid.)							G		
Oxidus gracilis				3					
Oxya chinensis					3				
Pantomorus godmani		3		2	2	3		3	
Physa sp.								G	
Porcellio sp.		3		3				3	
Pseudoamblyteles koebelei					3			3	G
Pycnoscelus surinamensis	2	3							
Rodentia				G					
Sarcophagidae (unid.)		3		3				3	G
Siphanta acuta		3							
Sphaeridium scarabaeoides				3				3	
Succinea konaensis				3					
Xenocrabro polynesialis								3	
Total crops	8	22	4	50	30	1	13	60	3
Total crops with measurable volumes	8	18	3	45	29	1	10	44	3
Total crops with traces	0	0	0	3	1	0	2	13	0
Total crops empty	0	4	1	2	0	0	1	3	0
Total gizzards	8	21	2	20	7	1	13	55	1

1. Food Class 1 = Above 6 per cent
Food Class 2 = Between 1 and 6 per cent
Food Class 3 = Below 1 per cent
G = Occurrence in gizzard only

Class 3 foods occurred as less than one per cent of the diet and included 59 plant species and 41 animals. These are considered less important here than the other two classes because of their small volumes, but they may be significant by other criteria such as serving as intermediate hosts for internal parasites or providing available and necessary nutrients.

Nine arthropods eaten by the collected pheasants are the intermediate hosts for parasites affecting pheasants or domestic poultry in Hawaii. These intermediate hosts and parasites are further discussed in the section on parasites and predators.

The consumption of living snails as well as their empty shells, although not in large volume, may be related to the reproductive requirements of females by providing a source of available calcium. Two species of snails, *Bradybaena similaris* and *Succinea konaensis*, were found only during March, April, and May in the crops of 7 breeding females; 25 males collected during these same months contained none. Pheasant egg shells in the crops of two laying females and a small sliver of rodent bone in the gizzard of one of these birds presumably also supplied calcium. Others have reported a similar preference for snails or egg shells by breeding female pheasants in the United States (Swenk, 1930; Fried, 1940; Sharp and McClure, 1945; Hiatt, 1946).

The only report of foods eaten by pheasants in Hawaii is by Munro (1944) who cited them as feeding upon "dandelion heads, sweet potatoes, guava fruit, pigeon peas, leaves of certain plants, cockroaches, caterpillars, etc."

Food Types.—Figure 1 presents pheasant food types classified as to fruit, browse, seeds, and animal matter by vegetation zone. Only crops with measurable volumes were utilized. Pheasants taken from C_1, D_2, and E_2 were omitted because the sample was too small.

In general, pheasants select a diet in all zones corresponding to the availability of food types. Animal matter, taken in largest volume in zone A and in smallest amount in D_3, consisted chiefly of insects. These were eaten throughout the year. Adults, larvae, nymphs, and certain pupae and egg cases were taken. Other types of arthropod foods included crustaceans, spiders, and millipedes.

Seeds are eaten in largest volume in zone C_2; with insects they probably furnish much protein. Apparently, leafy matter and fruit supplement each other (as indicated in zones A and E_1) by providing moisture, especially in dry areas.

In cultivated sections such as pineapple fields, small truck farms, and corn acreages, pheasants utilize both planted crops and weeds

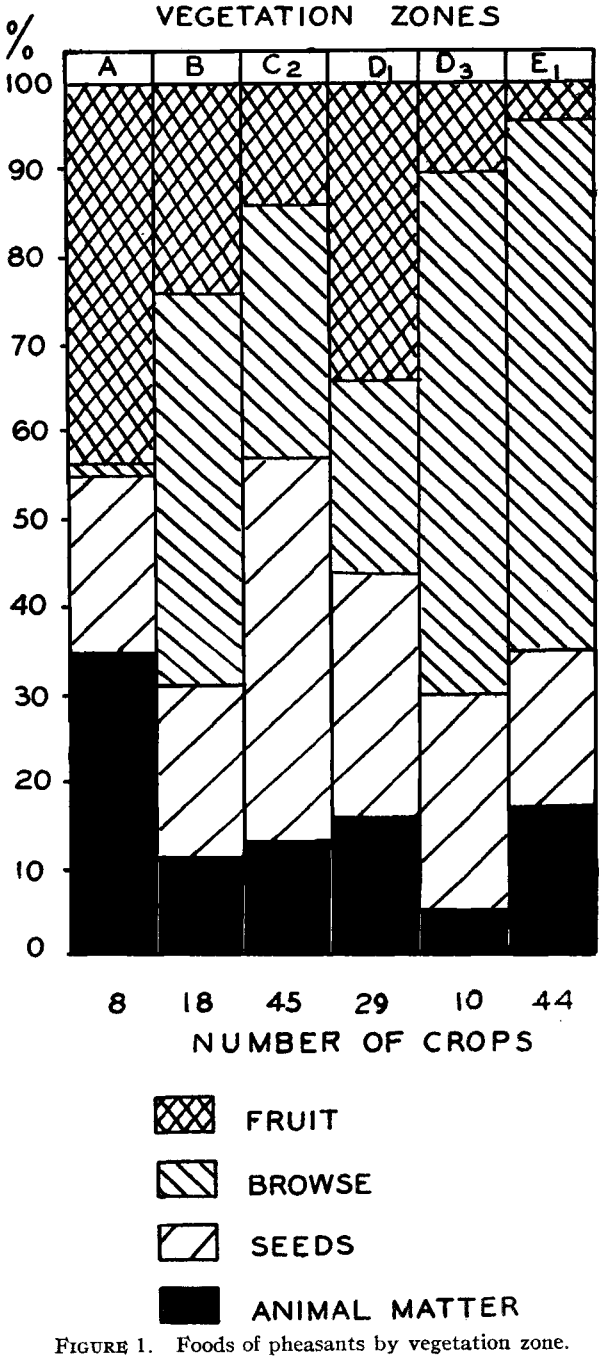

FIGURE 1. Foods of pheasants by vegetation zone.

responding to cultivation. In pasture areas both planted grasses and legumes occur in the diet, as well as herbaceous species which become established as a result of grazing pressure. Pheasants are destructive only locally where they damage some truck crops, principally sweet potatoes, tomatoes, and sprouting corn.

