THE BIOLOGY OF THE BAND-TAILED PIGEON (COLUMBA FASCIATA) IN BRITISH COLUMBIA

by

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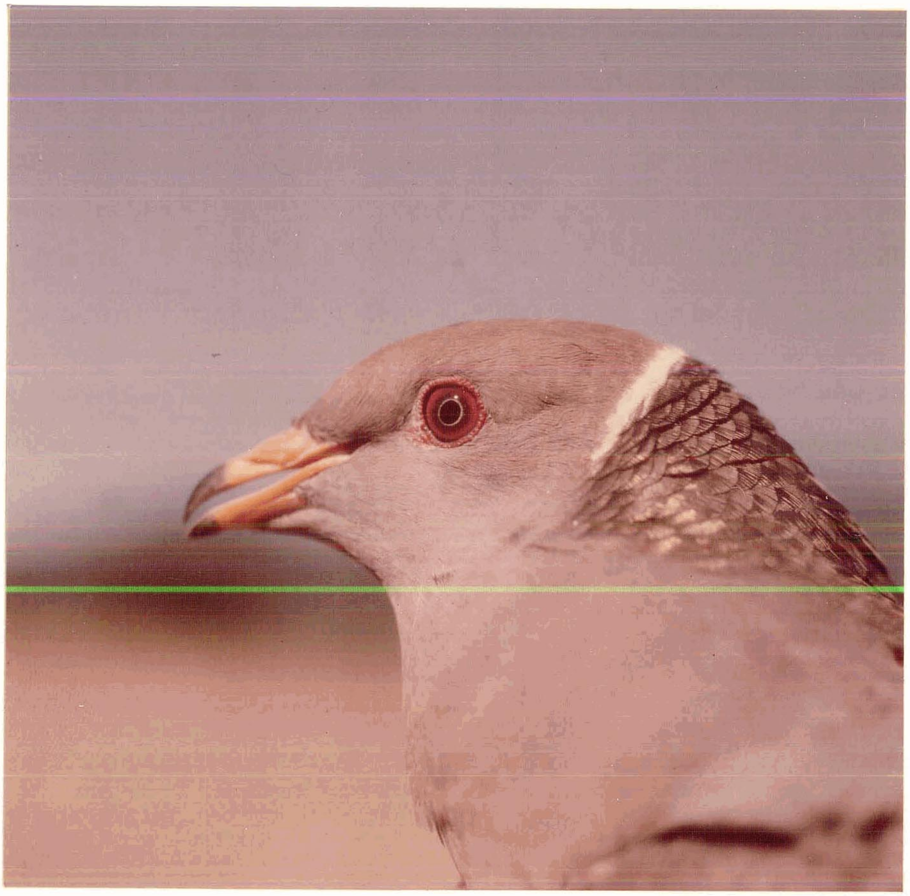

APPROVAL

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ABSTRACT

The band-tailed pigeon (Columba fasciata) migrates into British Columbia in April and remains there until September. During the breeding season this species ranges along the coast, west of the coastal mountain range and south of 52°N including Vancouver Island. The species extends inland appoximately 150 miles along the Fraser River Valley. Crop examination of shot birds indicated that they fed on grain and hemlock pollen in early spring after which there was sequential use of elderberry, cascara, and black mountain huckleberry as the season progressed.

Examination of reproductive tracts indicated that the band-tailed pigeon ovulates from April through July but not all females in the population do so early in the breeding season. Males are in breeding condition in April and remain so until late July. Two clutches (one egg each) are produced during the breeding season and females may ovulate while their crop gland is still producing curd. Many birds had active crops when shot during the hunting season in September indicating a potentially reduced recruitment of squabs being fed at this time. Four stages of crop gland

development are described in detail and the usefulness of this gland to indicate breeding status is demonstrated. Ovaries were classified into 4 stages of follicular development and compared with stages of crop gland activity to categorize the total reproductive cycle into 7 different phases. These phases were then used to categorize changes in serum and pituitary prolactin and serum and femur calcium levels during the reproductive cycle.

A radioimmunoassay technique involving antibodies to ovine prolactin was used to measure serum prolactin. Serum prolactin increased significantly during terminal development of the ovary and decreased after ovulation. A further decrease of serum followed initiation of crop gland activity. Serum calcium concentrations were at a maximum immediately after ovulation and then declined. Femur calcium levels in the female showed an inverse trend indicating a pattern of mobilization. Males with active crop glands had higher serum calcium concentrations than males with inactive crops although there was no indication of femur calcium changes during this period. The calcium requirements of this species may be the major factor in restricting its range and it is suggested that significant body weight loss in both sexes following completion of migration was due to a combination of increased reproductive activitv and intensive use of mineral resource areas.

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1. GENERAL INTRODUCTION

The band-tailed pigeon (Columba fasciata) was described by Say in 1823 from a specimen collected in Douglas County, Colorado (Bendire, 1892). The species breeds from the west coast of Canada below 52°N (not including the Queen Charlotte Islands) southward to the California-Mexican border. It is generally found west of the Cascade mountains, although the states of Utah, Colorado, Arizona, New Mexico and western Texas have considerable summer breeding populations (Neff, 1947). Isolated sightings of this species have occurred in Nevada, Oklahoma and North Dakota (Grinell, 1913) as well as north-central Alberta (Spalding and Hampson, 1969).

The first detailed study of the band-tailed pigeon was done in California (Grinell, 1913) and was stimulated by conservationists concerned over declining population numbers due to market gunners. Following this report were numerous publications from various states (Willard, 1913, 1916; Moran, 1919; Taylor, 1924; Abbott, 1927). More recent contributions to the knowledge of this species have been provided by Neff (1947), Glover (1953), MacGregor and Smith (1955), Peeters (1962), Drewien et al (1966), Wight et al (1967), Smith (1968), Sissons (1968), Silovsky (1969) and Keppie (1970).

The available information on this species in British Columbia is provided by 4 published notes (Munroe, 1922, 1924; Pearse, 1935, 1940), and one unpublished report (Munroe, 1951).

The band-tailed pigeon in Canada has been shot since the turn of the century and was included in the migratory bird protection treaty between Great Britain and the United States in 1918. The Canadian Wildlife Service is the responsible Federal agency for regulating this species in Canada. There is very limited information on this province's contribution to the band-tailed pigeon numbers in the Pacific flyway, or on how much of the knowledge available in the United States is applicable to the pigeon populations in British Columbia. To answer these and other questions, a contract to investigate the biology of the band-tailed pigeon in British Columbia was initiated during the autumn of 1967. The study as initially envisaged considered habitat selection, food resources, census techniques and reproductive biology based on nest site observations.

During the first breeding season (Summer, 1968), the study proceeded on a general ecological basis. The species was found to have a wide home range and to be extremely secretive in its nesting habits. Because nest sites could not be found, the breeding biology was investigated by examination of shot birds. This included the measurement of oviducts, ovary, ovulated follicle, testes and crop gland activity of each bird. Before particular phases of crop gland activity could be determined, a histological investigation of the crop gland of the domestic pigeon (Columba livia) was performed at various stages of the reproductive cycle. These stages of crop activity were then applied to a similar histological examination of the wild species being studied. In this manner, individuals of both sexes of band-tailed pigeons could be classified according to a particular phase of crop gland activity. This information, combined with that derived from the reproductive organs, provided a basis for describing a time-table of the reproductive cycle. This aspect of the study is contained in Chapter 3.

The total reproductive cycle could not yet be determined on the basis of examination of tracts and crop glands because it was impossible to distinguish between the reproductive status of individuals who were not breeding and those who were in early incubation. It was decided, therefore, to evaluate changes in serum prolactin concentration to determine these two types of individuals. Riddle et al., (1932a, b) had shown that serum prolactin concentration was at an elevated level prior to crop gland activity and it was hoped that these changes would elucidate this difference. A radioimmunoassay was used to determine serum prolactin concentrations in birds shot in 1969 and both serum and pituitary prolactin changes during 1970. It was found during mid-June, 1969, that the ovulated follicle was noticeable for at least 15 days (Meyer et al, 1947) and this follicular evidence allowed complete categorization of the reproductive cycle. Since the radioimmunoassay of shot birds had already begun it was decided to continue this work, and this portion of the study is detailed in Chapter 4.

From the beginning of this work it became evident that this species made extensive use of mineral resource areas (Appendix A). It appeared at this time that the required minerals would be of major importance to breeding success and it was decided to investigate the ionic concentration of minerals available at these particular sites. Previous research on domestic fowl (Simkiss, 1967) had shown importance of calcium in avian reproduction and this led to an investigation of the calcium balance in C. fasciata. There have been no such previous works on wild Columba reported.

To examine the practicality of using mineral-gravelling areas for census determination a banding and tagging program of cannon netted birds was carried out at the Hatzic mineral spring during May and June of 1969. In an attempt to determine home range, 90 birds were banded under a permit issued to W. A. Morris (Canadian Wildlife Service, Vancouver) and in addition, fluorescent back-tags were placed on each bird. The back-tags were 4" x 1" plastic strips and were attached at the nape of the neck by a 3/4" safety pin. This technique had been tried earlier in the year on a number of tame pigeons with a measure of success. Previous to netting the birds, a short study on the use of mild anesthetic was done. The oral anesthetic used was Methoxymol (Jansan Pharmeceutical, Beerse, Belgium) which is an imidozole derivitive. The use of the anesthetic was abandoned due to the problem of insuring acceptable field use and the banding and tagging project was not completed for logistic reasons.

Discussion of this study logically falls into 4 sections. The 1st is the ecological information on distribution, mineral-gravelling site usage and feeding habits which was obtained from observational data as well as shot samples (Chapter 2). The reproductive investigation although already published (March and Sadleir, 1970) forms Chapter 3. The

4th chapter contains the radioimmunoassay study of prolactin and provides detailed analysis of changes in the relative concentration of this hormone during the reproductive phases. The investigation of the calcium balance of this species is closely associated with its reproductive capacity and is placed in Chapter 5 of this study.

2. ECOLOGY - Migration, distribution, food resource and mineral-gravelling activity.

Introduction

The band-tailed pigeon (*Columba fasciata*) is a moderately common species of game bird found in Canada throughout the southwestern portion of British Columbia, including Vancouver Island. There have been no comprehensive investigations of this species in its northern range despite considerable hunting pressure. A general study of the bird was started in 1968 and details on reproduction have been reported (March and Sadleir, 1970). This chapter deals with the ecology of this species in British Columbia, with particular reference to migration, distribution, food utilization and mineral spring gravelling activity.

This species was first shot for market in the U.S.A. during the early nineteen-hundreds (Chambers, 1912) but hunting was stopped in 1913 because of the rapid and continual decline in population numbers. For the next twenty years there were subsequent reopenings and closings of the hunting season throughout the Pacific coast states of the U.S.A. and Canada. Although the season has remained substantially unchanged since the early thirties, hunting intensity has increased considerably. The estimated hunter-kill during

1967 for the States of California and Washington was 334,000 and 139,000 birds respectively (North American Wildlife Conference, 1967).

Previous investigations of the band-tailed pigeon have been carried out almost entirely in the U.S. and a food and habitat study by Neff (1947) reviewed the literature dealing with this species. Subsequent studies by MacGregor and Smith (1955) and Smith (1968) provided information on reproduction based on nest surveys in California. Glover (1953) and Wight et al (1967) dealt primarily with population dynamics of the species and estimated recruitment using hunter-kill samples.

The Canada-U.S. Migratory Bird Treaty Act became effective on July 3, 1918 and, from this date, hunting regulations in British Columbia have closely paralleled those of the U.S. Prior to the present investigation, there have been few published reports on the band-tailed pigeon in British Columbia. Burton (1922) and Munroe (1922, 1924) briefly described the feeding and nesting of this species on Vancouver Island. These early reports were followed by Pearse (1935, 1940) commenting on observations of display flights and reduction of population numbers and Munroe (1951) included information about band-tailed pigeons in a provincial survey of migratory birds. This species is extensively hunted in British Columbia with the most concentrated shooting areas being those where pigeons congregate for mineral-gravelling purposes (March and Sadleir, 1970). Increased hunting pressure, combined with the lack of knowledge of this species in British Columbia resulted in the issuing of a contract, by the Canadian Wildlife Services, to study the biology of the band-tailed pigeon in British Columbia. It is hoped that this study will provide a basis for future management and conservation of a presently diminishing species.

Methods and Materials

Samples of band-tailed pigeons were shot at mineral-gravelling sites in the Fraser River valley of British Columbia from April to August during 1968-1970. Large samples were obtained from co-operating hunters at the beginning of September of each year. Shot birds were immediately weighed and then reweighed after the removal and identification of crop contents. The sex and reproductive condition was recorded.

One gallon samples were collected by representatives of Oregon State Wildlife Branch, from mineral springs utilized by band-tailed pigeons in Oregon. The Hatzic spring in the Fraser Valley of British Columbia was sampled at various times throughout 1968-1970. Simultaneously, water samples were obtained from a ditch and slough not used by pigeons although both were located in the immediate vicinity of the mineral spring. Analysis of ion content was carried out by the Spectrophotometric method in a commercial laboratory (Warnock Hersey International). To determine the distribution of this species in British Columbia, band-tailed pigeon survey cards were distributed during 1968 to conservation officers throughout the province. Information was requested on the date, time and place of sightings of birds, their activity at time of sightings and the numbers of birds observed.

Results

The Pigeon Cove sample area is situated at the eastern end of Burrard Inlet (Fig. 1 and Fig. 2). The Hatzic mineral spring is located approximately 50 miles inland in a farming district of the Fraser Valley (Fig. 3). The distribution insert was derived from survey card reports received from British Columbia Fish and Game Department conservation officers.

Figure 1 : Map of the Lower Fraser River Valley showing the two major sample areas. The distribution of the band-tailed pigeons in British Columbia is indicated by the darkened region of the insert. The lower right hand corner of this darkened area represents the larger map.

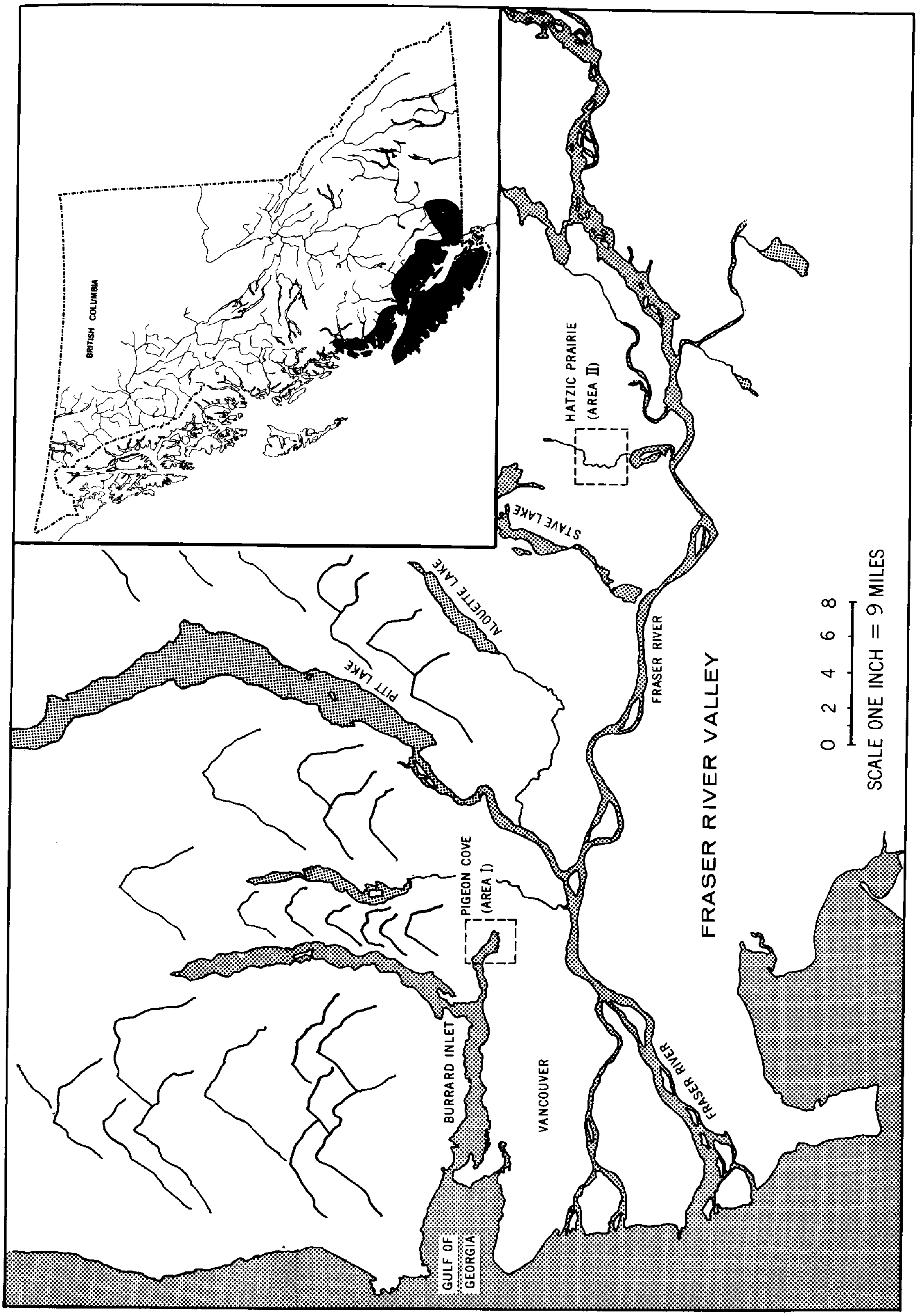

BRITISH COLUMBIA
HATZIC PRAIRIE
(AREA II)
STAVE LAKE
ALOUETTE LAKE
PITT LAKE
FRASER RIVER
PIGEON COVE
(AREA I)
BURRARD INLET
VANCOUVER
FRASER RIVER
GULF OF
GEORGIA
FRASER RIVER VALLEY
0 2 4 6 8
SCALE ONE INCH = 9 MILES

Figure 2: Top. View of mud flats at Pigeon Cove at low tide. Band-tailed pigeons gravel in the immediate vicinity of the log in the foreground. Note coniferous growth to the right of the photograph.