Pheasants in the United States also take a wide variety of foods, but they are highly granivorous where such food is plentiful. Cultivated foods constitute the majority of the annual dietary and amount up to 87 per cent in agricultural areas. Weed seeds are substituted where cultivated grains are lacking. Leafy matter is relatively unimportant in most grain areas but occurs more frequently in the diet where grain is absent, and especially in late winter. Only small amounts of fruit are taken; during winter this source is considered an emergency food. Animal matter varies from 2 to 25 per cent (Dalke, 1937; Fried, 1940; Cowan, 1942; Einarsen, 1945; Hiatt, 1946; Ferrel, Twining, and Herkenham, 1949).

Food habits of pheasants in Hawaii differ considerably from those in the United States, possibly because of climatic and vegetative differences. In Hawaii, pheasants utilize cultivated grain where available, but over the range as a whole this source of food is negligible.

There is little competition for food between the pheasant and the California Quail, *Lophortyx californica*, where they occupy the same range in Hawaii, because the few foods they share in any quantity are abundant. Pheasants show a preference for larger seeds, fruits, and more insects while California Quails select smaller seeds, more leafy browse, and fewer insects (Schwartz and Schwartz, 1950). Pheasants, Feral Pigeons, *Columba livia*, Jungle Fowls, *Gallus gallus*, and Lace-necked Doves, *Streptopelia chinensis*, all utilize the fruits of: ukiuki, *Dianella sandwicensis;* akia, *Wikstroemia phillyraefolia;* and popolo, *Solanum nodiflorum*, in large amounts (Schwartz and Schwartz, 1949). In dry areas or during dry periods this competition might be significant.

Foods of chicks.—The foods of five chicks are given in Table 4. The species eaten are the same as those taken by adults except for one plant, *Ipomoea* sp., taken only by the chicks. The crops of four chicks collected in zone E_1 showed 99.5 per cent animal matter while 12 older birds taken at the same time and place as the chicks showed 28.4 per cent animal matter. However, the chick taken in zone B showed only 6.2 per cent animal matter. A preponderance of animal food is selected by very young birds in the United States (Dalke, 1935; Einarsen, 1945; Pearce, 1945; Rasmussen and McKean, 1945; Ferrel, Twining, and Herkenham, 1949).

TABLE 4

FOODS OF PHEASANT CHICKS BY VEGETATION ZONE

	Zone B		*Zone E_1*	
Total Crops	1		4	
Crops with measurable volumes	1		3	
Crops with traces	0		0	
Crops empty	0		1	
Total Gizzards	1		1	
	Per cent crop volume	*In gizzard*	*Per cent crop volume*	*In gizzard*
PLANTS				
Ananas comosus	93.8			
Tephrosia purpurea	T			
Ipomoea sp.		x		
Vicia sativa			0.5	
Cirsium vulgare			T	
Lolium multiflorum				x
TOTAL PLANTS	93.8		0.5	
ANIMALS				
Carpophilus hemipterus	6.2			
Agrotis ypsilon			69.0	
Pantomorus godmani			12.2	
Gastropoda (unid.)			11.6	
Chaetogaedia monticola			2.3	
Sarcophagidae (unid.)			1.7	
Conoderus exsul			1.1	
Onthophagus insensus			1.1	
Nysius coenosulus			0.5	
Arachnida (unid.)			T	
Coleoptera (unid.)				x
TOTAL ANIMALS	6.2		99.5	

Grit.—Angular or well-rounded fragments of basalt, olivine, feldspar, bottle glass, opaline, and coral, ranging from one to five millimeters in diameter and averaging a total of 2.5 cubic centimeters per gizzard, were found in 101 gizzards; 27 gizzards had no grit, and 9 showed only traces (including nine not used in the food analysis). Similar types of grit averaging a total of 0.9 cubic centimeters per crop were recovered from five crops. One additional crop contained 4.5 cubic centimeters of charcoal, and two others showed pellets of dried earth averaging 16.5 cubic centimeters. Ample grit is available in Hawaii.

The hard seeds of puakeawe, *Styphelia Tameiameiae*, in zone E_1 and common vetch, *Vicia sativa*, in zone C_2 occurred statistically more often in gizzards than crops. In these two zones, grit occurred more abundantly in gizzards than in other zones with comparable amounts of seeds but of different species. It seems possible to us that more grit is required for the utilization of hard seeds although, Beer and Tidy-

man (1942) report grit to occur in inverse proportion to the volume of hard seeds.

In Michigan, Dalke (1938) found more grit in breeding females than in males and believed it was related to egg production. In Hawaii, more grit occurred in both males and females during the breeding season than at other times.

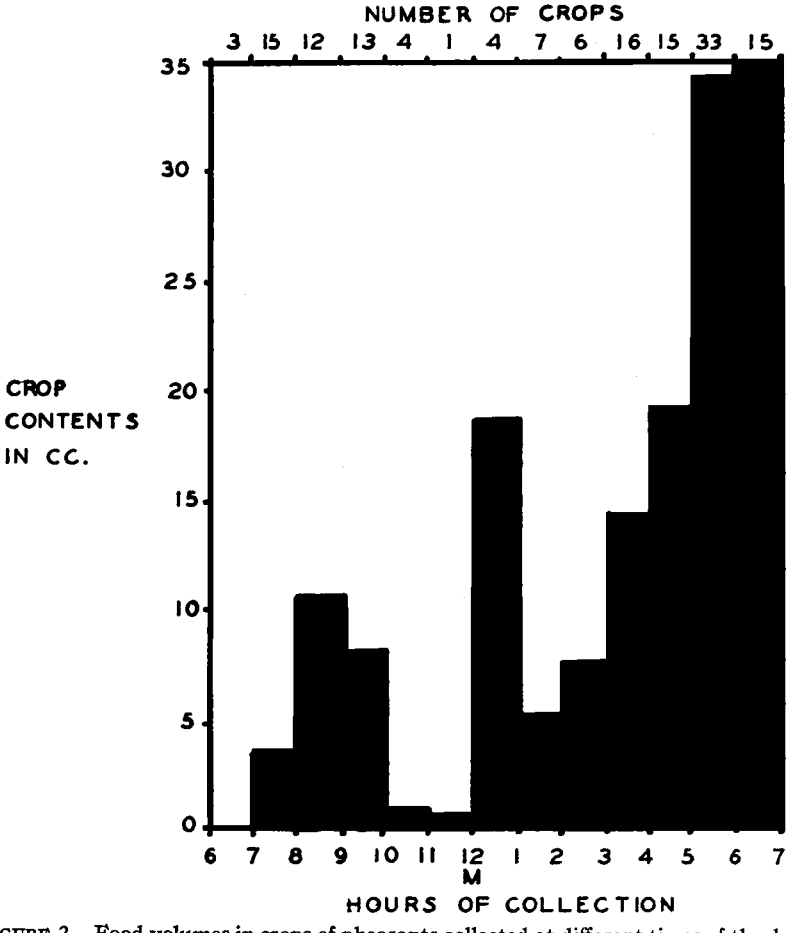

FIGURE 2. Food volumes in crops of pheasants collected at different times of the day.

Feeding Habits.—Figure 2 shows the amount of food in the crops of 144 pheasants with relation to the hour of collection. Apparently little feeding takes place during the first hour after awakening, and only small amounts are taken during the next three hours. From approximately 10 a. m. until noon, feeding almost ceases but after-

wards increases somewhat until about 5 p. m. From then until dark, feeding is greatly accelerated, and most birds go to roost with full crops. Forty-eight birds collected between 5 and 7 p. m. showed an average crop volume of 34.9 cubic centimeters; the maximum was 206.0 cubic centimeters. This general pattern of feeding agrees with reports in the United States (Dalke, 1937; Hiatt, 1946).

By locating the source of certain foods present in collected pheasants, we found the feeding range to cover a one-fourth mile radius, although mostly it lay within a one-eighth mile radius. In Montana, Hiatt (1946) found that pheasants seldom ranged more than one-fourth mile during feeding.

Munro (1944) pointed out (a fact salient in this study) that a pheasant in Hawaii would fill its crop on one article of food if that food were sufficiently available.

WATER

The amount of moisture available to pheasants varies throughout Hawaii. Since high populations of pheasants may occur where surface water is generally lacking, the birds must subsist on occasional dew or mist, infrequent rains, succulent vegetation, fleshy fruits, and soft-bodied insects. However, we have observed pheasants frequenting cattle watering places and irrigation ditches in dry areas where they utilized the accessible water. There are many areas in Hawaii where the pheasant population is limited because of a lack of water or moisture-providing foods.

COVER

Pheasants in Hawaii, in common with other upland game birds, respond best to areas where the cover pattern is one of interspersion and variety rather than uniformity. Dense stands of vegetation—whether heavily-forested areas, uniform expanses of sugar cane, guava, *Psidium Guajava*, cactus, *Opuntia megacantha*, or *Lantana Camara*, or gullies, draws, or slopes choked with such plants as staghorn fern, *Gleichenia linearis*, or pamakani, *Eupatorium adenophorum*—function as pheasant cover only along their margins. Areas under pineapple cultivation provide more usable cover than their extensiveness and uniformity would lead one to suppose because of numerous margins created by roadways. Grassland in open expanses tends to favor pheasants more than do these other vegetative types but provides its optimum cover where herbaceous and brushy growth is interspersed.

Pheasants roost both on the ground and in trees. Where trees are available, the birds seemingly prefer them at any season of the year. Medium-sized, densely-foliaged trees function best. In areas where

trees are sparse, pheasants roost on the ground in grassy cover. Young birds roost on the ground until capable of flight.

Because of the year-around growing season in Hawaii, there is no critical winter period without suitable cover, which is often a deciding factor in the success of pheasants in the United States. However, in both regions, the dispersal of desirable cover is related to maximum production of the range.

PARASITES AND PREDATORS

Arthropod Parasites.—Mites of the following species were present in light infestations on Ring-necked Pheasants in Hawaii: *Megninia ginglymura* (Megnin), *Raphignathus* sp., and *Megninia columbae* (Buchholz). Apparently the latter species is uncommon on pheasants, since its customary host is the pigeon from which it was recovered during our survey.

Two species of lice occurred on collected Green and hybrid pheasants, *Lipeurus maculosus* Clay, and *Menopon fulvomaculatum* Denny. These also occurred on Ring-necked Pheasants which had in addition the following species: *Lipeurus caponis* (L.), *Goniodes colchici* Denny, *Goniodes* sp., larva, *Uchida* sp., and *Goniodes mammilatus* Rudow. All infestations were light or moderate. *L. caponis* which we found on Jungle Fowl in Hawaii is reported also on domestic poultry in Hawaii (Alicata, 1947). *M. fulvomaculatum* and *G. mammilatus* occurred likewise on California Quail in Hawaii (Schwartz and Schwartz, 1950).

The hippoboscid fly, *Ornithoica vicina* (Walker), was recovered from only three Ring-necked Pheasants. The same species likewise occurred rarely on Japanese Quail, *Coturnix coturnix japonica*, and Jungle Fowl collected during this survey. It is not known if this fly harbors blood parasites.

Helminth Parasites.—The eyeworm, *Oxyspirura mansoni* (Cobbald), was commonly found in Ring-necked Pheasants taken below 3,000 feet elevation. *Pycnoscelus surinamensis* (L.) or burrowing roach, the intermediate host of this parasite (Alicata, 1947), occurred in the diet of pheasants in these low elevations. The heaviest infestation consisted of 17 worms in each eye of a single bird, but in no bird that we examined did this parasite cause obvious harm. This eyeworm is common in poultry in Hawaii and has been reported in the Lace-necked Dove here (Alicata, 1947). We also found it in this dove and in the Japanese Quail—a new record of occurrence. Eyeworms, *Oxyspirura petrowi*, have been reported in 40 per cent of the pheasants in north-central Nebraska (McClure, 1949).

Cheilospirura hamulosa (Diesing), the gizzard worm, was found occasionally in Ring-necked Pheasants. Known intermediate hosts listed by Alicata (1947) and found in our food studies to be eaten by pheasants are: *Gonocephalum seriatum*, *Conocephalus saltator*, *Oxya chinensis*, *Epitragus diremptus*, and *Atractomorpha ambigua*. This helminth parasite is believed responsible for anemia, emaciation, and deaths of island chickens (Alicata, 1947), but we have no evidence that it adversely affects pheasants.