Figure 3: Bottom. General view of Hatzic mineral spring area. The water and mud combined surface area of the spring is approximately 6 square feet immediately in front of the figure. Note the close proximity of heavily treed hillside.

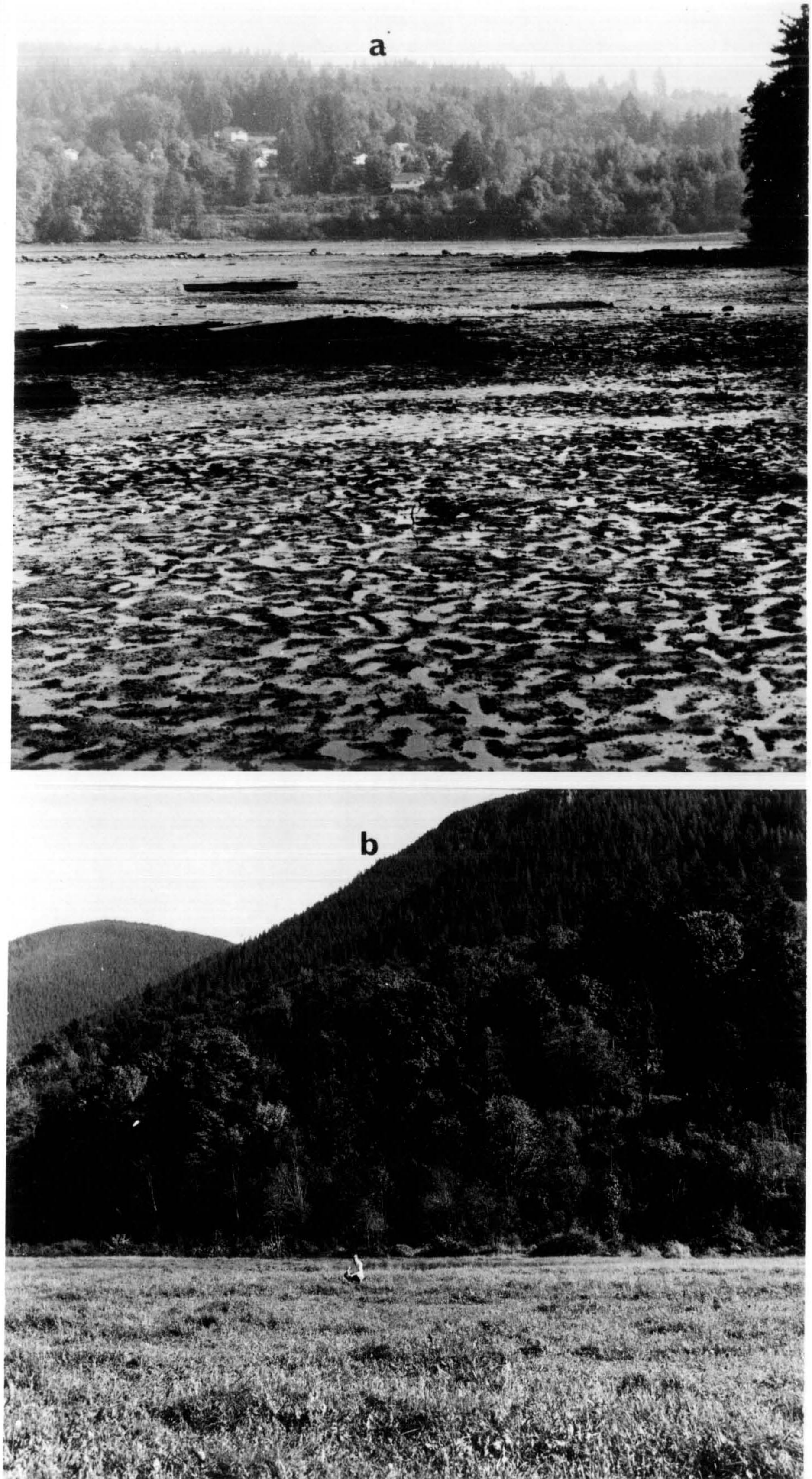

a
b

Table 1 provides analysis of mineral spring water gathered from different areas in Washington, Oregon and British Columbia. Calcium and sodium are the only two cations that are continually in excess of those found in the slough or ditch.

Seasonal change in food items is shown in Fig. 4. The percentage of empty crops increased during the first half of June and coincided with the initial appearance of the first major natural food item and the first peak in breeding (Chapter 3). The percentage reached a maximum during the first half of July and remained relatively constant from this time until the final September sample

Discussion

a) Migration. Compared with other migratory species in British Columbia, the band-tail pigeon arrives late from the south. The migration from California is completed by April (Smith, 1968). Although there have been a few sightings in British Columbia during late March, the majority of the birds arrive in April, and migration continues until early June. On arrival, the birds frequent freshly cultivated grain fields and railway yards. They remain in these areas until mid-June when they leave agricultural and populated

MINERAL SPRING IONS

Table 1. Analysis of mineral spring and sea water sampled from areas frequented by band-tailed pigeons. The results are reported in "Parts per Million" except for pH determination. *Hatzic slough and Hatzic ditch are not used by pigeons.

	SEA WATER	PIGEON BUTTE	SILVER SPRINGS	FAIRDALE	ZUICKEN RANCH	NASHVILLE	PIGEON SPRINGS LEWIS COUNTY	PIGEON SPRINGS COWLITE COUNTY	JACK KELLY RANCH	KESTER PROPERTY	SODA SPRINGS	HATZIC SPRING	HATZIC SLOUGH*	HATZIC DITCH*
Na	10,561	650	6,400	1,100	4,200	1,600	11,500	6,900	145	2,500	1,100	700	22	18
K	380	14	24	9	81	9	14	12	2	8	95	7.0	2.0	2.0
Ca	400	3,400	20,000	5,350	1,900	1,400	7,250	9,450	233	7,500	383	275	2.0	10.5
Mg	1,272	87	47	7.0	190	100	58	24	34	23	51	12	8.1	1.0
Fe	.005	8.0	0.4	0.6	1,000	3.0	120	0.4	0.6	1.6	280	62	1.6	1.4
SO_4		450	617	157	1.0	1.0	280	192	1.0	32	1.0	462	102	8.5
Cl	18,980	4,900	31,150	10,000	5,500	4,040	26,200	20,300	210	10,100	1,012	1,313	21	29
pH		5.7	6.1	6.5	6.7	7.1	4.2	7.3	7.5	6.5	6.7	7.3	5.6	6.5

regions for the remote mountain valleys of the coast. The latter movements have been confirmed by sighting records of British Columbia Fish and Game Department conservation officers. The northward migration is completed when the band-tailed pigeons are distributed throughout the coastal regions of the mainland and Vancouver Island, generally south of the 52nd latitude (Fig. 1).

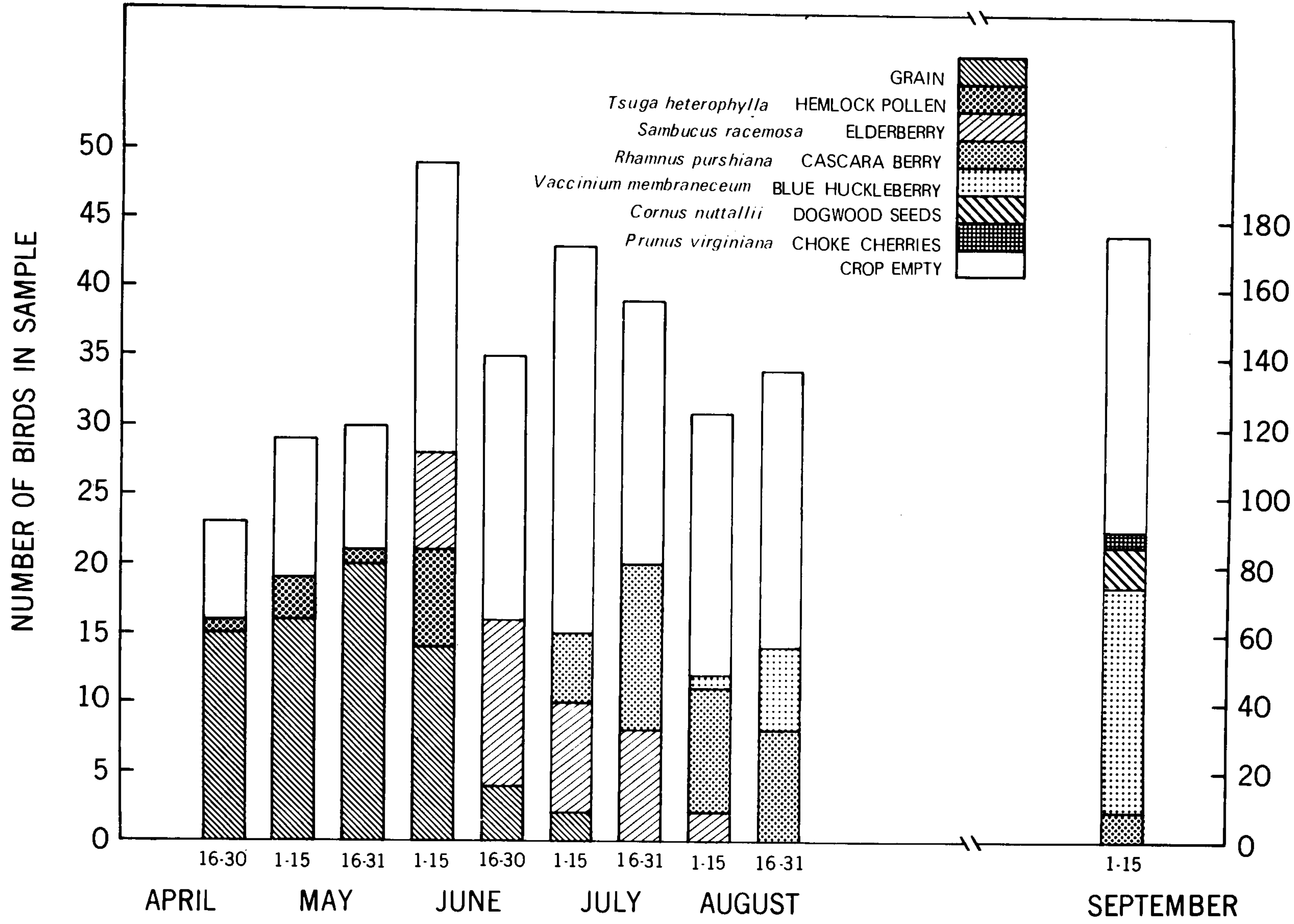
The beginning of southward migration varies with the food resource available, the temperature and rainfall of the late summer months. It is at a peak during the first two weeks of September and is usually completed at the end of the same month. Conservation officers have noted two migratory routes south. One is along the coastline of British Columbia, continuing through Washington and Oregon into California. Pigeons using the second route move from Vancouver Island and the Gulf Islands (Fig. 1), over the Straits of Juan de Fuca, through Washington and Oregon, joining the coastal route (Sissons, 1968).

b) Distribution. The band-tailed pigeon in British Columbia is found all along the coast west of the Coastal Mountain Range (Fig. 1). It has been reported northward to 52°N and the longest penetration eastward occurs in the Fraser River Valley and extends 150 miles from the Pacific

Ocean. This species, during the summer breeding period, is found over the entire Gulf Islands and Vancouver Island areas. The range of these birds may be expanding since a female pigeon was shot 30 miles south of Edmonton, Alberta, in July 1967 (Spalding and Hampson, 1969).

c) Food habits. On arrival from their wintering areas, the birds frequent railway yards and utilize grain spillage (Fig. 4). During this study, band-tailed pigeons were repeatedly observed feeding in large flocks along one short section of track 4 miles east of Area I (Fig. 2). Their numbers often exceeded 500 birds. These individuals did not leave this area each year until natural fruits become available in June. The continued presence of birds in the region of the railway yards would indicate that they were not engaged in active reproduction as there were no nesting sites in the surrounding area. Pair bonding may be involved as numerous courtship flights were observed similar to that described by Glover (1953) and Peeters (1962). Prior to June, similar congregations were seen in newly seeded oat fields. Small groups would leave the vicinity of the fields at different periods during the day. By nightfall they had returned to sit in the trees surrounding the feeding site. There was no observable indication of participation in breeding

Figure 4. : Seasonal change in food items as revealed by crop analysis (1968-1969 combined). Note that September sample is indicated on a different scale and that each crop when sampled contained only a single food item.


NUMBER OF BIRDS IN SAMPLE
50
45
40
35
30
25
20
15
10
5
0
180
160
140
120
100
80
60
40
20
0
GRAIN
Tsuga heterophylla HEMLOCK POLLEN
Sambucus racemosa ELDERBERRY
Rhamnus purshiana CASCARA BERRY
Vaccinium membraneceum BLUE HUCKLEBERRY
Cornus nuttallii DOGWOOD SEEDS
Prunus virginiana CHOKE CHERRIES
CROP EMPTY
16-30
1-15
16-31
1-15
16-30
1-15
16-31
1-15
16-31
1-15
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER

activity. Thus there appears to be a pause between completion of migration and active participation in reproduction. It seems likely that this delay is due to the lack of natural foods in the high altitudinal nesting areas of this species. During the 3 years of this study, the band-tailed pigeons have moved from railway yards and cultivated fields to remote areas as soon as the earliest wild fruits became available.

During April and May of 1970, it was noted that all females with an enlarged follicle (indicating imminent ovulation) which had food in their crops had been feeding on hemlock pollen. Previous observation in 1968 and 1969 during similar months (Chapter 3) showed that 37% of females sampled had similiar enlarged follicles. The sudden departure of birds from cultivated fields and railway yards in June, coinciding with the onset of reproduction in females, suggests that food is the stimulus for completion of follicular development prior to ovulation.

Crop samples indicated the utilization of six different varieties of natural foods (Fig. 4). Red elderberry is used extensively during its entire period of availability from the second week of June until the first week of August. As elderberries become less available, the pigeons feed primarily on cascara berries which ripen during mid-July and are utilized until early September. During late August, the presence of black mountain huckleberry indicates a third major change in diet. The birds at this time are feeding at higher altitudes as this plant is commonly found above 2500 feet (Lyons, 1965). During September a small number of shot birds had fed on dogwood and choke cherries. Although this species has been shown to feed on a few other varieties of fruits (Munroe, 1951), none were found in any of the approximately six hundred crops sampled over three years. It is interesting that band-tailed pigeons do not use grain spillage in railway yards again until the following spring, although it is available at all times.

d) Mineral Spring utilization. Prior to discussing the band-tailed pigeon's use of mineral spring areas, it is pertinent to mention the relationship this has to reproduction. Chapter 3 describes physiological evidence which strongly suggests that these birds require considerable calcium during breeding for egg production and crop gland function. The ecological evidence for this requirement is based on the pigeons extensive use of high calcium mineral spring sites during the breeding season (Chapter 5).

Neff (1947) and Smith (1968) have described pigeons drinking water at traditional mineral spring sites in California. Similar areas are known in Washington and Oregon (J. Chatten, personal communication; Table 1). Neff (1947) also reports observations of pigeons drinking salt water along the mud flats of the Puget Sound. "Mineral springs" and "gravelling areas" in certain cases may be considered synonomous as both mineral acquisition and gravelling may occur at a common site. Pigeon Cove (Area I, Fig. 1) is such a site. In this tidal bay, the birds come to obtain grit, washed out onto the mud flats by small streams (see Fig. 2). They also pick up salts which have dried on the pebbles as the tide recedes. The ecology of the area is of critical importance to the band-tailed pigeons as they will only gravel in the immediate vicinity of shoreline coniferous growth. They remain in these trees until the tide has exposed small pebbles close to the shoreline and salt deposition is complete. The birds then fly down in groups numbering from 5 to 25 and very quickly pick up a few pebbles and return to the trees. This movement for a single bird takes approximately 2 minutes and may be performed 4 to 5 times. The area for gravelling does not exceed 100 yards in length and is approximately 50 feet out from the shoreline (Fig. 2).

The pigeons have never been observed to gravel outside of the described area during the 3 years of this study. There are no reported band-tailed pigeon populations in British Columbia that do not have access to a mineral spring area or a mineral-gravelling site. Murton (1965) described pigeons (Columba palumbus) pecking at cattle salt licks and Ljunggren (1968), working on the same species in Sweden, found pulmonate shells in the crops during the summer months. Similar animal materials were obtained from analysis of doves (Zenaidura macroura), (McClure, 1943). There was no evidence of this type of mineral resource being used by band-tailed pigeons.

An analysis of a number of mineral spring waters used by band-tailed pigeons indicated a high concentration of calcium, sodium and chloride ions (Table 1). The importance of trace elements is not fully understood, but further evidence points to calcium as the main mineral involved. Calcium chloride is used each summer to reduce dust on gravel roads near the municipal airport at Hope (extreme right, Fig. 1). Immediately after this salt was scattered on the road, large flocks of band-tailed pigeons were seen during the 3 year period, picking up pebbles that were coated with the calcium chloride. The pigeons do not frequent this area at any other time. Further evidence of the importance of these mineral-gravelling sites at the time of breeding was provided by the absence of band-tailed pigeons from mineral areas until the second week of May. The number of birds using these resources reaches a peak about mid-July, corresponding to the period of most intense reproductive activity (Chapter 3). McCann (1939) investigated the importance of grit as a source of minerals. This work, as well as a number of later studies have shown grit selection during the breeding season in favour of those containing calcium (Sadler, 1961; Harper, 1963).

e) Diurnal activity. Adverse weather conditions affect utilization of the mineral-gravelling area. Heavy rainfall washes the salt from pebbles and, although there may be a few birds in the area, they do not attempt to gravel. The mineral spring at Hatzic is not affected the same way although the number of birds in this area will also be substantially reduced.

A thorough tagging and banding program at several mineral sites would provide valuable information on population numbers. Once the number of visits per individual bird was determined a census estimate would be possible. Finally, there have been a number of investigators describing the lack of young in the hunter-kill samples (Edminster, 1954; Smith, 1968). In British Columbia, the kill ratios (young to adult) for the 1968 to 1970 season have been 1:4, 1:9.5, 1:9 respectively. The lower ratio given by Edminster (1954), 1:3, and Smith (1968), 1:2, may be explained by the fact that all birds in British Columbia are shot at mineral-gravelling sites whereas, in Oregon and California, feeding grounds are also important harvest areas. The elevated ratio in British Columbia is probably due to the young not having the same mineral requirements as the reproducing adult.

3. REPRODUCTION - Seasonal changes in gonadal development and crop gland activity.

Introduction

The band-tailed pigeon (Columba fasciata)is a migratory species that winters in the southwestern United States. Considerable numbers migrate north to breed and are found in the southwest corner of British Columbia from April to September. The band-tailed pigeon is a game bird that is extensively hunted from the opening of the season on September 1st until the departure for the southward migration is completed some weeks later.

There has been no study of the breeding of C. fasciata in its northern range. Although there have been a number of general investigations into its biology in the United States (Neff, 1947; Glover, 1953; MacGregor and Smith, 1955; Drewien et al, 1966; Wight et al, 1967; Smith, 1968) only 3 of these papers give any details on breeding and those are based on nesting observations only. A number of detailed investigations on other species of Columba in Europe have been well documented. Lofts et al, (1966) reviewed many years' work on C. livia, C. palumbus, and C. oenas in Britain with details of gonadal cycles of both sexes. Ljunggren (1969) studied the gonadal cycles of

C. palumbus in Sweden and also reported for the first time seasonal changes in crop gland activity. This chapter reports a 2-year investigation of the breeding biology of C. fasciata based entirely on autopsy of shot samples with emphasis on gonadal and crop development.

Methods and Materials

a) Field. Samples of band-tailed pigeons were shot at various localities, usually in the vicinity of mineral springs in the Fraser River Valley of British Columbia from April to September in 1968 and 1969. Large samples were obtained from cooperating hunters at the beginning of September in both years. Gonads were immediately dissected after shooting and placed in Bouin's fixative. One lateral lobe of the crop gland was removed and spread over a 1½ inch circular cardboard disk. On the basis of its appearance the gland was recorded as being in one of the phases described below and placed in Bouin's fixative.

b) Laboratory. Ovaries were weighed after being blotted dry and the diameter of the largest follicle measured with Vernier calipers. Ovaries were inspected for the presence of collapsed follicles indicating ovulation. They were then processed by standard histological techniques, sectioned at 6 μ, and stained in hematoxylin and eosin. Wedges of the crop lobe were cut at right angles to the curd-producing surface, processed by standard techniques, sectioned at 7 to 10 μ, and stained in periodic acid - Schiff (PAS). Testes were also sectioned and the phases of testicular activity categorized according to the descriptions of Lofts _et al_, (1966).

c) _Crop Gland Phases_. Phase I (inactive) - Macroscopically (Fig. 5) the gland is almost indistinguishable from the general epithelium lining the crop cavity. Microscopically (Fig. 6) the stratified epithelial layer of the gland area is much thinner than the lamina propria beneath. Terminology follows that of Dumont (1965), who described certain of these phases for _C. livia_. The _stratum basale_ and _stratum disjunctum_ are apparent but the _stratum spinosum_ is difficult to distinguish.

Phase II (growth) - Macroscopically (Fig. 7) the gland is seen as a slightly convoluted ovoid disk about 2 cm in diameter and about 1 cm thick. It is vascular with visible surface blood vessels. Microscopically (Fig. 8) the first sign of this phase is a distinct increase in the thickness of the proliferating epithelium, especially the _stratum_ _disjunctum_ and _stratum spinosum_, which are now distinct layers. The epithelium grows into folds projecting downwards into the lamina propria.

Phase III (active) - During this phase, macroscopic appearance (Fig. 9) and thickness of the gland are very variable although the diameter remains the same as in phase II. The surface is extremely convoluted and may appear tesselated. Its color when fresh ranges from pink to pale cream depending on the stage of lipid accumulation. Loose segments of curd may be seen adhering to the surface of the gland or free in the crop lumen. This stage is easily detectable by palpation from the exterior.

Microscopically the squamous layer is now so thickened that the lumen surface of the individual folds are touching and the extensions of the lamina propria between the folds are very thin but highly vascularized (Fig. 10). During this phase the absolute thickness of the combined _strata spinosum_ and _disjunctum_ varies with curd accumulation and desqualmation but at all times the remaining epithelium is considerably thicker than in phase II and IV. It is exceedingly difficult to distinguish between the _stratum disjunctum_ and _stratum spinosum_.

Phase IV (lag) - During its decline in activity, the

Figures 5 to 12 : The stages of crop gland activity. In all sections the lumen surface is at the top.

Figure 5 : Appearance of crop gland phase I (inactive).

Figure 6 : Section of crop gland phase I (inactive, x 100).

Figure 7 : Appearance of crop gland phase II (growth). The approximate thickness is indicated by cross section.

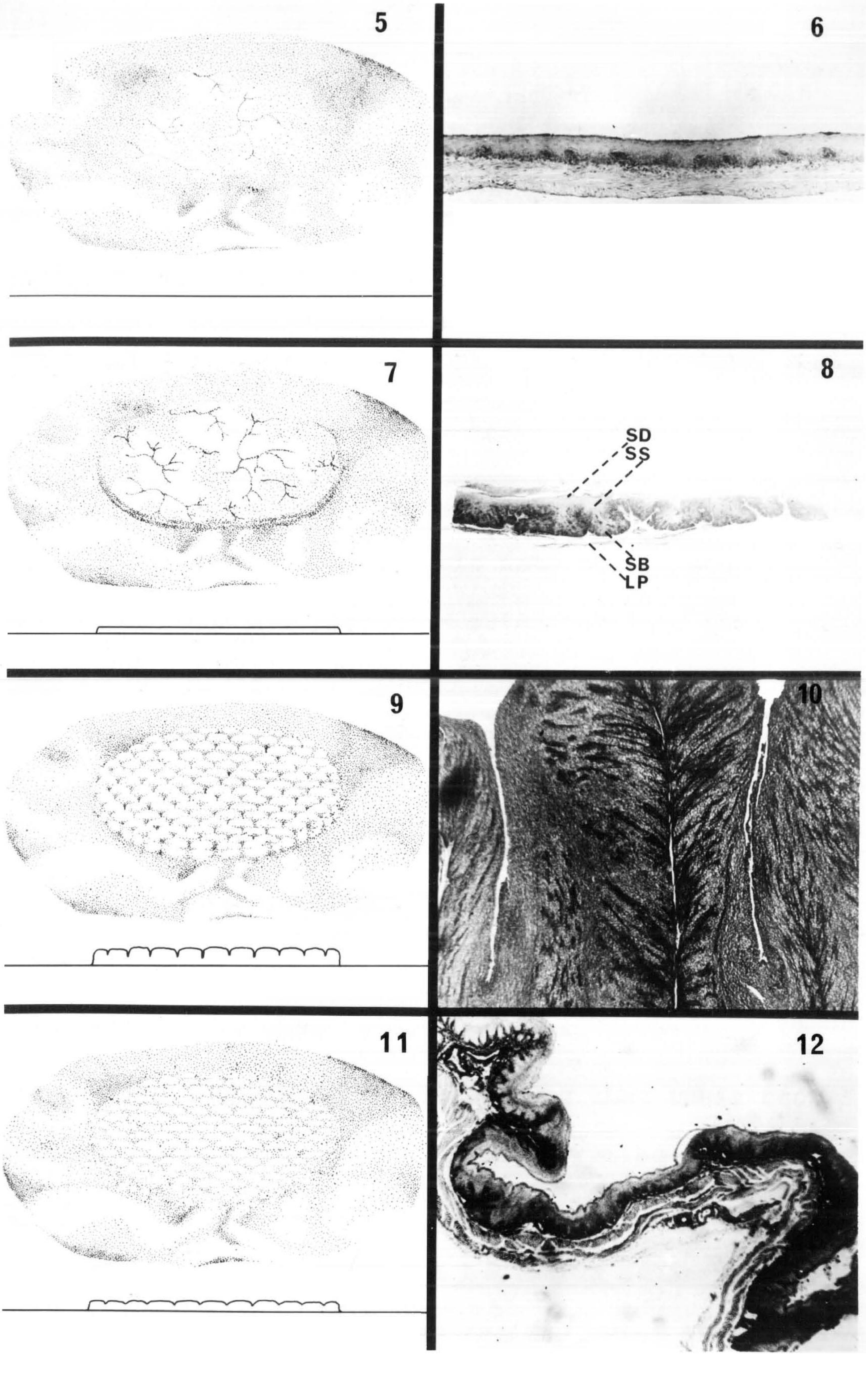
Figure 8 : Section of crop gland phase II (growth x 25). SB = _stratum basale_, SD = _stratum disjunctum_, SS = _stratum spinosum_, LP = _lamina propria_.

Figure 9 : Appearance of crop gland phase III (active).

Figure 10 : Section of crop gland phase III (Active x 25).

Figure 11 : Appearance of crop gland phase IV (lag).

Figure 12 : Section of crop gland phase IV (lag x 25).


5
6
7
8
SD
SS
SB
LP
9
10
11
12

gland's appearance is somewhat difficult to distinguish from the later stages of phase III as loose pieces of curd may still be present (Fig. 11). However, it is in a state of attrition and is much redder, less convoluted, and thinner. Microscopically (Fig. 12) the layers of squamous epithelium are much reduced and approach the thickness of the <u>lamina propria</u>. The definitive characteristic of this phase is the presence of numerous finger-like projections of the <u>lamina propria</u> into the <u>stratum basale</u>. These projections are also seen extending into the <u>stratum basale</u> in the areas where the <u>lamina propria</u> is included in the gross epithelial folds. All microphotographs were taken at 550 nm.

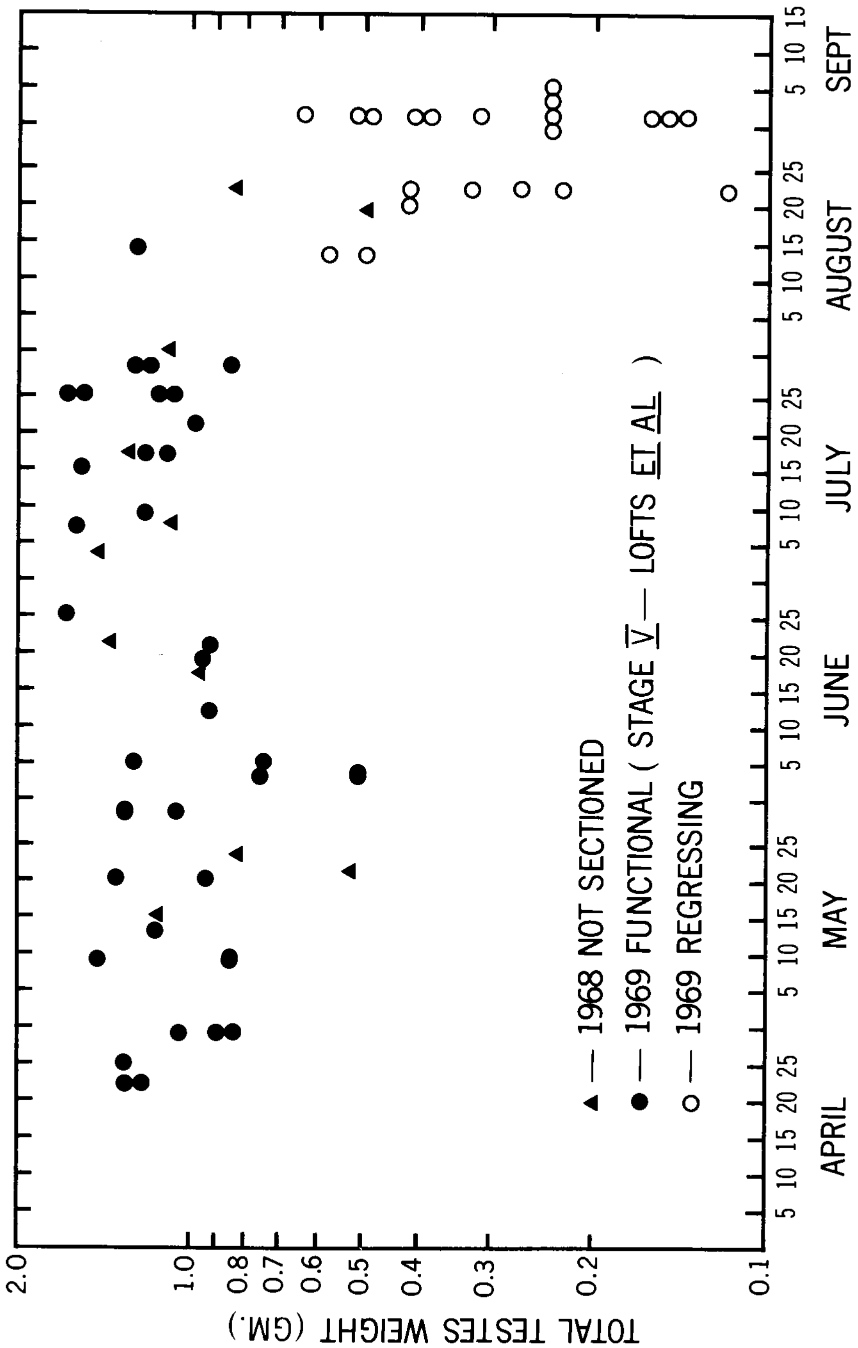
Results

a) <u>Testes</u>. Seasonal changes in the testes are shown in Fig. 13. Males were in full breeding condition when first sampled in both years, suggesting that their testes are functional during the northward migration. All males sampled during the summer had testes undergoing full spermatogenesis (Fig. 14) until the beginning of August at which time the gonads regressed rapidly (Fig. 15).

b) Ovaries. Changes in ovarian weights are shown in Fig. 19 and the times that birds with enlarged or ovulated follicles were sampled is shown in Table 2. Follicles over 5.5 mm in diameter are considered to be expanding just before ovulation (Fig. 15). This is based on comparisons with similar measurements for *C. livia* (Bartelmez, 1912) and *C. palumbus* (Ljunggren, 1969). Ovarian weights indicate some feamles were in potential breeding condition when first sampled, and similar females were collected until early August. Because of the rapidity of follicular swelling (see discussion), the probability of sampling birds at any one time with enlarged follicles (*i.e.* greater than 5.5 mm) is small. The data (Fig. 19 and Table 2) indicate that there are two such periods in May and July. There then follows a rapid regression of the ovaries before the southward migration.

c) Crop Gland. No differences in the proportion of birds with crop glands in different phases were found between years or between sexes. Therefore, the data for 2 years were pooled (Fig. 20). The large hunter-kill samples in September are shown separately. There was no crop development before June but from mid-June until the end of July over half the birds had crops in either the growth

Figure 13 : Changes in testes weight with season. Each point represents the weight of the testes from an individual bird.


TOTAL TESTES WEIGHT (GM.)
2.0
1.0
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
APRIL
MAY
JUNE
JULY
AUGUST
SEPT
5 10 15 20 25
▲ — 1968 NOT SECTIONED
● — 1969 FUNCTIONAL (STAGE V — LOFTS ET AL)
○ — 1969 REGRESSING

Figures 14 to 18 : Changes in testes and ovaries.

Figure 14 : Testes tubule undergoing active spermatogenesis (x 400). This stage is identical with stage V of Lofts *et al*. (1966).

Figure 15 : A testes tubule showing regression (x 400). N.B. Plentiful cellular debri in the lumen.

Figure 16 : Ovarian section with one enlarged follicle (x 25).

Figure 17 : Section of undifferentiated, uniform ovary (x 25).

Figure 18 : Section of collapsed follicle (x 25). The stigma is to the right.