Subulura brumpti (Lopez Neyra), the cecal worm of island poultry, occurred commonly in the Ring-necked Pheasant which served as a new known host for this species. The following arthropods eaten by pheasants are listed by Alicata (1947) as intermediate hosts of this parasite: *Gonocephalum seriatum*, *Conocephalus saltator*, *Oxya chinensis*, and *Euborellia annulipes*. We also found this parasite in other new hosts in Hawaii, the Japanese Quail and the Lace-necked Dove. It is probably of little economic importance.

Heterakis gallinae (Gmelin), another cecal worm common in island chickens, was recovered from Ring-necked, Green, and hybrid pheasants. This parasite requires no intermediate host. Since it is the known carrier of the causative agent of blackhead, this latter disease might result. In Oregon, *H. gallinae* occurred rarely in pheasants (Einarsen, 1945), but in pheasants in Ohio it was more common (Leedy and Hicks, 1945).

Cyrnea graphophasiani Yamaguti, a gizzard worm, occurred in only one pheasant, but *Cheilospirura hamulosa* was also present in the gizzard of this bird. The pheasant is a new host for *C. graphophasiani* and apparently the second host species reported.

Ascaridia sp., possibly either *A. lineata* or *A. perspicillum*, was found in only one Ring-necked Pheasant.

Certain other parasites not found in pheasants, but which infect island poultry and use as intermediate hosts arthropods which were eaten by pheasants, indicate their potentialities as parasites of pheasants.

Predators.—The mongoose, *Herpestes javanicus auropunctatus* (Hodgson), which occurs only on the islands of Hawaii, Maui, Oahu, and Molokai, is probably the most important predator upon pheasants in Hawaii. In an analysis of 86 scats we collected from the island of Hawaii, bird feathers constituted only four per cent of the food. However, this is scarcely indicative of the true volume of bird food consumed, since in feeding the mongoose usually takes the soft parts such as brain, blood, viscera, and contents of eggs. These items are not apt to show up in a scat analysis. Pheasant poult feathers were

the only evidence of predation upon pheasants from this scat analysis, but mongooses have been discovered feeding on pheasant eggs at the nest. Cock pheasant remains have been found in mongoose dens, but these could easily have been birds killed or crippled during the hunting season which just preceded these observations. Freshly-killed and dissected pheasants were taken on six occasions from our camp by mongooses, all in plain sight of the observers. However, no great difference exists with respect to densities of pheasants between islands having mongooses and those without mongooses.

Rats, feral cats, feral pigs, and fire ants, *Solenopsis* sp., are other predators which may be important in certain localities but evidence of their take is very scanty. The Hawaiian Hawk, *Buteo solitarius* Peale, exists in such few numbers as to be of little influence as a winged predator. While the Hawaiian Owl, *Asio flammeus sandwichensis* (Bloxam), is more numerous than the Hawaiian Hawk, its small numbers make it negligible as a potential predator. Approximately 75 regurgitated food pellets of this owl were examined during this survey and all consisted of mouse, *Mus musculus*, and rat, *Rattus* sp., remains. We believe the pheasant population in Hawaii reflects the quality of its environment with respect to food, cover, water, and climate, rather than the probable effect of predators.

Pheasants probably suffer more from illegal kill than all other game bird species on the islands. The out-of-season take consists mostly of cocks whose brilliant plumage is used in making feathered *leis*. However, this toll is less serious than the willful illegal take of hens during the open season.

BREEDING

Observations on gonadal size and development in collected pheasants indicate one annual period of reproductive activity. Figure 3 presents by months the distribution and average of testis size in cubic millimeters for 54 collected pheasants. This size was roughly computed by multiplying average length by width by depth of both testes per individual. The only male we collected in January had testes averaging 121 cubic millimeters. Four others collected by Hiatt (1945) on Hawaii from January 20 to February 5 were of a similar small size. Increase in testis size probably starts in February, because in March testes showed a great increase in volume over January and reached an average of 7,200 cubic millimeters. This large size generally continued in April and increased to a maximum of 7,500 cubic millimeters in May. The development of the testes was presumably accompanied by formation of spermatozoa since volumetric changes reported

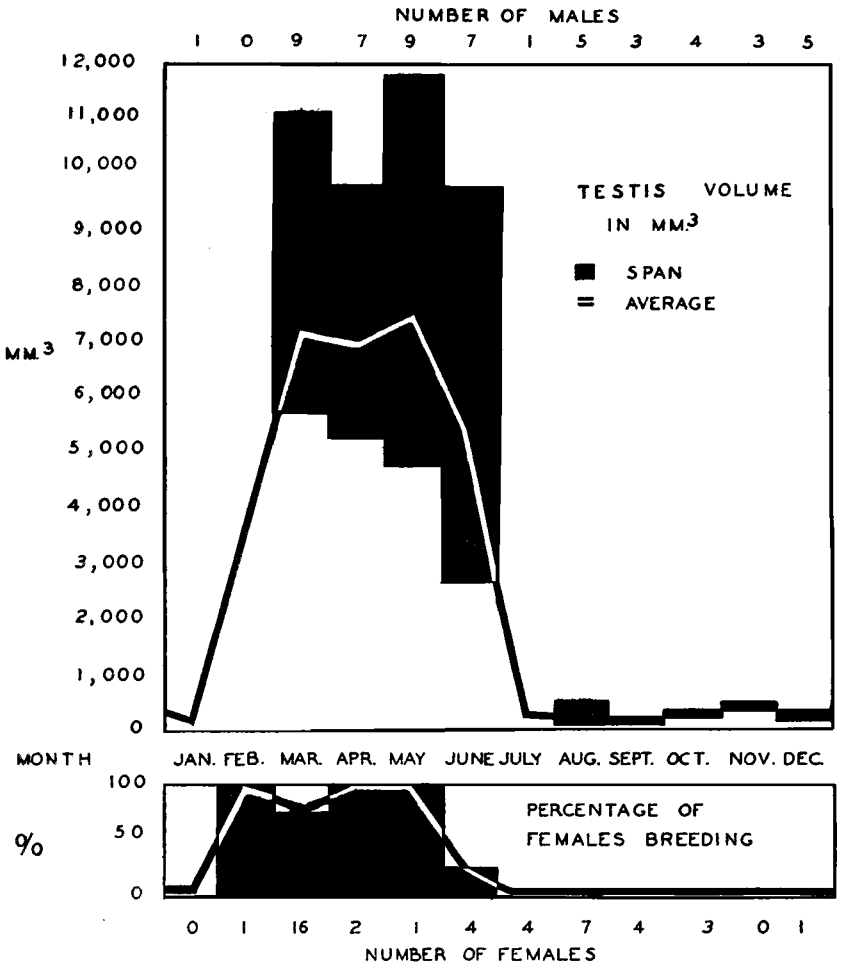

FIGURE 3. Breeding season of pheasants as indicated by testis volumes and maturing Graafian follicles.