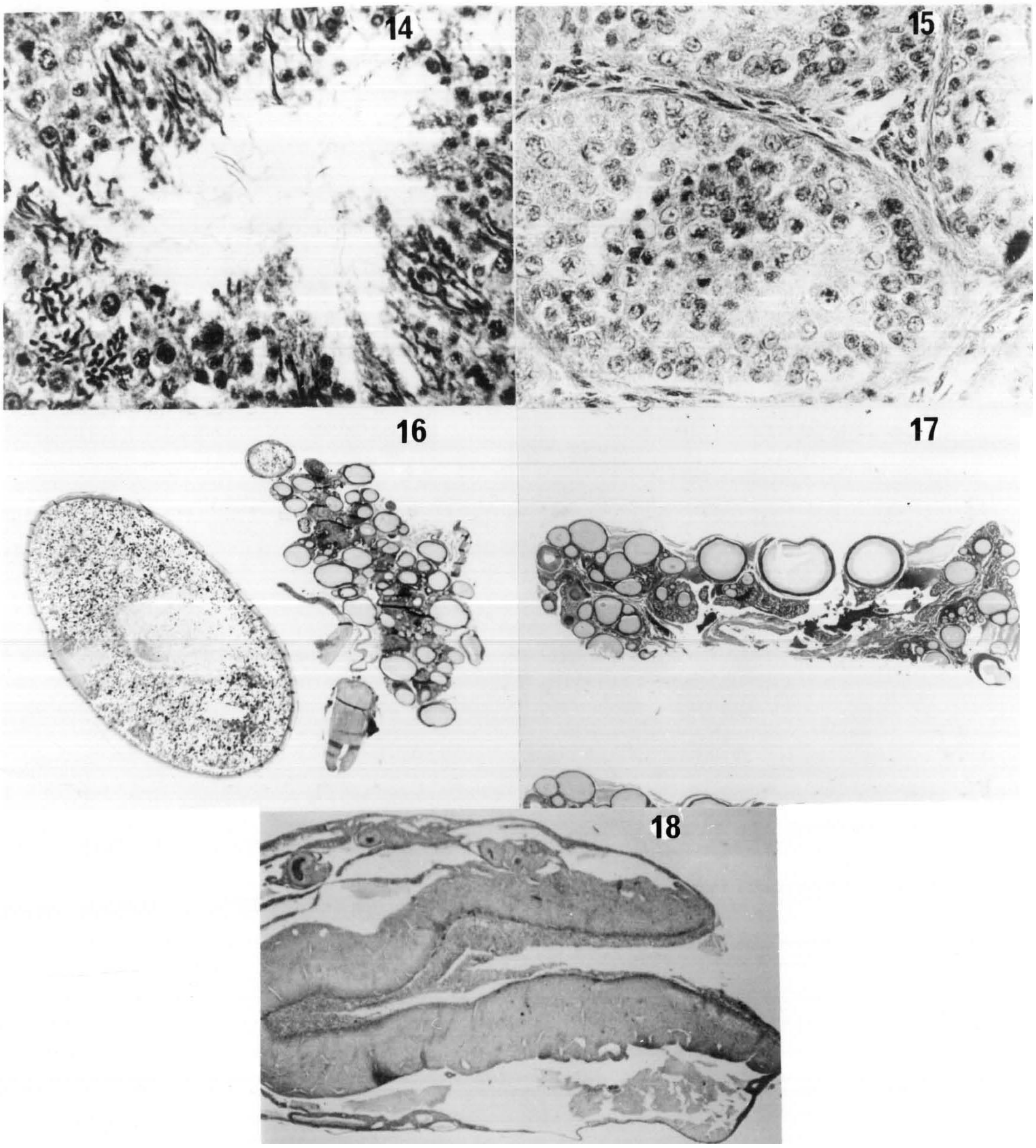
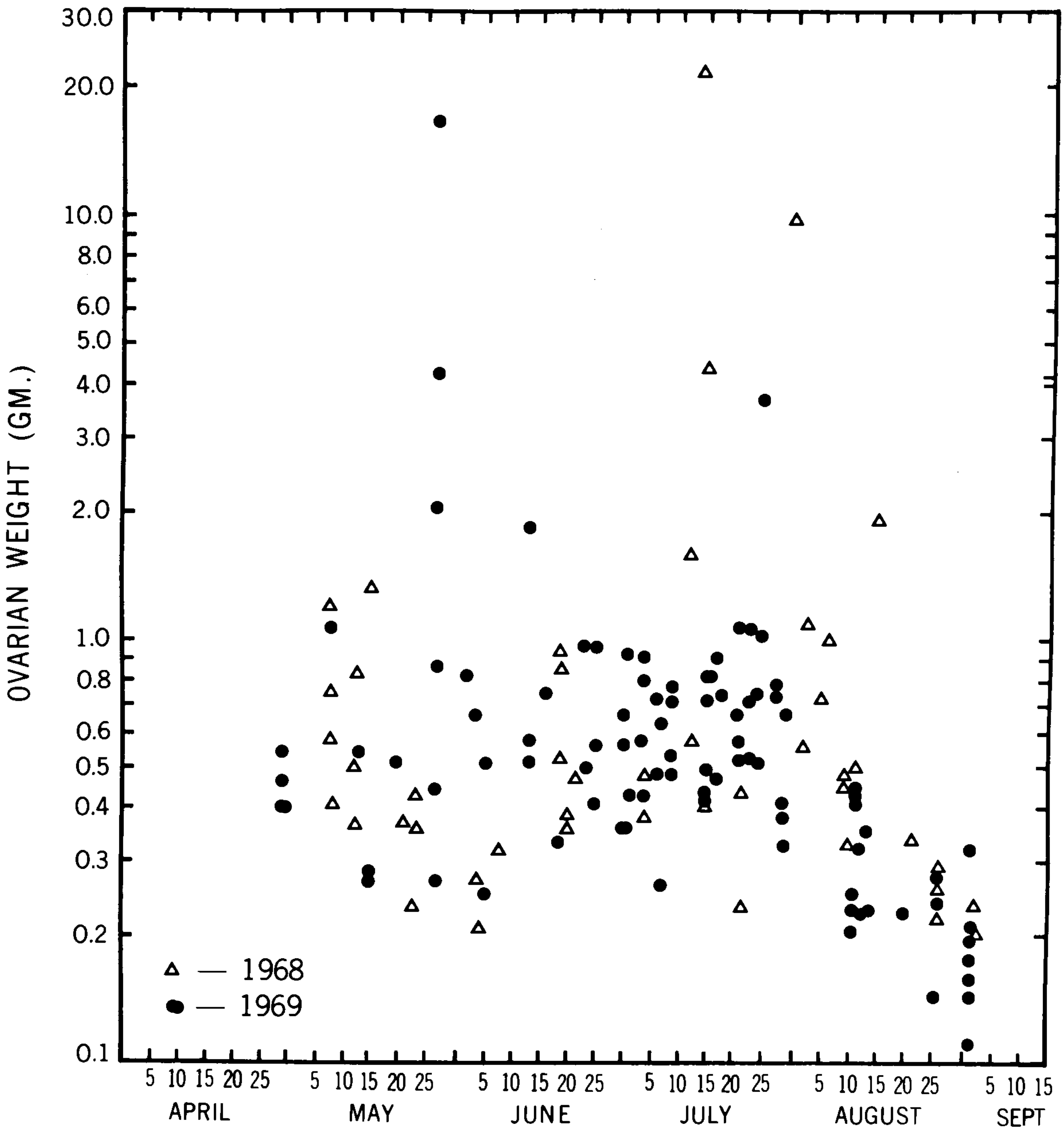

14
15
16
17
18

Figure 19 : Changes in ovarian weights with season. Each point represents the ovarian weight of an individual bird.

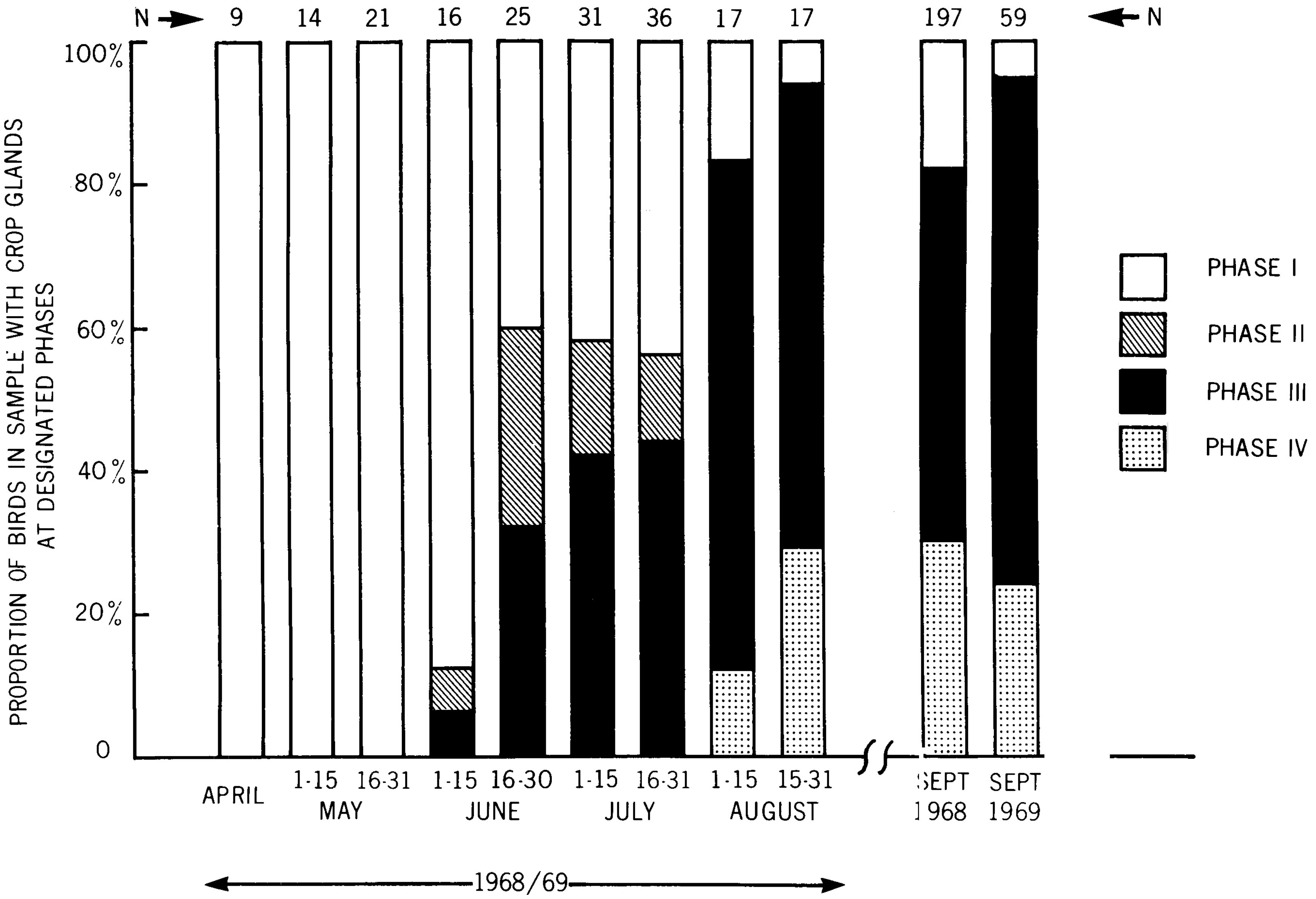


30.0
20.0
10.0
8.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
OVARIAN WEIGHT (GM.)
△ — 1968
● — 1969
5 10 15 20 25
APRIL
MAY
JUNE
JULY
AUGUST
5 10 15
SEPT

Table 2 Ovarian status of females shot in 1969.

Date	Diameter of largest follicle: <3.0mm (uniform)	Diameter of largest follicle: 3.0-5.5mm	Diameter of largest follicle: >5.5mm	Number of birds with recently ovulated follicles
	Number of birds in size class			
April	3	0	0	0
May 1-15	3	1	1	0
May 16-31	2	0	4	0
June 1-15	5	0	0	0
June 16-30	4	0	3	5
July 1-15	0	9	9	3
July 16-31	1	9	10	3
Aug. 1-15	6	5	0	0
Aug. 16-31	6	0	0	0
Sept.	9	0	0	0

Figure 20 : Seasonal changes in proportion of sampled birds with crop glands at designated phases. The sample size is provided at top of column.


N
9
14
21
16
25
31
36
17
17
197
59
N
100%
80%
60%
40%
20%
0
PROPORTION OF BIRDS IN SAMPLE WITH CROP GLANDS AT DESIGNATED PHASES
APRIL
1-15
16-31
MAY
1-15
16-30
JUNE
1-15
16-31
JULY
1-15
15-31
AUGUST
SEPT 1968
SEPT 1969
1968/69
PHASE I
PHASE II
PHASE III
PHASE IV

-35B-

or active phases. By August almost all crops were either fully active or starting into lag phase.

The proportions of birds with crops in different phases in September were significantly different between the 2 years (x^2(2 d.f.) = 7.671, p < 2.5%). Many birds were shot during the hunting season of both years which were still feeding squabs.

Discussion

The follicle of the domestic pigeon requires less than 8 days to develop from a differentiated state of 5.5 mm diameter to the point of ovulation (Bartelmez, 1912). Lofts *et al* (1966) suggested that, in domestic and wood pigeons, follicles larger than 4.0 mm were undergoing swelling just before ovulation. Both these workers used a size category of largest follicular diameter (3 - 5.5 mm and 2 - 4 mm) to designate pigeons which had a differentiated ovary. The follicles in this size range were considered to be in a quiescent stage before terminal development, which is presumably stimulated by mating activity. In *C. fasciata*, ovaries were considered undifferentiated when the largest follicular diameter was beneath 3 mm because in these ovaries no single swelling follicle could be seen (Fig. 17).

Bartelmez's size range was therefore used in the present study.

A number of ovaries were found with collapsed follicles with an external slit (Fig. 18), which indicates ovulation. This is a useful feature to designate pigeons which have just laid before being shot, and has been investigated in the ring-necked pheasant (Phasianus colchicus) by Meyer et al (1947), who demonstrated that the ovulated follicle was discernable for 15 days after ovulation. Of the 11 band-tailed pigeons shot which had ovulated follicles, 6 had inactive crops, 4 had active crops, and 1 was in lag phase. This indicates that in band-tailed pigeons either the ovulated follicle can be detected for at least 19 - 21 days (as incubation takes from 18 - 20 days and the squab feeds on crop milk from the day of hatching; MacGregor and Smith, 1955) or ovulation can take place during the latter period that the squab is being fed.

The breeding season of male birds lasts from April until August but follicular enlargement was not found in females until May 9 and then only in 37% of the females sampled until mid-June. After July most of the sample of females had active ovaries, showing that full breeding had begun, and the last female sampled with a follicle larger than 5.5 mm was shot July 28. The breeding season of band-tailed pigeons is thus much shorter than reported in the United States and is probably attributable to the latitudinal difference. Neff's review (1947) mentions nesting in California from March to September, while MacGregor and Smith (1955) observed nests in southern California from February to October and Glover (1953) reported nests in northern California from April to August.

Despite the short season in British Columbia it is still possible that band-tailed pigeons at this latitude could raise two clutches. MacGregor and Smith (1955) reported an incubation period of 19 days and a fledging time of from 15 to 28 days although about 20 days can be considered an average. As females in British Columbia were sampled which had oviducal eggs and functional milk-producing crops (*i.e.* just finished feeding a squab and immediately about to lay), this whole process may be somewhat telescoped and take a shorter period of time. Thus, females laying in May could easily raise two clutches by the end of the season. The indication of two peaks in ovarian weight and follicular swelling suggests that this may actually occur. Another piece of supporting evidence is the occurrence, in a parallel investigation, of two surges in the serum prolactin levels in the same species.

As incubation takes about 20 days, it could be expected that the maximum activity in pigeon crops would follow major gonadal development by a similar time period. The most intensive crop activity occurs in the first half of August which reflects peak gonadal development in the previous July (Fig. 20). The proportion of active crops remains high until the early part of September. Incubation to fledging requires about 40 days. From a management point of view, this means that hunting during the first part of September will potentially reduce recruitment into the pigeon population. Not all the female population sampled was breeding in May and early June compared with full breeding in July (Table 2). Only 6 of 16 birds showed ovarian activity in the former period whereas 43 of 44 birds were actively breeding in July. The slow development of breeding by most of the population could be due either to late arrival from the northward migration or to a proportion of established females not breeding for reasons which may be connected with their diet. It should be emphasized, however, that all males sampled were undergoing full spermatogenesis from the onset of sampling in April.

No more than one follicle was found swelling in any ovary, bearing out the observations of previous workers (Neff, 1947; MacGregor and Smith, 1955; Smith, 1968) that _C_. _fasciata_ only lays one egg per clutch. It is interesting that the European species of the genus (_C_. _palumbus_, _C_. _livia_ and _C_. _oenas_) lay a normal clutch of two (Lofts _et al_, 1966; Ljunggren, 1969). Finally, it should be emphasized that very few juveniles were taken in either year. This absence is probably a reflection of their lack of participation in reproduction in the first year of life.

4. SERUM AND PITUITARY PROLACTIN CHANGES - In relation to the reproductive cycle

Introduction

Although the crop gland in the band-tailed pigeon is a useful indicator of the individual's reproductive status (Chapter 3), in practice it has proven difficult to distinguish between recrudesence and regression of this structure. As prolactin is known to be associated with crop gland development (Riddle et al, 1932a, b), this prompted an investigation of the production of this hormone in this species. Pituitary prolactin concentrations have been measured by the pigeon crop bioassay in California Quail (*Lophortyx californicus*) (Jones, 1969) and turkey (Cherms et al, 1962) and changes in the level of this hormone were associated with brood patch development and broodiness respectively.

It was thought that measuring any changes in prolactin concentrations would provide a better understanding of the relationship between this hormone and the reproductive cycle of the band-tailed pigeon.

Radioimmunoassays have been used extensively to measure mammalian serum prolactin concentrations (Kwa and Verhofstad, 1967a, b; Kwa et al, 1967; Arai and Lee, 1967; Niswender et al, 1969), using an assay based on the use of antibodies to mammalian prolactin. Evidence exists for cross reactions of such antibodies to prolactin between mammalian species (Hayashida and Li, 1959; Hayashida and Contopolous, 1967; Tashjian et al, 1965), and also with non-mammalian species such as the teleosts (*Fundulus heteroclitus*)(Emmart et al, 1966, 1967); *Carassium auratus* (Emmart, 1969), *Oncorhynchus nerka* (Mckeown and van Overbeeke, 1969), and *Gallus gallus* (Hayashida, 1969). It was therefore expected that this method could also be used to measure serum prolactin concentrations of the band-tailed pigeon.

Methods and Materials

a) Collection and preparation of samples. Adult band-tailed pigeons were shot at two locations in the Fraser River Valley, British Columbia, from May to September, 1969-1970 between 10a.m. and 12 noon. The crop gland was immediately removed and aortic blood collected simultaneously during both sample years. The head of each bird was removed, cleaned of feathers and quick-frozen in dry ice for transport to the laboratory (1970 only).

When removed, crop glands were stretched over a small circle of cardboard and placed in Bouin's fixative. These glands were embedded in paraffin, sectioned at 7 to 10 μ, and stained in periodic acid - Schiff's (PAS). Following extraction by syringe, aortic blood was placed in 10 ml vials in a cooler for transport to the laboratory where it was allowed to clot and then centrifuged. The serum was removed and diluted 1:50 with 0.15 M NaCl using merthiolate as a preservative in a final concentration of 1:10,000. These samples were then stored frozen until assayed. The frozen heads were thawed, pituitary glands dissected out and homogenized separately in a 3 ml. chambered homogenizer containing 1 ml of 0.15 M NaCl. After centrifugation, the supernatant was diluted 1:50 and refrozen.

Individual crop glands were characterised as active or inactive and each bird was placed in a particular reproductive phase as described in Chapter 3. These phases based on follicular diameter (see Table 2) were specified as follows:

1) Non-Breeding - follicles uniform and less that 3.5 mm
2) Quiescent - one follicle greater than 3.5 mm but less than 5.5 mm.
3) Terminal development - one follicle greater than 5.5 mm.

4) Ovulated follicle - those birds whose ovaries contain an ovulated follicle.

Crop activity is absent from phases 1 to 4.

5) Active crop - those birds whose crop gland is actively producing curd (Phase III, Chapter 3).

6) Lag crop - those birds whose crop gland is in lag phase (Phase IV, Chapter 3).

Phases 5 and 6 must have no follicle larger than 5.5 mm.

b) Determination of cross reactivity. Immunological reactivity between pigeon "prolactin" and anti-ovine prolactin was investigated using the haemogglutination test described by Campbell et al (1964). The antigen in each case was a pituitary homogenate containing 2 pigeon pituitaries per ml of 0.15 M NaCl.

c) Radioimmunoassay. Antisera specific to ovine prolactin (NIH-P-S8, 28 IU/mg) were produced by immunization of rabbits as outlined by McKeown and van Overbeeke (1969). The radioiodination procedure was basically that followed by Greenwood and Hunter (1963). Two Ci of $Na^{131}I$ in 0.1 ml of 0.1 N NaOH (New England Nuclear Co.) were used. 5 μg of prolactin (NIH-P-S8, 28 IU/mg) were added to produce the iodinated antigen. After Sephadex-G50 filtration, the iodinated prolactin fraction was diluted with a solution of bovine plasma albumin (0.5 mg/ml) in 0.07 M barbitone buffer (pH 8.6) so that 0.6 ml of the final solution contained 100,000 counts/min. The iodine labelled prolactin was eluted from the column before the free iodide (Fig. 21). However, this first peak was much lower than that found for growth hormone by Greenwood and Hunter (1963) which indicates a lower percentage transfer of radioactive iodine to the prolactin molecule. This may be a reflection of the different amounts of tyrosine in these two hormones.

Before assays were performed, various dilutions of the antiserum and samples were tested to determine the optimum concentrations for the antibody-antigen reations (Fig. 25). The assay procedure followed was the solid-phase method of Catt and Tregear (1967). For this type of assay 12 x 75 mm disposable polystyrene test tubes (Lab-Tek) were coated with 1.0 ml of an antiserum preparation diluted to 1:200 with 0.025 M carbonate-bicarbonate buffer (pH 9.0). Adsorption of the antibody solution to the sides of the polymeric test tubes continued for two hours at room temperature. Unadsorbed antibodies were removed by pouring out the coating solution, and washing the tube three times with 0.15 M NaCl and once with a solution of 5.0% normal rabbit serum

Figure 21 : Separation of Iodinated prolactin from free iodide by Sephadex G-50 filtration. The first peak represents the labelled prolactin and is followed by a second peak of (^{131}I) iodide.

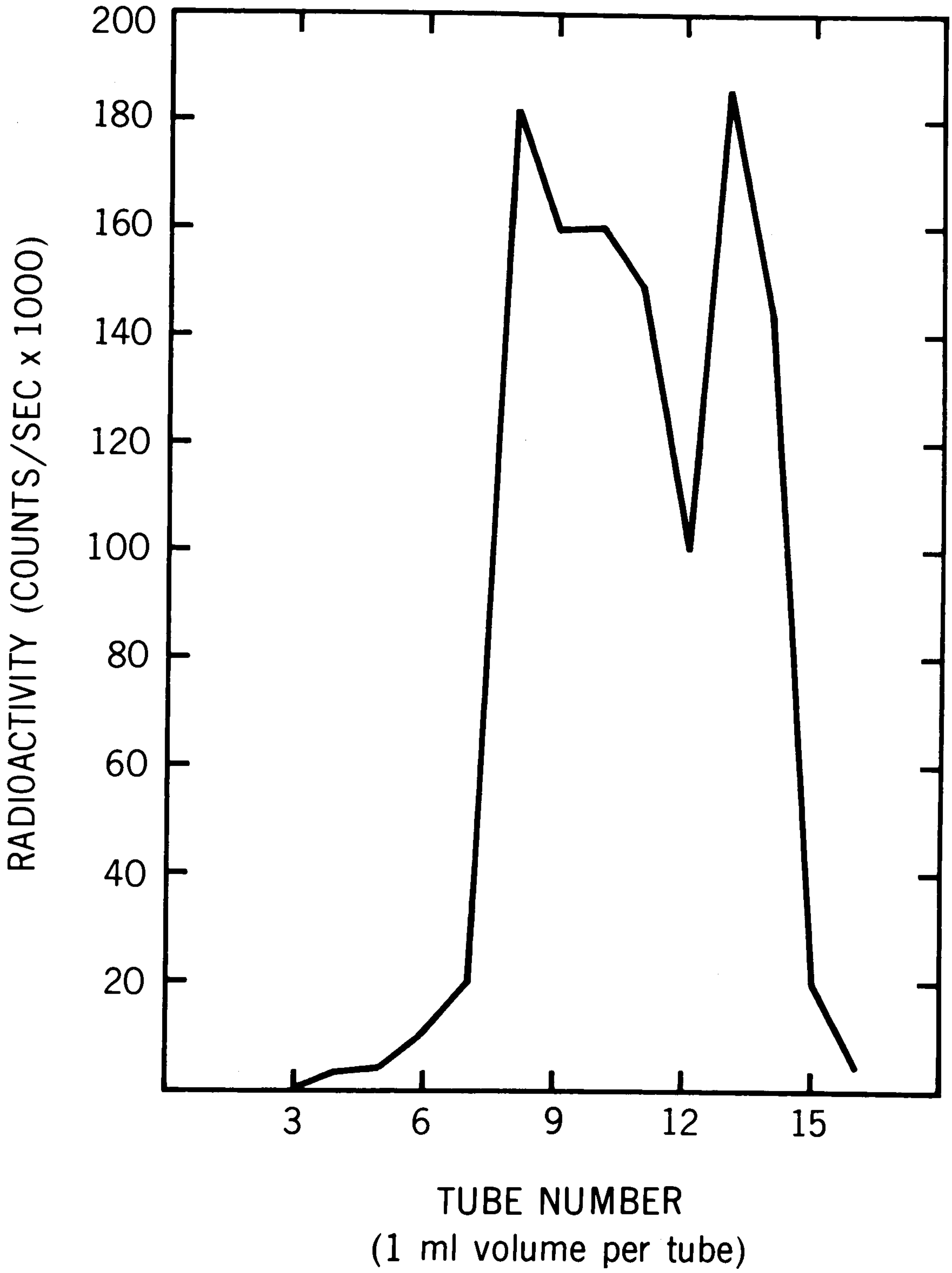
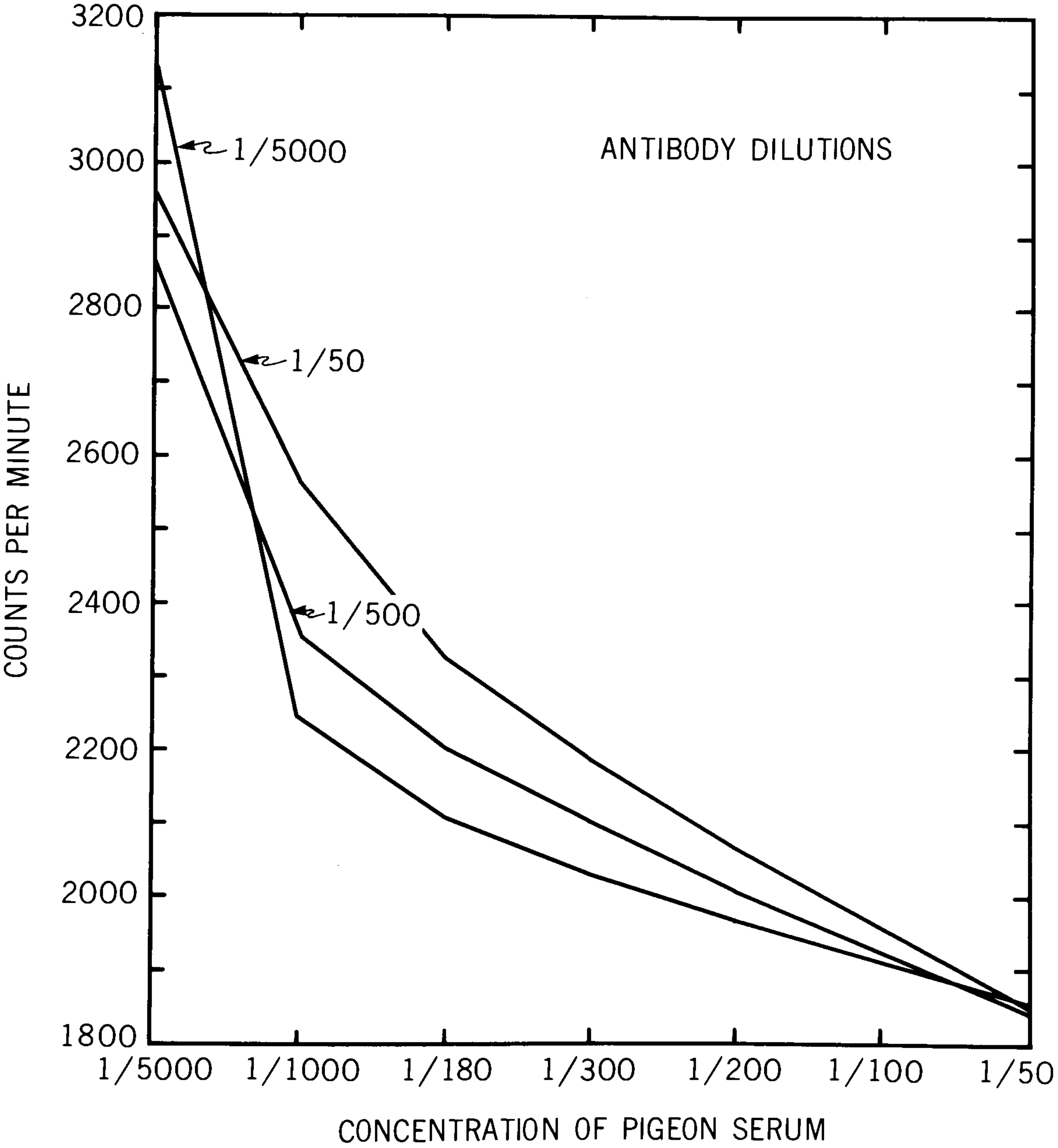

200
180
160
140
120
100
80
60
40
20
RADIOACTIVITY (COUNTS/SEC x 1000)
3
6
9
12
15
TUBE NUMBER
(1 ml volume per tube)

Figure 22 : Standard curve of serial dilution of antiovine prolactin.


3200
3000
2800
2600
2400
2200
2000
1800
COUNTS PER MINUTE
1/5000
1/50
1/500
ANTIBODY DILUTIONS
1/5000
1/1000
1/180
1/300
1/200
1/100
1/50
CONCENTRATION OF PIGEON SERUM

in 0.15 M NaCl and 0.01% merthiolate to block any further sites on the test tube surface. The coated test tubes were used immediately or stored frozen for future assays. For an assay, 0.6 ml of a serum or pituitary sample and 0.6 ml of iodinated prolactin (100,000 counts/min) were added to the coated tubes and the reaction allowed to continue for 16 hours at room temperature. After pouring out the reaction mixture and washing twice with tap water, the tubes were placed in a plastic protective capsule and counted for 1 min in a 3 x 3 inch NaI (Tl) well crystal connected to a single channel analyzer (Hewlett Packard).

d) Evaluation of data. Since purified pigeon prolactin was not available, a standard curve could not be produced and, therefore, the absolute concentration of this hormone could not be determined. Thus, the results indicate relative amounts only. To measure the relative difference between samples, each sample was assayed at 3 different concentrations (1:100, 1:300, 1:500). One sample was chosen as a reference (e.g. x_1, x_2, x_3) and the activity of all other samples (e.g. y_1, y_2, y_3) were expressed as relative percent differences from this arbitrary point (*i.e.* $\frac{x_1 - y_1}{x_1} \times 100$,

$\frac{x_2 - y_2}{x_2} \times 100$, $\frac{x_3 - y_x}{x_3} \times 100$).

The three percentages thus obtained were then averaged ($\bar{X}$). Since the relationship between concentration and activity in radioimmunoassays is exponential, these averaged percentages ($\bar{X}$) were converted into relative hormone concentrations for each serum sample.

For each sample a line was drawn which best fit the three points (*e.g.* y_1, y_2, y_3) representing the measured activities. The slope (m) of each of these lines was calculated and the average percentage ($\bar{X}$) divided by this slope was considered the hormone concentration, expressed as a percentage of the reference sample. The reference sample, which was chosen arbitrarily, was given a value of zero. Samples below this zero were expressed as a negative percentage and those above expressed as a positive percentage.

Results

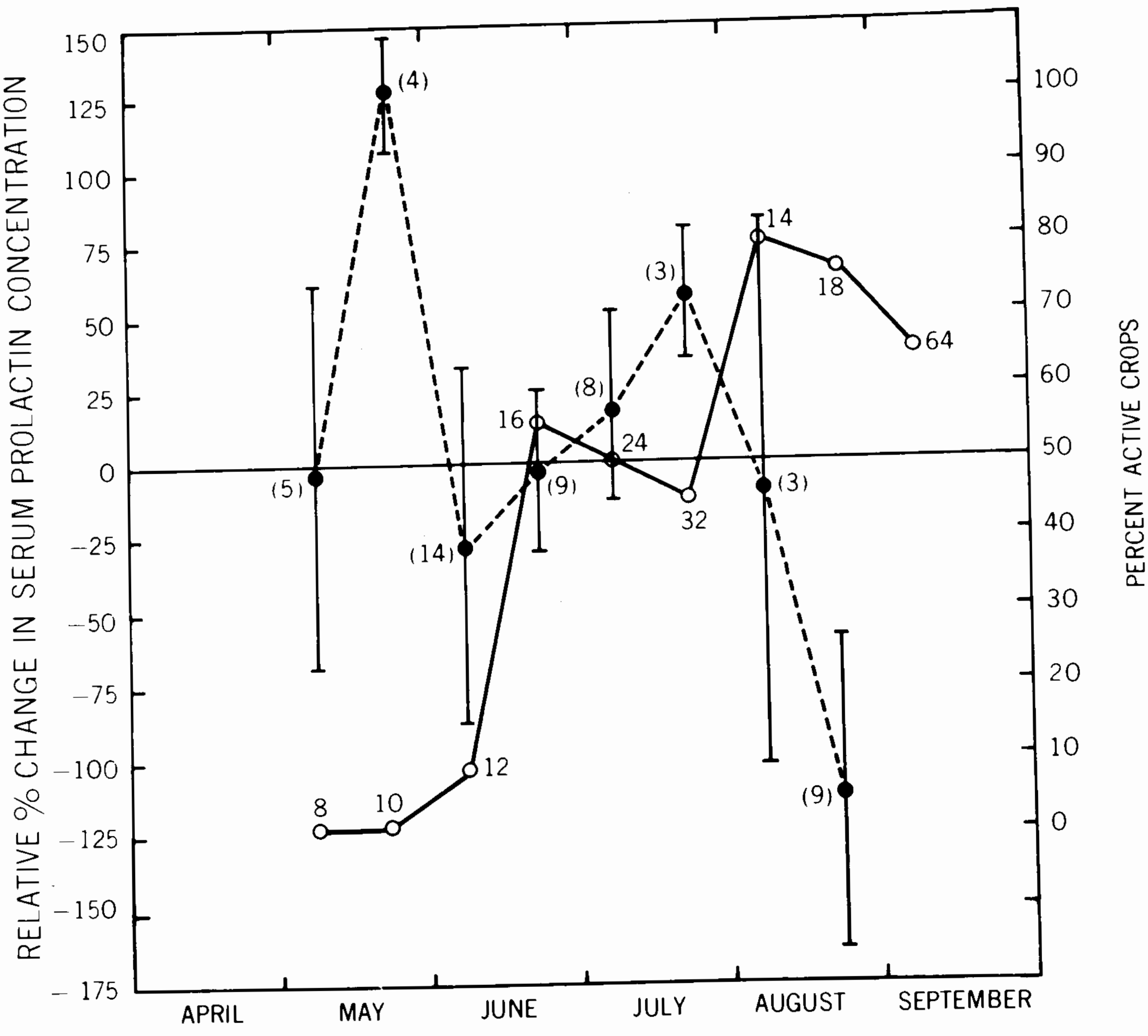
a) *Crop Gland*. The percentage of active crop glands per sample of birds collected during 1969 was used as the index of activity. Analysis of these crops indicates that the number of birds with actively producing crops increased from the early part of June and reached a maximum during the first part of August. The last sample collected in the first half of September was noticeably less active (Fig. 23).

b) Cross-reaction tests. A positive cross-reaction between pigeon "prolactin" and anti-ovine prolactin was demonstrated by the settling pattern of the erythrocytes.

c) Immunoassay. The initial determination of this assay during 1969 was performed on the serum of each individual bird and the results were pooled to give a half-monthly average (Fig. 23). The changes in the concentration of serum prolactin indicates a significant increase in May and a considerable decrease during the month of August. The assay also demonstrated a noticeable fluctuation in the concentration of this hormone throughout the summer months.

The radioimmunoassay performed during 1970 demonstrated a significant decrease in serum prolactin concentration (Fig. 24) at the first stage of potential breeding (Quiescent phase). There is then a subsequent increase during the terminal development of the follicle which is maintained through

Figure 23 : Each open circle represents the percentage of birds sampled exhibiting an active crop. The total period is divided into half-monthly intervals. The number beside each circle indicates sample size. Relative ½ monthly changes in serum prolactin concentration are represented by the dotted line. Each solid circle represents the mean of the sample size provided in parenthesis. Use of the positive-negative scale demonstrates a greater or less than concentration relative to an arbitrarily chosen zero point. Each bar indicates one standard error.



RELATIVE % CHANGE IN SERUM PROLACTIN CONCENTRATION
PERCENT ACTIVE CROPS
150
125
100
75
50
25
0
−25
−50
−75
−100
−125
−150
−175
100
90
80
70
60
50
40
30
20
10
0
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
(4)
(5)
(14)
(9)
(8)
(3)
(3)
(9)
8
10
12
16
24
32
14
18
64

ovulation. Following this there is then a significant decrease during crop gland activity and regression.

The assay of pituitary prolactin concentrations (Fig. 25) appear to follow inversely those changes noted in the serum with the exception of the terminal development stage. During this period there is a significant increase in the concentration of the hormone. The non-breeding phase is omitted due to lack of samples in this phase. All changes noted above are statistically significant ($p < 0.05$).

Discussion

The assay procedure used in this study involved a heterologous cross reaction involving anti-ovine prolactin with pigeon prolactin. This cross reaction is demonstrated by the positive heamogglutination test and the standard curve (Fig. 22). This technique for measuring low concentrations of serum hormone provided a means of evaluating changes in prolactin concentrations in the band-tailed pigeon. Meier and Davis (1967) have demonstrated a diurnal period of sensitivity in many vertebrates during which a response to fat inducing hormones may occur. These and other workers (Clark and Baker, 1964) suggest the possibility of a daily cycle in certain hormones, one of which is

Figure 24 : Relative percent change in the concentration of serum prolactin related to the reproductive cycle. Closed circles indicate individual determinations and a closed square represents the average. The standard error is indicated by a bar.