herein compare favorably with weight changes that Hiatt and Fisher (1947) correlated with spermatogenesis in the testes of wild pheasants in Montana. Testes taken in June showed a decrease in average size to 5,400 cubic millimeters, followed in July by a great reduction to a relatively small size (275 cubic millimeters) which was generally maintained until about February. In Montana, testes are without sperm after early August (Hiatt and Fisher, 1947) and this perhaps applies to pheasants in Hawaii.

The percentage of females breeding (determined by the presence of maturing Graafian follicles) is given by month for 43 females in Figure 3. The only female we took in February had a fully-formed egg in her oviduct, but five females collected from January 20 to February 5 on Hawaii by Hiatt (1945) showed no or only slight gonadal development. In March, 14 of 16 collected hens were breeding and 13 of these were laying; those two not breeding were collected on March 1 and 2 and might have come into breeding condition later in the season. In April, one of two females collected was laying; the other showed maturing Graafian follicles. The one female collected in May showed yolky Graafian follicles. In June, only one of four females collected was laying; ovaries of the other three indicated previous ovulation. From July through December, ovaries contained no yolky follicles.

General crowing of the males begins in late January or early February, although crowing is occasional previously. Courtship is most pronounced from early February through March. From observations on the general behavior pattern of pheasants in the spring and on broods, supplemented by the gonadal development shown in our limited study, we believe that general laying begins early in March. In 55 observed or reported nests, the eggs numbered from 6 to 11. Incubation takes place mostly during April and May, and hatching occurs from early May through June. However, some birds breed earlier or later than the majority of the population, as indicated by a brood about one week old which was seen on March 7 and a young bird about six weeks old which was observed the last of October. No evidence was obtained that more than one brood per female was produced during the breeding season. There may be a revival of crowing in the fall, but it is not as intensive or lengthy as in the spring and no breeding ensues.

In Montana and other sections of the United States, laying females are usually found from mid-April to mid-July (Hiatt and Fisher, 1947). Thus, laying in Hawaii begins about six weeks earlier than in the United States, which may be related to differences in latitude of these different habitats. We have no information concerning any differences in initiation of breeding in relation to altitude in Hawaii.

Sex Ratio.—Nearly all the ranges of pheasants in Hawaii showed a sex ratio of approximately 100 males to 100 females regardless of the density of the population. This sex ratio, which apparently persisted from hatching, occurred either where little hunting was done or where both males and females were taken during the hunting season, although males only were legal game.

Two exceptions to this normal ratio occurred—in the Waikii area and at Kahua Ranch, Hawaii—and here the sex ratio approximated 50 males to 100 females. This ratio is similar to the one (55 males to 100 females) reported for these areas by Hiatt (1945). In these two localities, a high breeding population occurred and hunting, although moderately high, was rigidly controlled so that only cocks were taken.

Survival of Young.—Young per observed brood varied from one to eight, averaging 3.0 in 49 broods. These low numbers occurred regardless of climatic conditions or islands with or without the mongoose. Compared to clutch size, this indicates a high mortality, apparently occurring between laying and when the broods are first seen commonly—about a week or so of age.

RANGE EVALUATION

Zone A.—Zone A is poor pheasant range. Pheasants occur here in non-arable sections, used either for pasture or waste, and in sugar cane lands. The non-arable lands constitute the driest occupied range and have densities of 10 or fewer birds per square mile. Water provided for cattle is accessible to pheasants in only a few places. While food plants are abundant following periods of rain, there are many months of drouth when pheasant forage is extremely meager. Likewise, the variety of plant species used as food is small, and competition through grazing of domestic cattle and feral stock reduces the restricted supply still more. Soils are generally poor and contribute to the inferior plant growth and sparse ground cover.

Sugar cane occurs on the better soil portions of this zone and higher populations (11 to 25 birds per square mile) are found here, probably because of the water provided for irrigation. This water, which is available over comparatively large areas throughout the year, likewise increases the growth of weedy plants along the margins of the fertilized cane fields. However, the beneficial effects of fertilization and irrigation are largely nullified as regards pheasant habitat because of the constant weed eradication practiced by the plantations and the extensiveness of sugar cane tracts with their uniform, dense growth which limits diversification of food and cover species.

The aridity of this zone, expressed in an absence of both rainfall and succulent forage, is the principal limiting factor since it affects not only the survival of young and adult birds but breeding as well. If our limited food study in this zone is indicative, pheasants seek moisture-providing foods, since the dietary here consists of 44 per cent fruits, 1 per cent browse, and 35 per cent animal matter (largely lepidopterous larvae or beetles) with only 20 per cent constituting seeds.

Zone B.—Zone B is considered one of the most productive vegetation zones for pheasants. Here, the bird lives in sugar cane, pineapple, and small truck-garden areas, and in pasture or waste lands. In sugar cane areas of this zone where densities of 25 or fewer birds per square mile occur, the same conditions prevail as in zone A. Higher densities are found where the irrigated cane fields are broken into small units by well-vegetated gulches and better developed pasture lands, creating an interspersion of food and cover species adjacent to available water.

The culture of pineapple plays an important rôle in maintaining pheasant populations in zone B. Approximately one-fifth of each plantation's acreage is allowed to fallow each year. Prior to being "knocked-down" and re-cultivated, these fallow fields promote an abundant weedy growth which with old pineapple plants produces a highly desirable food and cover system. Pineapples and the succulent fruits of interspersed weeds furnish a valuable source of moisture, but some water is also available from rainfall and dew. However, the capabilities of different plantations vary according to the extensiveness and degree to which the fields are dissected by broken land with its accompanying heavily wooded and weedy vegetation. Densities below 26 birds per square mile occur in those pineapple areas without this interspersion, while higher densities are found where the proportion of broken land is greater.