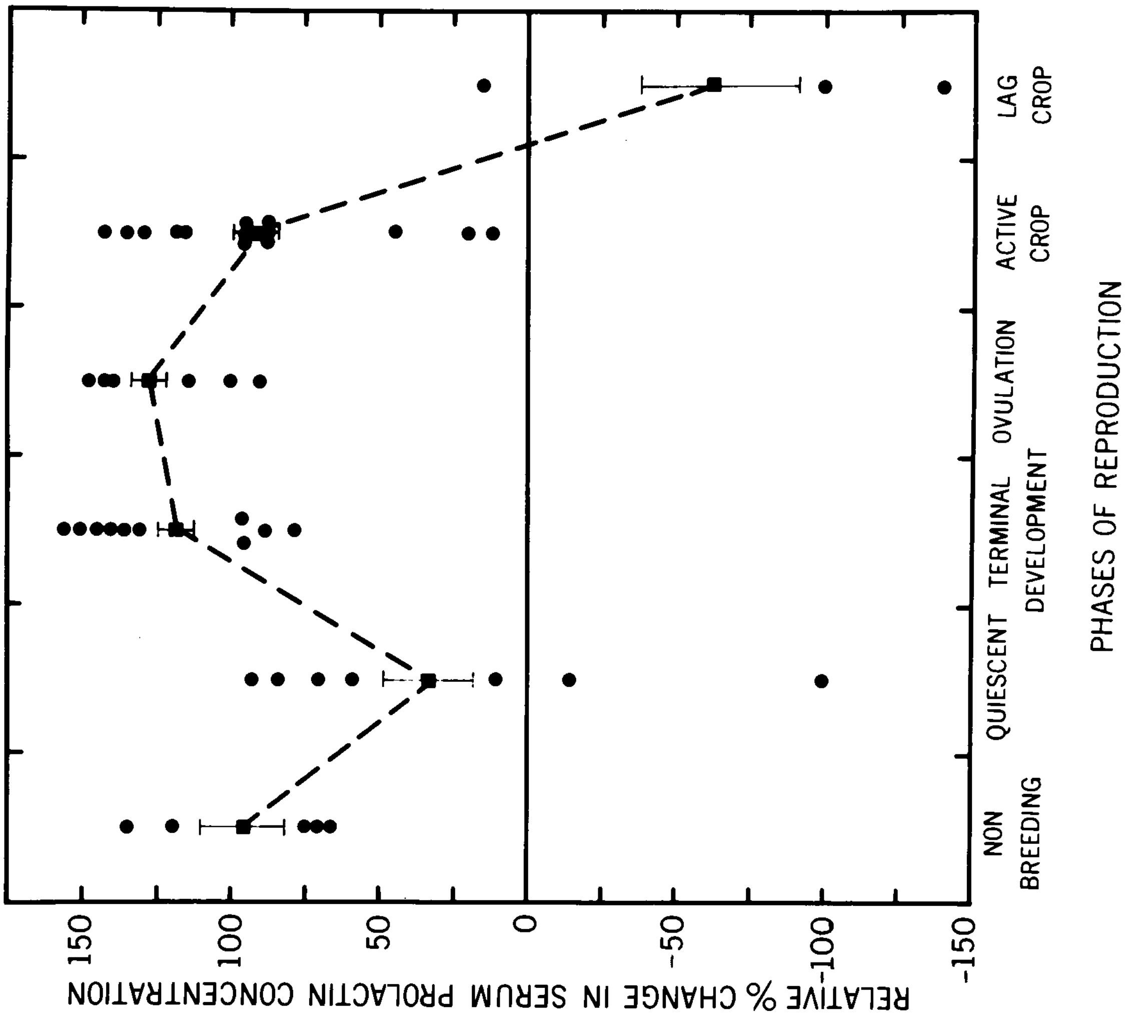
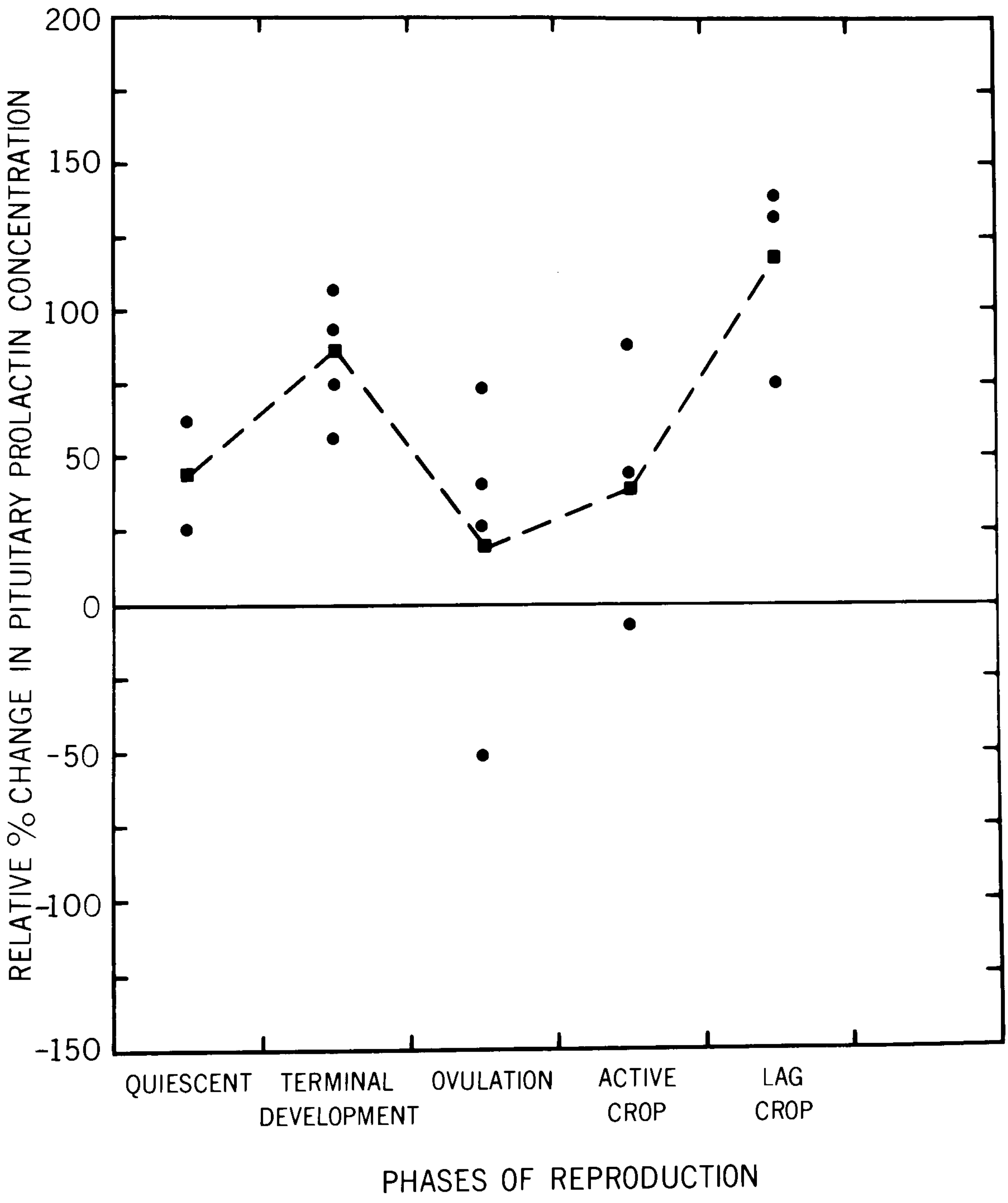

RELATIVE % CHANGE IN SERUM PROLACTIN CONCENTRATION
150
100
50
0
-50
-100
-150
NON BREEDING
QUIESCENT
TERMINAL DEVELOPMENT
OVULATION
ACTIVE CROP
LAG CROP
PHASES OF REPRODUCTION

Figure 25 : Relative percent change in pigeon pituitary prolactin, concentration related to the reproductive cycle. Note - non-breeding stage omitted. Closed circles indicate individual determinations and a closed square represents the average.


200
150
100
50
0
-50
-100
-150
RELATIVE % CHANGE IN PITUITARY PROLACTIN CONCENTRATION
QUIESCENT
TERMINAL DEVELOPMENT
OVULATION
ACTIVE CROP
LAG CROP
PHASES OF REPRODUCTION

prolactin. To avoid this problem the sampling time was restricted.

The work done by Riddle et al (1932a, b, 1933) suggests that crop gland activation would be preceded by an increase in serum prolactin concentration. This investigation during 1969 indicated that the maximum level in serum concentration of this hormone is at least 20 - 25 days previous to maximum percent crop gland activity (Fig. 23) and corresponds to the period of terminal development and ovulation (Fig. 24). This study indicates pituitary prolactin to be at a lowered level during early incubation and increasing through the period of crop gland activity. Jones (1969) has demonstrated an increase in this pituitary hormone during the brooding stage in the California quail which corresponds to the active crop gland phase of the band-tailed pigeon (Fig. 25). The small sample of pituitaries obtained in this work prevents any definitive discussion of these changes. Comparisons of the values for the first sample (April - May) and the last sample (late August - September) suggests that the concentration of serum prolactin, when first sampled, already represented an elevated state.

The period of most intensive crop activity is during August and yet at this time there is a rapid decline in the concentration of serum prolactin. This evidence, combined with the reduction of this hormone following ovulation strongly suggests that prolactin is not necessary for the maintenance of the active crop gland.

5. MINERAL REQUIREMENTS - Seasonal Changes in body weights and calcium balance.

Introduction

The band-tailed pigeon (Columba fasciata) is a migratory game bird whose northernmost range is in southwestern British Columbia. A three year study of this species has considered seasonal changes in body weight, blood constituents and calcium balance. The physiological parameters will be related to the utilization of food sources and mineral gravelling sites.

Many avian species have higher body weight in winter and early spring than at other times of the year. Baldwin and Kendeigh (1938) found a 12% loss of weight by June or July in a large number of species. Seasonal variation in fat deposits have been used as an indicator of prenuptual migration in small passerines (McGreal and Farner, 1956; King and Farner, 1956) and the amount of these deposits was related to gonadal activity (Wolfson, 1945; Marshall, 1961). Both Murton (1965) and Ljunggren (1968) have described decrease in body weights prior to reproduction in other Columba species which they suggest is caused by variation in food supply and reproductive activity.

There has been little work on seasonal alteration in avian blood parameters of wild species, although a number of investigations have been reported on calcium change in tame pigeons (Riddle and Reinhart, 1926; McDonald and Riddle, 1945; Sendroy et al, 1961).

Serum calcium in pigeons has been demonstrated to rise sharply during ovulation (Riddle and Reinhart, 1926; Sendroy et al, 1961). Hurwitz (1964) showed, by use of radioisotopes, that approximately twelve days previous to laying, extra stores of calcium are retained in the medullary bone areas of the skeleton. This form of bone is then retained at the expense of structural bone (Simkiss, 1967). Bloom et al (1942) have shown histologically that approximately ten days after laying, the bone in medullary area of the femur has almost completely disappeared.

Evidence presented in Chapter 3 indicated that band-tailed pigeons laid two clutches in each breeding season and noted intensive crop gland development to produce curd for feeding the nestlings. As that study progressed, it was found that the calcium content of the curd was considerably higher than that of the blood serum, suggesting an additional drain on the calcium reserves. Other investigators have shown a similar high calcium content in the milk of lactating mammals (Simkiss, 1967). In wild bird populations the mineral requirements must be obtained from either the food, the water, or from specific gravelling areas. Pheasants have been observed to select calcium-bearing grit such as limestone over granite which is non-calcareous. McCann (1939), Sadler (1961) and Funk (1932) had previously shown that domestic chickens have a similar ability. The band-tailed pigeon is known to frequent mineral spring areas in very large numbers (Smith, 1968; Chapter 2). This study was initiated to investigate the importance of such mineral sources to the reproductive physiology of this species with particular emphasis on changes in serum and femur calcium.

Methods and Materials

Shot samples of band-tailed pigeons were collected near railway yards and at mineral-gravelling sites as previously described (Chapter 3) in the Fraser River Valley of British Columbia from April to September 1968 - 1970. Crop contents were removed and each bird was weighed on a spring balance. In 1970 aortic blood was immediately collected by syringe, allowed to clot and transported on ice to the laboratory for centrifugation. The serum was diluted

1:20 with physiological saline and analysed flourometrically for serum calcium (Hill, 1965; DeWitt and Parsons, 1970a and b). A femur was removed from each bird collected during 1970 and placed in a 100°C oven for 24 hours prior to dry weighing. The bone was then ashed at 600°C for 96 hours. The ash was dissolved in 3 ml of 3 M HCL and diluted to 1:20 with 0.1 N HCL and then analysed for calcium by the flourometric method.

Results

The changes in average body weight are shown for 1969-1970 combined (Fig. 26). The body weight of females drops significantly between the second-half of April and the beginning of May ($p < 0.01$). The female undergoes a significant weight increase from mid-July until the final September sample ($p < 0.01$). The males maintained body weight through May and although the average weight decreased in early June, the decrease between the mean was not significant until the last half of June ($p < 0.05$). From mid-August onward the increase in weight was highly significant ($p < 0.01$).

The sex ratio of the shot sample is shown in Table 3. Chi-squared tests showed that during May and June the sex

Figure 26 : Seasonal fluctuations in body weights of band-tailed pigeons. Open circles represent the average bi-monthly body weight of male birds. Closed circles indicate the average bi-monthly body weight of females. Sample size of each circle is given at the top of the figure.

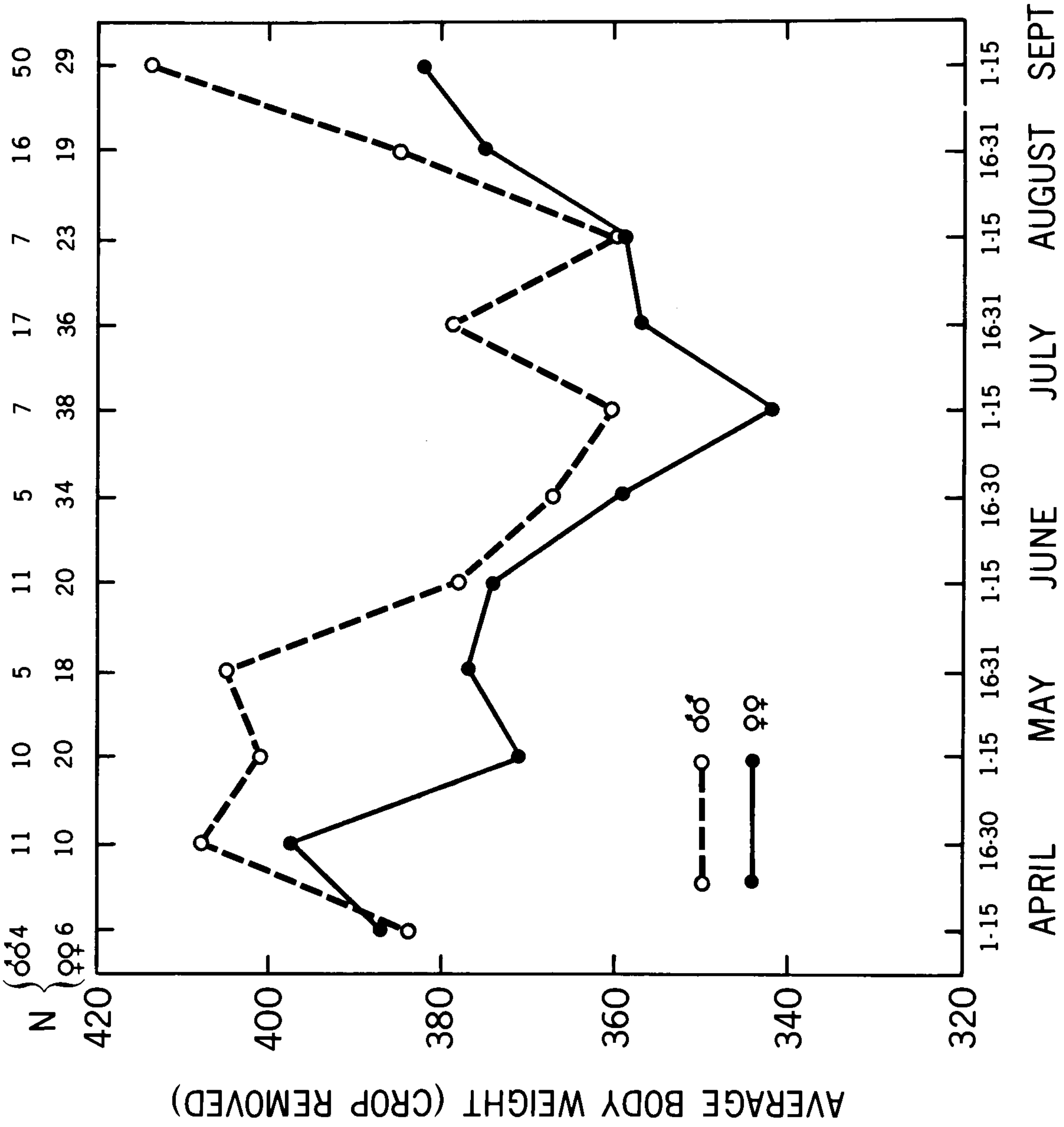

AVERAGE BODY WEIGHT (CROP REMOVED)
420
400
380
360
340
320
N
♂♂ 4 11 10 5 11 5 7 17 7 16 50
♀♀ 6 10 20 18 20 34 38 36 23 19 29
1-15 16-30 1-15 16-31 1-15 16-30 1-15 16-31 1-15 16-31 1-15
APRIL MAY JUNE JULY AUGUST SEPT
♂♂
♀♀

Table 3 Seasonal variation in sex ratios of sample birds.

	Non Mineral Spring Area		Mineral Spring Area		
Month	Sex Ratio ♂♂/♀♀	N	Sex Ratio ♂♂/♀♀	N	χ^2
April	1.0/7.5	21	1.0/1.0	4	0.06 (NS)
May	1.0/1.4	36	1.0/5.8	41	5.76*
June	1.0/1.3	27	1.0/4.4	43	4.21*
July			1.0/3.3	115	
August			1.0/2.0	88	
September			1.0/0.6	164	

ratio of samples collected at mineral spring areas was significantly different from those obtained from non-mineral spring sites, there being a predominance of females in the former (May - $p < 0.05$, June - $p < 0.05$). There is a steady increase in the proportion of males in the sample collected at mineral spring areas from May to September.