Densities of 51 to 100 birds per square mile on Kauai can be traced to the development of an irrigated area, scattered portions of which were withdrawn from sugar cane production. These were cultivated as vegetable gardens and experimental cattle forage plots during the late war and subsequently have been continued on a smaller scale. Accompanying and following the gardening, abundant herbaceous cover developed. The surrounding natural cover composed of dense thickets of *Lantana*, puakeawe, and bracken fern, *Pteridium aquilinum* var. *decompositum*, on the sides and bottoms of dissecting gullies, in combination with the abundant cultivated and weedy foods in this heavily fertilized and irrigated section, furnishes a desirable environment for pheasants.

Land in pasture or waste supports, for the most part, populations of 25 or fewer birds per square mile because of the aridity, extremely poor rocky soil, and often dense stands of cactus or *Lantana* which furnish their maximum food and cover value only along their peripheries. Domestic stock and, to a lesser extent, feral goats compete with pheasants for food throughout these non-arable lands, especially during drier portions of the year. Higher pheasant populations occur

along margins of pasture lands adjacent to zone C_2, where habitat conditions are considerably better.

Food studies in zone B show the following: 24 per cent fruits, 45 per cent browse, 20 per cent seeds, and 11 per cent animal matter. Here, in common with the semi-arid conditions of zone A, pheasants eat a majority of moisture-providing foods, but because of a somewhat higher rainfall there is a greater variety of food plants.

Zone C_1.—This zone is only moderately productive of pheasants. Perhaps the most favorable factor when compared with zones A and B is increased rainfall and its fairly uniform distribution throughout the year.

Pheasants are found in pasture areas, pineapple lands, or sugar plantations. Pastures consist mostly of submarginal land covered in many places with dense stands of *Lantana* or dissected by gullies and ravines often choked with guava. The best habitat for pheasants occurs along the margins of these heavily vegetated areas which usually possess a variety of food species. However, pheasants are present only in densities of 25 or fewer birds per square mile.

A large part of the pineapple land supports densities of 26 to 50 birds per square mile because of interspersed submarginal land which is usually grown up to good cover of both herbaceous and woody types. Here, cane lands and their productivity of pheasants are similar to zone B.

Zone C_2.—Zone C_2 has some of the best pheasant range in Hawaii. The elevations of this zone favor temperate plants, and the dry summers permit good seed production. Well distributed annual rainfall and plentiful dew, coupled with abundant browse and fruits, amply meet the pheasant's moisture requirements.

Highest densities in this zone (51 to 100 birds per square mile) occur in the vicinity of Waikii, Hawaii, and are the result of a distinctive combination of environmental factors. Because this area represents a pocket of fertile soil situated in a suitable climate, large acreages of corn are possible. For the past 10 years parts of this section, varying from 700 to 1,500 acres annually, have been cultivated in corn and cereal grains, with rotation from cultivation to sod occurring within two- to six-year periods. This system created a vegetative pattern of rich volunteer herbaceous food and cover in the fallow fields interspersed with cultivated areas. Large expanses of good grassland likewise contributed to a very desirable habitat.

Since 1944, the crop acreage has been reduced to less than 200 acres and thus the present range consists almost entirely of grassland with some weedy fallow fields remaining from the former more extensive

cultivation. All the factors contributing to the present populations are difficult to evaluate, but good soil coupled with secondary results of cultivation and primary crops has doubtless been influential.

Adjacent to this area and elsewhere in this zone, densities from 26 to 50 birds per square mile occur in good but heavily grazed pasture lands or in scattered truck-garden areas with poor adjacent cover.

Densities of less than 25 birds per square mile occur in the poorer soil and drier portions of zone C_2 where plant growth is inferior and dense stands of cactus, pamakani, or timber often occur. One exception to this general analysis occurs in the Kapapala region of Hawaii, where range conditions appear much better for pheasants than population figures indicate. A dwindling population is reported in this area and we suspect this may be associated with the decrease in cultivation of certain forage crops, principally pigeon pea, *Cajanus Cajan*, which was formerly grown here in scattered locations.

In this zone, seeds constitute 44 per cent of the food, browse 29 per cent, fruits 14 per cent, and animal matter 13 per cent. An examination of the important food species shows a direct relationship to the pasture system; with the exception of the endemic shrub akia which occurs on rocky outcrops, planted pasture species, and weedy growth responding to grazing form the bulk of the diet. Food species are plentiful throughout the year, but there are places where heavy grazing and poorer soils limit their abundance. Cultivated foods are important only locally.

Zone D_1.—Zone D_1 is another good pheasant zone. However, here the rainfall is very high, with a minimum of 60 inches annually, and toward the upper limits this greatly inhibits successful reproduction.

Densities above 26 birds per square mile occur in regions affiliated with pineapple cultivation, in non-irrigated, sugar cane lands with considerable interspersion of gullies and other broken land, and in good pasture having a combination of shrubby cover and abundant food.

Lower densities are found in grazed areas on poorer soils which are thought to show nutrient deficiencies. This grassland is interspersed with numerous, deep ravines choked with dense guava and staghorn fern which afford little attraction to pheasants.

The distribution of food types in the diet is as follows: 28 per cent seeds, 34 per cent fruits, 22 per cent browse, and 16 per cent animal matter.

Zone D_2.—Zone D_2 is very poor pheasant range because of the heavy annual rainfall (100 to 450 inches) which practically prohibits successful breeding and because of the prevailing dense forest cover. There

is little variety of pheasant food except in occasional small clearings, along trails, or margins of the forests.

Occupied portions occur where small areas of open land on the borders of this zone are continuous with ranges in adjacent zones.

Zone D_3.—This zone is considered of intermediate quality on the basis of population figures. Rainfall limits lie between 50 and 100 inches annually and this rainfall, together with adequate moisture-providing plants, more than fulfills the requirements for available water. Yet this same precipitation, which occurs commonly as mist, doubtless limits production of young by requiring their constant brooding by the hen. Chicks which become wet and chilled are unable to forage satisfactorily and hence perish.