The concentration of calcium in the serum and femur during the different phases of reproduction is shown in Figs. 27 and 28. The largest follicle of non-breeding birds measured less than 3.0 mm in diameter, of quiescent birds, between 3.0 and 5.5 mm and of terminal birds it was greater than 5.5 mm. The allocation of these size categories and crop gland phases is described on Page 36. Serum calcium levels are significantly higher immediately following ovulation than at any other time ($p < 0.05$ cf. terminal development; $p < 0.02$ cf. active crop). It continues to decline as crops regress (active crop cf. lag crop $p < 0.01$). The serum calcium level was significantly higher in males with active crops compared to those with inactive crops ($p < 0.01$). Female femur calcium concentrations showed an inverse pattern. The levels were significantly lower ($p < 0.01$) after ovulation compared with females with enlarged follicles. Levels then increased so that females with lag crops had a signi-

Figure 27 : Seasonal change of serum calcium during 1970. Males with active crops are compared to those having crops showing no activity. The mean is represented by a bar.

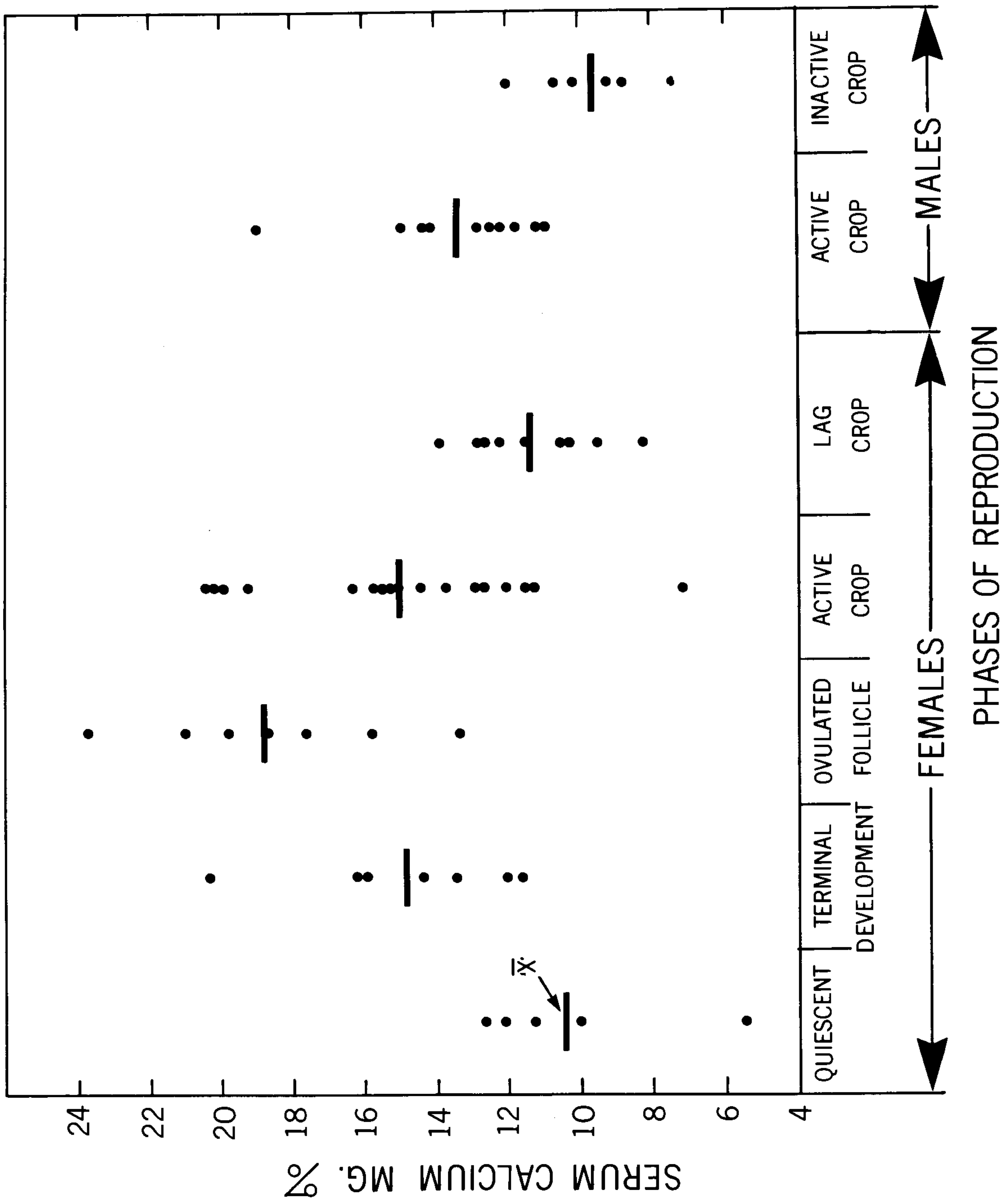
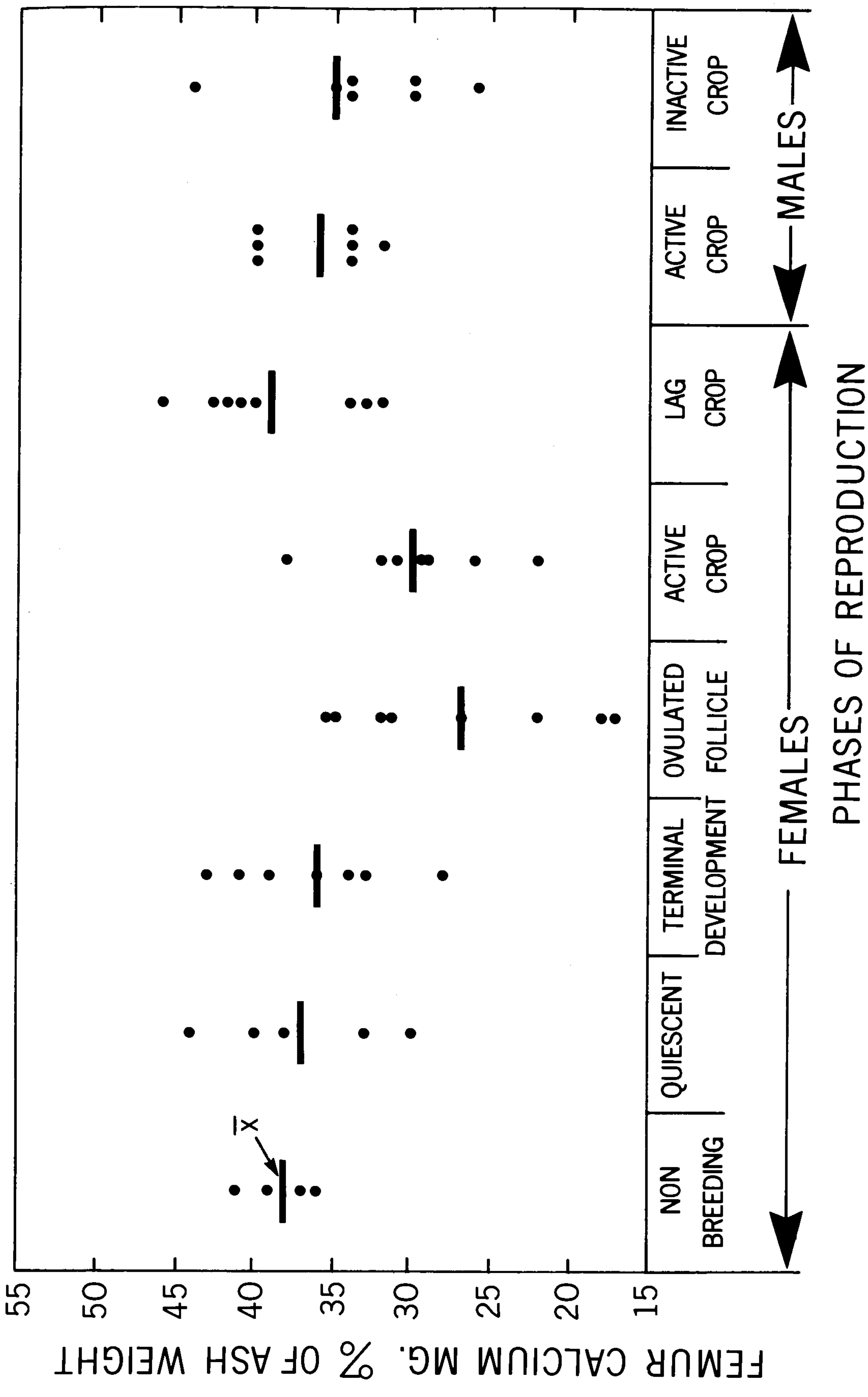

SERUM CALCIUM MG. %
24
22
20
18
16
14
12
10
8
6
4
x̄
QUIESCENT
TERMINAL DEVELOPMENT
OVULATED FOLLICLE
ACTIVE CROP
LAG CROP
ACTIVE CROP
INACTIVE CROP
FEMALES
MALES
PHASES OF REPRODUCTION

Figure 28 : Seasonal change of femur calcium during 1970. Males with active crops are compared to those having crops showing no activity. The mean is represented by a bar.


FEMUR CALCIUM MG. % OF ASH WEIGHT
55
50
45
40
35
30
25
20
15
X̄
NON BREEDING
QUIESCENT
TERMINAL DEVELOPMENT
OVULATED FOLLICLE
ACTIVE CROP
LAG CROP
ACTIVE CROP
INACTIVE CROP
FEMALES
MALES
PHASES OF REPRODUCTION

ficantly higher concentration of femur calcium ($p < 0.01$). No significant difference was found in males.

Discussion

The seasonal changes in body weight of band-tailed pigeons in British Columbia follows closely those reported for the same species in northern California (Drewien *et al*, 1966). Both sexes exhibit a post migratory increase in weight (Fig. 26) similar to those described for the wood-pigeon (*Columba palumbus*) in Sweden (Ljunggren, 1969). There is a continual decline in body weight until early August at which time a pre-migratory increase begins. Wolfson (1954) describes a weight loss of 22 to 25 percent in captured migratory White-Throated Sparrows (*Zonotrichia albicollis*). The maximum decline for the band-tailed pigeon is approximately 17% for males and 13% for females. Although annual weight fluctuations have been described for this wild pigeon and other migratory species, Hanson and Kossack (1957) found no such changes in the mourning doves (*Zenaidura macroura*). This migrant showed no annual fluctuation and little or no premigratory fat.

Baldwin and Kendeigh (1938) attribute annual weight fluctuation to a number of factors but emphasize the importance of temperature tolerance and changing feeding habits. Other workers have stressed the role of the endocrine system (Riddle, 1947; Wolfson, 1945, 1954; Breitenbach et al, 1961; Meier and Davis, 1967). Ljunggren (1969) attributes the post-migratory loss in the Swedish woodpigeon to a decrease in food quality and not quantity. This is unlikely in the band-tailed pigeon. A detailed study of crop contents (Chapter 2) showed that this species feeds on grain (4.92 kcals/gm ash free dry weight) until June and then switches to feeding on elderberry (Sambucus racemosa, 6.75 kcals/gm) and cascara (Rhamnus purshiana, 6.23 kcals/gm), both relatively high energy value foods. Thus, the decline in body weight in this species takes place when calorific value of the food is improving. In species where both sexes feed the young, the amount of time available for self-feeding is substantially decreased, while the young are in the nest. It appears in band-tailed pigeons that such reproductive behavior may influence annual body weight changes (Fig. 26). It would be expected that if food availability was the major factor involved, then both sexes would exhibit weight losses at the same time. This is not the case, as male pigeons maintain their body weights for approximately 30 days following the initial decline in the females. Further, both sexes are on a predominantly grain diet until mid-June (Chapter 2). The first decline in female body weights occurred during the same period over 3 years, simultaneous to a third of the female population being reproductively active. The second decline coincided with the period when breeding was most intense during late June, July and early August. There is no indication of diminishing food availability and the food is, as previously stated, of relatively high caloric value.

The maintenance of body weight in the male can be explained by their lack of participation in mineral-gravelling activity. On the basis of crop development (Chapter 3), feeding of the young does not occur until the last part of May and early June. It is during this period that the male must prepare for calcium loss through crop gland activity by frequenting mineral-gravelling sites. This is substantiated by the predominantly female samples obtained early in the breeding season and the increasing proportion of males as the summer progresses (Table 3). Previous workers have shown that increased amounts of calcium have depressed feed intake and caused a marked retardation in body weight gain (Hurwitz _et al_, 1969). It is therefore suggested that the weight loss during the post-migratory period is a combination of the increased reproductive activity of both sexes and the behavioral pattern of mineral spring utilization. The major changes of body weights in both sexes during late August and September is partially attributed to the decrease in time consuming parental activity.

Serum calcium also shows considerable fluctuation over the reproductive cycle. These changes were first described by Riddle and Reinhart (1926) for the domestic pigeon. In the band-tailed pigeon there is an initial increase in serum calcium during terminal development of the follicle (Fig. 27). The concentration of serum calcium peaks during ovulation and then decreases gradually as crop gland activity declines. The serum calcium is at an elevated level during crop gland activity for both sexes. Similar fluctuations were described for tame pigeons by Sendroy et al (1961) although the increase for the period of intense crop activity was noticeably higher in the present study (Fig. 27).

The change in femur calcium present in the female (Fig. 28) is inverse to that found in the serum, indicating calcium movement from the bone to the reproductive tract. The femur was used as an indicator of calcium fluctuation because it has been shown to contain a high percentage of medullary bone in female birds prior to ovulation (Keyes and Potter, 1934; Taylor and Moore, 1954). Femur calcium concentration in the band-tailed pigeon shows little change until ovulation at which time it decreases (Fig. 28). This lower level is maintained until the female completes the period of crop gland production. Structural bone changes are not found in male birds (Keyes and Potter, 1934) and in the present study no differences in femur calcium were found when comparing males with active or inactive crops (Fig. 28). Although the female shows a lowered level of calcium at the active crop stage, this is probably due to the follicular calcium loss and not that contained in the crop secretion. The amount of milk-curd produced per day by an actively feeding adult is 5% of its total weight (Bates, personal communication). The amount of calcium found in crop milk is .5 mg per gram of curd. This is well within the calcium content of the milk of many lactating mammals (Simkiss, 1967) and would mean that the pigeon must obtain approximately 10. mg of calcium per day to remain in equilibrium during feeding of the young.

Evidence indicates that, although there is no decrease in femur calcium in the male, the serum calcium is at an increased level during crop gland production (Fig. 24). This is difficult to explain since it suggests the blood acts as a storage area during crop gland activity. Previous workers have dealt exclusively with calcium changes in female cycles or males treated with sex hormones (Bloom et al, 1941; Bloom et al, 1942; Riddle et al, 1944; Taylor and Moore, 1954; Taylor and Hertelendy, 1961). Keyes and Potter (1934) investigated the ossification of the femur in male pigeons but did not indicate whether or not they were breeding birds. Further, histological work during the male parental period would clarify this problem. The increased acitivity of the male pigeon to acquire extra calcium is demonstrated by the increasing number appearing at mineral-gravelling sites (Table 3). This sexual difference is altered to the point of male predominance during the sample period of September.

6. GENERAL DISCUSSION

The band-tailed pigeon has been shown to undergo active breeding in the northern section of its range in southern British Columbia. A majority of sampled birds are in a potentially reproductive condition on arrival from the south in April, based on the condition of reproductive tracts and crop gland activity. However, nothing is known of the recruitment of young into the population in British Columbia. The number of juveniles that migrate south in the autumn and return to breed in the spring is undetermined. The problem of distinguishing those breeding for the first time from the parental stock causes difficulty in assessing changes in reproductive age classes. As there is a total lack of census information it is not possible, therefore, to discuss the population dynamics of this species.

Although there has been no estimation of population numbers, there appears to be an ideal census system available. The time required to execute a program of tagging and banding birds at mineral sites (Appendix B) prevented adequate investigation of diurnal habits or home range. However, it demonstrated the feasibility of using such areas for gathering census information. Four weeks of cannon netting at the Hatzic mineral spring showed that birds were not frightened away by this method of capture. As many as 3 netting shots were fired in a single day and in a few instances birds were recaptured on the initial day of their tagging. The major problem would be the development of a tagging system whereby individual birds could be identified. When this has been accomplished, an accurate evaluation of population numbers utilizing the Hatzic mineral spring would be possible. If such numbers were known, data produced in the present study (breeding rates, sex ratios at springs, etc.) could be used to estimate recruitment. The census information gathered at a particular mineral spring may then be applied to similar mineral areas throughout the total range of this species. This study has emphasized the need for such a program and it should be initiated as soon as possible as the availability, to the band-tailed pigeon, of many mineral areas appears to be in jeopardy.

The heavy use of mineral-gravelling areas by band-tailed pigeons suggests that the major common ion in all cases was calcium. The combined physiological and ecological evidence suggests that the band-tailed pigeons must use the mineral sites to maintain sufficient calcium balance for breeding to occur. The mineral-gravelling areas, therefore, constitute an essential resource for this species.

Despite the heavy usage of these areas, there are no policies by wildlife conservation agencies to ensure their continued availability. The mineral spring at Hatzic is located in a cultivated field on an active farm. This mineral spring could, at any time, be ploughed over or drained, as it potentially constitutes a hazard for both the farmer and his cattle. The mineral-gravelling area at Pigeon Cove is in an even more precarious position of becoming useless as a calcium source for band-tailed pigeons. Land developers have acquired a substantial portion of the waterfront property around the bay area and plans presently under consideration by the Port Moody City Council involve restructuring this area for economic purposes. A major portion of these plans entail the building of a causeway which would control the water level with the result of permanently covering the mud flat area and destroying it as a mineral-gravelling site. Unfortunately, the shoreline coniferous growth, as well as the mud flat area, is of critical importance to the band-tailed pigeon. Thus, there is an immediate need for conservation of both the Hatzic and Pigeon Cove area by Federal and Provincial Wildlife agencies if these populations are to be maintained.