Grazing is the major land use. Densities above 26 birds per square mile are found primarily in open forested sections which have resulted from past grazing. The present range consists principally of koa forest interspersed with open grassy meadows or deeper ravines where ferns predominate. Where grazing has been curtailed, more herbaceous species occur. Here the Green Pheasant thrives.

Uniform expanses of grass resulting from heavy grazing and heavier-forested sections without interspersion of food or cover necessary for pheasants support densities of less than 26 birds per square mile. Ring-necked and hybrid pheasants are more common than Green Pheasants in these latter cover types.

The diet in this zone consists of 60 per cent browse, 5 per cent animal matter, 25 per cent seeds, and 10 per cent fruits, indicating the relative availability of each food type.

Zone E_1.—Vegetation zone E_1 ranks among the better zones for pheasants, and here both Ring-necked and Green pheasants do well.

Grazing is the major use of the land though some small sections are capable of supporting corn. Densities above 51 birds per square mile occur near Waikii, Hawaii, for the same reasons discussed under zone C_2.

Densities of less than 26 birds per square mile occur on Hawaii where the range is broken by numerous recent lava flows. Food species are sparser and cover denser here than in the best parts of the range in this zone. Near Humuula, Hawaii, overgrazing by domestic sheep and the accompanying soil erosion create only poor range for pheasants.

Densities between 26 and 50 birds per square mile prevail on Maui where the grassland is very open with little interspersion except for scattered *Eucalyptus* groves. In places, pamakani occurs in stands so dense as to provide habitat only along the peripheries.

Food studies made primarily in grassland regions indicate that browse constitutes 61 per cent of the diet, fruits 4 per cent, seeds 18 per cent, and animal matter 17 per cent. The species eaten are common in these sections, and food and moisture are not limiting factors here. However, in other regions of this zone variations in seasonal rainfall and lowered moisture retention by the shallow soils affect availability of browse species which, combined with a lack of other available moisture sources, may limit pheasant populations.

Zone E_2.—The poor quality of zone E_2 may be attributed to the prevailing arid conditions and on Hawaii to vast expanses of barren lava or shallow soils with little vegetation. While almost none of this zone is used for domestic cattle, feral sheep graze it heavily and compete with pheasants for food.

Densities between 26 and 50 birds per square mile are found primarily on Maui where soil and moisture conditions are somewhat better and result in improved food and cover. The general scattered abundance of puakeawe provides good shrubby interspersion, but it tends to become too dense in spots. Heavy grazing by feral goats adversely influences cover in places.

Zone E_3.—No pheasants occur in this zone. Temperatures during the summer are too low to permit growth of seed-producing plants which pheasants require for food and cover and, during the winter, ice and snow accompany the below-freezing temperatures.

SUMMARY

1. The Ring-necked Pheasant was first brought to Hawaii about 1865, but subsequent liberations were made on all islands. The Green or Versicolor Pheasant was liberated on all islands prior to 1900 but other plantings also occurred. Hybrid pheasants result from matings between Ring-necked and Green pheasants. All other species of pheasants introduced into Hawaii failed to survive.

2. A description of the Hawaiian Islands includes a discussion of their location, origin, topography, size, elevation, climate, soils, land use, and vegetation.

3. In Hawaii, Ring-necked Pheasants range: (1) from sea level to 11,000 feet elevation; (2) from subtropical regions to those where freezing temperatures occur frequently; (3) where less than 10 inches of rain falls annually to places receiving 300 inches; (4) on recent soils (lava) to those soils with deep pockets of loam; (5) in forested and grassland regions, deserts, and other waste areas; (6) in pineapple fields, sugar cane lands, small truck-gardens and corn acreages; and (7) in all types of topographic conditions. Best populations are

found on soils of better fertility where the land use permits, in areas receiving between approximately 20 and 80 inches of rainfall annually, and in generally open cover interspersed with abundant forage species, and with some form of available moisture.

4. The best range for Green Pheasants occurs between approximately 4,000 and 7,000 feet elevation in vegetation zones D_3 and E_1 on the island of Hawaii. This area is primarily open *Acacia Koa* forest with interspersed grassy meadows containing mixed herbaceous growth. The mean annual temperature is about 50° F., and maximum rainfall is 125 inches at lower elevations and 20 inches at higher altitudes. Soils are better than in other occupied areas and the surface is gently sloping.

5. The Green Pheasant is decreasing in Hawaii through hybridization, and its restricted distribution and fewer numbers favor the Ring-necked Pheasant.

6. A population of 70,000 pheasants was estimated in 1946–1947 for 3,700 square miles of range on all the major Hawaiian Islands. Population densities varied from less than 10 to 100 birds per square mile. The most productive vegetation zones for pheasants are B, C_2, D_1, and E_1. Zones C_1 and D_3 are moderately productive, and the poorest are A, D_2, and E_2. No pheasants occur in zone E_3.

7. An analysis of foods of 191 pheasants showed 97 plant and 55 animal foods. The relative amounts of fruit, browse, seeds, and animal matter corresponded to availability in the various zones. The wide variety of foods that pheasants eat illustrates the adaptability of this bird to the different habitat conditions in Hawaii. Foods of chicks are the same as for adults, but chicks tend to take more animal matter. Grit was found in 80.2 per cent of the gizzards and in 2.6 per cent of the crops. Feeding is casual during the morning but increases after mid-day, and most birds go to roost with full crops. The feeding range covers about a one-fourth mile radius.

8. Where surface water is unavailable, pheasants subsist on occasional dew or mist, infrequent rains, succulent vegetation, fleshy fruits, and soft-bodied insects. There are many areas in Hawaii where the pheasant population is limited because of lack of water or moisture-providing foods.

9. Pheasants roost both on the ground and in trees, but trees are preferred.

10. External arthropod parasites consist of three species of mites, seven species of lice, and one species of hippoboscid fly. Helminth parasites include the eye worm, one species of ascarid worm, and two species each of cecal worms and gizzard worms. The occurrence of

the respective parasites in pheasants is related to the intermediate hosts taken as food.

11. The mongoose is probably the most important predator, while rats, feral cats, feral pigs, and fire ants are possible predators.