Further management problems may arise from this species' dependence on mans' cultivation and grain spillage as an important food resource during the spring. Prior to June, only 1/3 of females sampled are in an active breeding state. Crop examination of these females indicated that only a small proportion of their diet was natural foods with grain being eaten almost exclusively. If grain spillage in railway yards ceases, as may possibly occur in connection with a rodent control program, the band-tailed pigeons would be hard pressed to find alternate food items. It is possible that the initial clutch of this species depends on this relatively artificial food source and breeding may be postponed if such food becomes unavailable.

On the basis of the knowledge gathered from this investigation, the following recommendations can be made with regard to the function of the band-tailed pigeon as a game species:

a) That endangered mineral spring or mineral-gravelling areas be purchased by Federal or Provincial Wildlife agencies for the purpose of establishing reserves;

b) That a feasibility study be conducted to determine if band-tailed pigeons would utilize artificial mineral sites in the absence of natural sites;

c) That an intensive tagging program be initiated as a basis for census to provide information on the population dynamics of this wild pigeon;

d) That the hunting season in British Columbia be delayed for approximately 10 days as information on crop gland development indicates that a large percentage of birds shot during the early portion of the hunting season are still actively feeding young;

e) That a similar study of the biology of this species be initiated to include Vancouver Island and its northern range in British Columbia.

As well as resulting in recommendations for the management of this species, this study has disclosed a number of avenues from which future research may proceed. Such answers to the question of the definitive role of these mineral springs in terms of calcium can only be found by experimentation with penned birds. Manipulation of the calcium concentration of their drinking water and maintenance of adequate controls would provide a basis for determining this ion's influence on such physiological process as clutch size and crop gland activity. Further investigation should be made of the effect of crop gland secretion on the calcium balance in the male. There is no information available on the presence of medullary bone in male pigeons. Further, it is not fully understood how the crop gland remains active when the level of prolactin is relatively low. Prolactin has also been shown to inhibit spermatogenesis in many avian species either indirectly (Bates <u>et al</u>, 1937) or directly (Lofts and Marshall, 1956) and yet there was no indication of this occurring at any time in the male band-tailed pigeon. A final comment on the avenues of new research pertains to the hormone, calcitonin. Samples of pigeon serum analyzed in Dr. Copp's laboratory at The University of British Columbia indicated levels of calcitonin (10 mu/cc) are considerably higher than that found in humans (60-100 mu/liter; Sturtridge <u>et al</u>, 1969). The high concentration of this hormone in the serum of the band-tailed pigeon should certainly be investigated.

SUMMARY

1. The band-tailed pigeon arrives in its northern breeding range in southern British Columbia in mid-April and migrates south during late August - September. This species ranges inland approximately 150 miles and is found west of the coastal mountain range, south of 52°N. This area includes Vancouver Island as well as the gulf islands but not the Queen Charlotte group.
2. Crop examination indicated the use of 7 different varieties of food items. Grain from rural railway yards and freshly cultivated fields is used extensively prior to mid-June and included in this sample period is a small proportion of hemlock pollen. There is then a sudden shift to red elderberry, cascara, and black mountain huckleberry as the season progressed. More variety was noted during the late August - September sample as the birds also used dogwood and choke cherries.
3. During the breeding season, the pigeons frequent high calcium mineral-gravelling sites. These are specific areas and may occur inland (i.e. Hatzic mineral spring) or on the coastline (i.e. Pigeon Cove gravelling site). The mineral-gravelling activity at Pigeon Cove involves the swallowing of small pebbles coated with salt deposits

from the receding tide. The birds fly down on to the mud flats, pick up bits of gravel and return to the shoreline coniferous growth. This movement for a single bird takes approximately 2 minutes and may be performed 4 or 5 times. The pigeons at the Hatzic mineral spring make a similar rapid movement to drink from the muddy water surrounding the actual seep.

4. An analysis of mineral spring waters used by pigeons indicates a high concentration of calcium, sodium and chloride ions. Observations of pigeon utilization of calcium chloride sprayed on a gravel road in the Hope area suggest calcium to be the required mineral. The pigeons do not frequent this area at any other time. Further evidence of the importance of these mineral-gravelling areas to breeding was provided by the absence of band-tailed pigeons from mineral sites until the 2nd week of May.

5. Because of difficulty in obtaining nest site information, reproductive activity was based on physiological parameters. Examination of reproductive tracts indicated band-tailed pigeons ovulate from April through July but not all females do so early in the breeding season. Males are in breeding condition in April and

remain so until late July. Evidence suggests the production of two clutches (one egg each) during the breeding season and that females may ovulate while actively feeding young. Ovaries were classified into 4 separate stages of development, as follows:

a) Non-breeding

b) Quiescent

c) Terminal

d) Ovulation

6. Crop glands were histologically examined and placed into 4 distinct phases of activity, as follows:

a) Non-active

b) Early active

c) Active

d) Lag

These categories were combined with the stages of ovarian development to categorize the total reproductive cycle into 7 different phases. These phases were then used to describe serum and pituitary prolactin and serum and femur calcium changes during the reproductive cycle.

7. Serum prolactin concentration was shown to be at a maximum level approximately 20 - 25 days previous to

the period of maximum percent crop gland activity in the population. This corresponds to the time of maximum ovarian development. There was a rapid decline in concentration of this hormone during crop gland activity indicating that it is not necessary for crop gland maintenance.

8. Pituitary prolactin concentration varied inversely to the changes found in serum prolactin except for the period of terminal development.

9. Femur calcium decreased rapidly during terminal development. This lowered level was maintained through the period of crop gland activity and increased during crop gland lag phase.

10. Serum calcium reached a peak during ovulation and then declined gradually as crop gland activity decreased.

11. Serum calcium in the male pigeon is at an increased level during the period of crop gland activity although there is no indication of femur calcium change. It is suggested that breeding weight loss occurs due to increased reproductive activity and the behavioral pattern of mineral spring utilization.

12. Observational and experimantal data gathered at mineral-

gravelling sites demonstrates their usefulness as a basis for a banding and tagging program pertaining to population dynamics.

13. On the basis of the study, several management recommendations have been made including a short discussion of views on new avenues of research pertaining to this work.

APPENDIX A - Diurnal activity at mineral areas and their potential for censusing band-tailed pigeons.

During the collecting of band-tailed pigeons for this study, it became apparent that there was a diurnal pattern of activity of the birds at mineral-gravelling sites. Actual counts of birds present in the area were made on two days (early and late summer) at sites 1 and 2. The average counts per hour are shown in Figure A-1. Although not quantified, repeated visits to these areas to collect samples indicated that these patterns were extremely constant.

During 1969, cannon-netting was attempted on several occasions at the Hatzic spring and proved moderately successful. One-hundred birds were back tagged with colored plastic markers and 90 of these were also leg-banded (Fig. A-2). Very low recoveries of marked birds precluded an assessment of this technique.

Figure A-1 : Diurnal activity of band-tailed pigeons at mineral-gravelling sites (Pigeon Cove is the left hand column, Hatzic Spring is on the right in each pair).

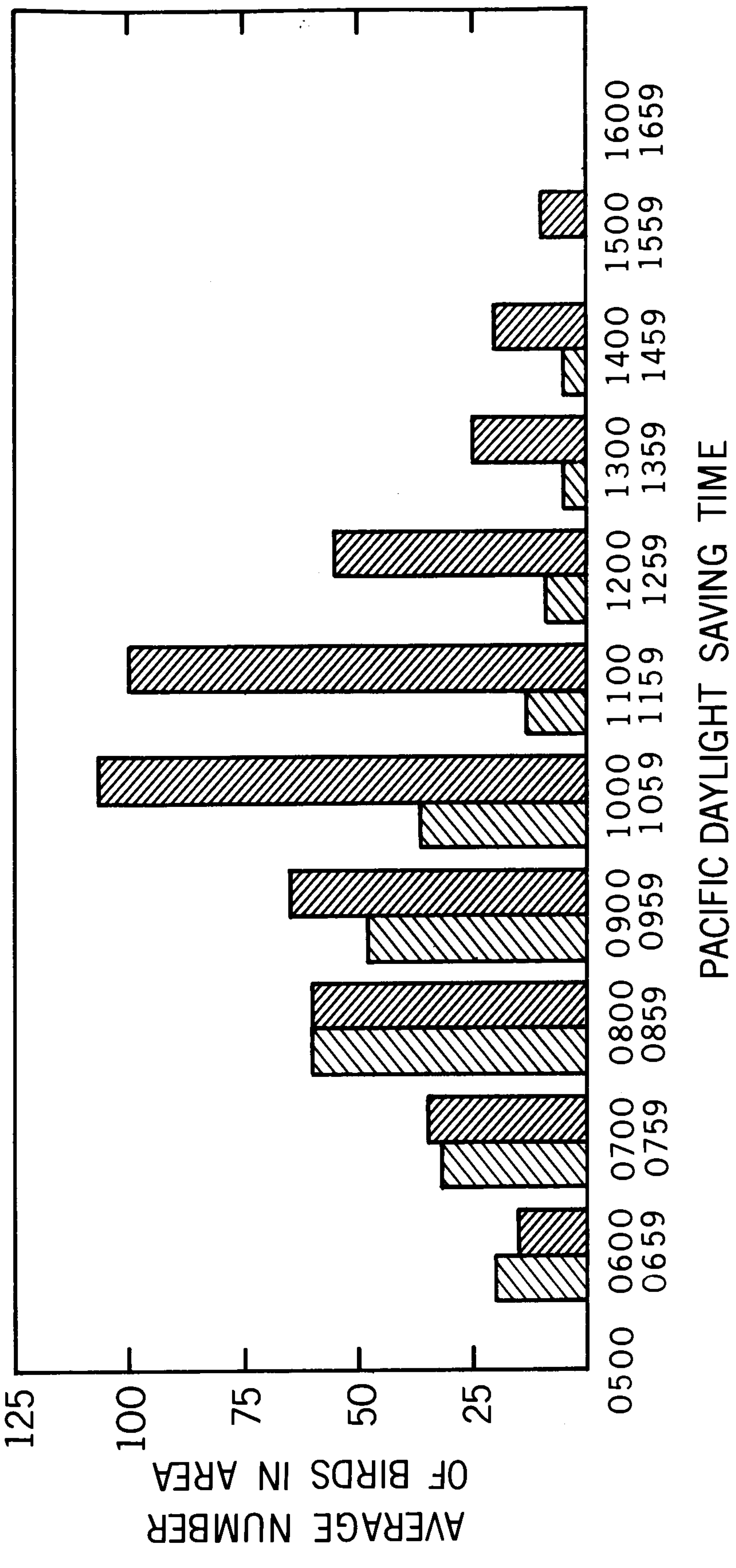

AVERAGE NUMBER OF BIRDS IN AREA
125
100
75
50
25
PACIFIC DAYLIGHT SAVING TIME
0500
0600 0659
0700 0759
0800 0859
0900 0959
1000 1059
1100 1159
1200 1259
1300 1359
1400 1459
1500 1559
1600 1659

Figure A-2 : Top - Band-tailed pigeon captured under cannon-net May 27, 1969. The green vegetation surrounds the actual mineral spring.

Bottom - Band-tailed just prior to being released, indicating type and area of placement of colored back-tag.

APPENDIX B - Reproduction of band-tailed pigeons 1970.

During 1970 the emphasis of this study swung away from reproduction per se to an investigation of the role of calcium in breeding. However, collection of reproductive data continued throughout 1970. As this data showed no major differences to that collected during 1968 and 1969, it has not been included in Chapter 3 but is presented here for comparison.

The status of ovarian development in the 1970 sample is shown in Table B-1. The seasonal distribution of birds with ovulated follicles suggests two periods of egg laying as noted in the discussion of Table 2 in Chapter 3. However, in 1970 it appears that both clutches may have been laid about 2 weeks earlier than in 1969. A feature of Table B-1 is that many more birds had terminal follicles (1970, 39% of 129 birds cf. 1969, 27% of 101 birds) indicating imminent ovulation.

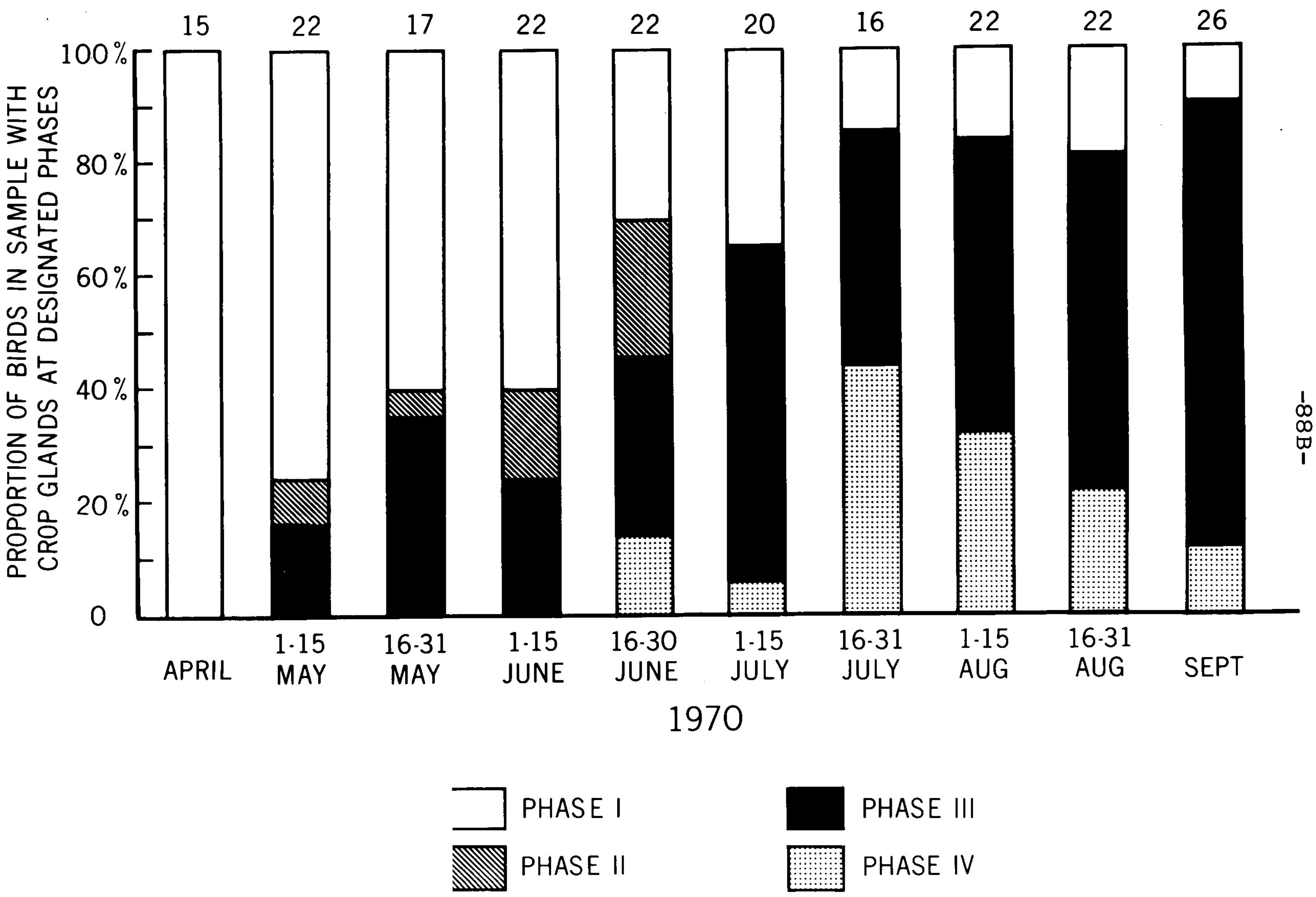
The seasonal changes in crop gland activity are shown in Figure B-1. Comparison with Figure 20, Chapter 3, indicates a similar progression in that approximately 1/3 of the females were breeding in the period prior to mid-June.

Table B-1

Ovarian status of females shot in 1970

	Diameter of largest follicle			
	<3.0 mm Uniform	3.6-5.5 Quiescent	<5.5 mm Terminal	Number of birds with recently ovulated follicles
Date	Number of birds in size class			
April 15-31	3	0	1	3
May 1-15	1	4	7	1
May 16-31	2	5	3	3
June 1-15	1	4	10	0
June 16-30	2	6	10	1
July 1-15	0	4	11	4
July 16-31	0	7	3	3
Aug. 1-15	4	6	4	0
Aug. 15-31	3	6	0	1
Sept.	6	0	0	0

Figure B-1 : Seasonal changes in proportion of birds sampled during 1970, with crop glands at designated phases. The sample size is provided at the top of the column.


15
22
17
22
22
20
16
22
22
26
100%
80%
60%
40%
20%
0
PROPORTION OF BIRDS IN SAMPLE WITH CROP GLANDS AT DESIGNATED PHASES
APRIL
1-15 MAY
16-31 MAY
1-15 JUNE
16-30 JUNE
1-15 JULY
16-31 JULY
1-15 AUG
16-31 AUG
SEPT
1970
PHASE I
PHASE II
PHASE III
PHASE IV

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CURRICULUM VITAE

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Educational Background:

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Completed junior matriculation through Vancouver Night School, 1960-62
Completed senior matriculation through Vancouver Night School, 1964-65

Degrees:

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Awards:

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Canadian Wildlife Services Grant, 1968-70
Teaching Associate, Simon Fraser University, 1969
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Teaching Experience:

Teaching Assistant, Simon Fraser University: BISC. 202 - Genetics, BISC. 203 - Embryology, BISC. 204 - Ecology

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Publications:

"Studies on the Band-Tailed Pigeon (Columba fasciata) in British Columbia. 1. Seasonal changes in gonadal development and crop gland activity", Canadian Journal of Zoology, Vol. 48, pp. 1353-57, November, 1970 (with R. M. Sadleir).

Manuscripts in preparation

a. Studies on the Band-Tailed Pigeon (Columba fasciata) in British Columbia. 2. Food and mineral resource utilization (with R. M. Sadleir).

b. Serum prolactin level and crop gland development in the band-tailed pigeon (*Columba fasciata*) (March).

Paper Read:

Canadian Zoological Society
Winnipeg, Manitoba, May 30, 1970
Title: The Breeding Biology of the Band-Tailed Pigeon (*Columba fasciata*) in British Columbia.