12. Pheasant cocks are taken out-of-season for their plumage, and hens suffer from illegal kill during the open season on cocks.

13. General crowing of the males begins in late January or early February. Laying starts early in March, and incubation takes place mostly during April and May. Hatching occurs from early May through June. There may be a revival of crowing in the fall but no breeding ensues.

14. The sex ratio in nearly all the ranges of pheasants in Hawaii is approximately 100 males to 100 females. Exceptions occurred in two areas where due to managed hunting the sex ratio approximated 50 males to 100 females.

15. From 6 to 11 eggs occurred in 55 nests, but the average of young in 49 broods was 3.0.

16. Each vegetation zone with its land uses is evaluated as pheasant range.

LITERATURE CITED

ALICATA, J. E. 1947. Parasites and parasitic diseases of domestic animals in the Hawaiian Islands. Pacific Sci., 1 (2): 69–84.

BALDWIN, P. H. 1941. Checklist of the birds of the Hawaii National Park, Kilauea—Mauna Loa Section, with remarks on their present status and a field key for their identification. Hawaii Natl. Park, mimeo. 38 pp.

BEEBE, W. 1936. Pheasants, their lives and homes. (Doubleday, Doran, and Co., New York), Vol. 2: 1–309, 29 pls.

BEER, J., AND W. TIDYMAN. 1942. The substitution of hard seeds for grit. Journ. Wildl. Manag., 6 (1): 70–82.

CAUM, E. L. 1933. The exotic birds of Hawaii. B. P. Bishop Mus. Occ. Papers, 10 (9): 1–55.

COULTER, J. W. 1940. Agricultural land-use planning in the Territory of Hawaii. Agri. Ext. Serv. Bull. 36: 1–124.

COWAN, I. M. 1942. Economic status of the pheasant on cultivated lands of the Okanagan Valley, British Columbia. Rept. Brit. Columbia Game Comm., pp. 49–63.

DALKE, P. D. 1935. Food of young pheasants in Michigan. Amer. Game, 24 (3): 36, 43, 44–45, 46.

DALKE, P. D. 1937. Food habits of adult pheasants in Michigan based on crop analysis method. Ecology, 18 (2): 119–213.

DALKE, P. D. 1938. Amount of grit taken by pheasants in southern Michigan. Journ. Wildl. Manag., 2 (2): 53–54.

EINARSEN, A. S. 1945. The pheasant in the Pacific northwest. *In* The Ring-necked Pheasant edited by W. L. McAtee. (Amer. Wildl. Inst. Wash.), pp. 254–274.

FERREL, C. M., H. TWINING, AND N. B. HERKENHAM. 1949. Food habits of the Ring-necked Pheasant (*Phasianus colchicus*) in the Sacramento Valley, California. Calif. Fish and Game, 35 (1): 51–69.

FISHER, H. I. 1951. The Avifauna of Niihau Island, Hawaiian Archipelago. Condor, 53: 31–42, 5 figs.

FRIED, L. A. 1940. The food habits of the Ring-necked Pheasant in Minnesota. Journ. Wildl. Manag., 4 (1): 27–36.

HIATT, R. W. 1945. A brief survey of the status of the Ring-necked Pheasant with supplementary remarks concerning the status of the California Quail on Hawaii. (Rept. to Bd. Agri. and For., Honolulu), mimeo. 12 pp.

HIATT, R. W. 1946. The relation of pheasants to agriculture in the Yellowstone and Big Horn River valleys of Montana. (Montana State Game and Fish Comm.), 72 pp.

HIATT, R. W., AND H. I. FISHER. 1947. The reproductive cycle of Ring-necked Pheasants in Montana. Auk, 64: 528–548, 3 figs., 6 tables.

KIMBALL, J. W. 1949. The crowing count pheasant census. Journ. Wildl. Manag., 13 (1): 101–120.

LEEDY, D. L., AND L. E. HICKS. 1945. The pheasants in Ohio. *In* The Ring-necked Pheasant edited by W. L. McAtee. (Amer. Wildl. Inst. Wash.), pp. 57–130.

MCCLURE, H. E. 1949. The eyeworm, *Oxyspirura petrowi*, in Nebraska pheasants. Journ. Wildl. Manag., 13 (3): 304–307.

MUNRO, G. C. 1944. Birds of Hawaii. (Tongg Publ. Co., Honolulu), 189 pp., 20 pls.

PEARCE, J. 1945. The pheasant in the Northeast. *In* The Ring-necked Pheasant edited by W. L. McAtee. (Amer. Wildl. Inst. Wash.), pp. 32–56.

RASMUSSEN, D. I., AND W. T. MCKEAN. 1945. The pheasant in the Intermountain irrigated region. *In* The Ring-necked Pheasant edited by W. L. McAtee. (Amer. Wildl. Inst. Wash.), pp. 234–253.

RIPPERTON, J. C., AND E. Y. HOSAKA. 1942. Vegetation Zones of Hawaii. Hawaii Agri. Exp. Sta. Bull. 89: 1–61.

SCHWARTZ, C. W., AND E. R. SCHWARTZ. 1949. A reconnaissance of the game birds in Hawaii. (Bd. Agri. and For., Honolulu), 168 pp.

SCHWARTZ, C. W., AND E. R. SCHWARTZ. 1950. The California Quail in Hawaii. Auk, 67: 1–38, 3 figs., 1 pl., 10 tables.

SHARP, W. M., AND H. E. MCCLURE. 1945. The pheasant in the sandhill region of Nebraska. *In* The Ring-necked Pheasant edited by W. L. McAtee. (Amer. Wildl. Inst. Wash.), pp. 203–233.

STEARNS, H. T. 1946. Geology of the Hawaiian Islands. (U. S. Geol. Survey, Honolulu), Bull. 8: 1–106.

SWENK, M. H. 1930. Food habits of the Ring-necked Pheasant in central Nebraska. Nebr. Agri. Exp. Sta. Res. Bull. 50: 1–33.

TERRITORIAL PLANNING BOARD. 1939. First progress report: An historic inventory of the physical, social and economic and industrial resources of the Territory of Hawaii. (Honolulu), 322 pp.

Conservation Commission, Jefferson City, Missouri, November 1, 1949.