Development and Evaluation of the Applicability for a Parts Collection Survey for White-Winged Doves (*Zenadia asiatica*) in the Southwestern United States

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1 Introduction

1.1 Project Justification

Information on harvest age ratio (ratio of immature birds per adult in the harvest) combined with data on age-specific harvest vulnerability reported from banding and recovery data provides wildlife biologists with the basic foundation for estimating recruitment of migratory game birds at the population level (Munro and Kimball 1982). These estimates of recruitment, when combined with data on population distribution, size, and rates of survival and movements provide the structural building blocks for development of population models focused on harvest management of doves within the United States (Runge et al. 2002).

Age ratio data for migratory birds are typically acquired via a parts collection survey (PCS) where parts (typically wings or tail fans) from harvested individuals (e.g., doves, waterfowl, gallinules, woodcock) are collected via random mail surveys or field collection stations and are assigned to age class (typically hatch year (HY) or after hatch year (AHY)) based on morphological characteristics (Morrow et al. 1995, Mirarchi 1993, Miller and Otis 2010). As outlined in the "Priority Information Needs for Mourning and White-winged Doves" (Ad Hoc Dove Advisory Committee 2008), development of an operational dove parts collection program for both mourning and white-winged doves has been identified as a major priority supporting the long term population management and sustainability of both species. This priority was repeated in the 2010 Webless Migratory Game Bird Program RFP: Appendix A, highlighting the importance of accurate PCS methods for a range of webless migratory species. One major problem that currently exists with the state of the United States Fish and Wildlife Services (USFWS) Parts Collection Survey (PCS) for doves is that only the mourning dove has a practical, tested key for morphological based aging, and even this key is not 100% accurate (Cannell 1984, Miller and Otis 2010). This lack of fundamental information on white-winged doves limits regulatory and management planning, particularly where regulatory restrictions are expected to be based on informed knowledge of species population trajectory and status. As white-winged dove harvest exceeds 1.6 million doves in the Central and Pacific Flyway, supporting $\geq$500,000 hunter days afield (Raftovich et al. 2014), and with white-winged doves expanding across the southeastern United States it is an opportune time to identify metrics useful for estimating white-winged dove age thus supporting white-winged dove inclusion in the USFWS PCS for doves.

Over the last 60 years, there have been a variety of morphological measures suggested as potential options for aging white-winged doves. Early research indicated that the number of juvenile primaries present on harvested white-winged doves provided a good measure of individual age (Saunders 1944, but also reproduced in Cottam and Treften 1968: pp 324-325). Saunders (1950) key approximated age based on primary replacement (Swank 1955, Bivings and Silvy 1980), however aging based on primary replacement is known to exhibit considerable variation in mourning doves (Rous and Tomlinson 1967, Morrow et al. 1992) and we would expect a similar result with white-winged doves. George et al. (2000), working with data from 1950-1978, suggested that white-winged doves can be classified to juvenile or adult using a combination of leg color and primary covert color (thin white borders, pp 11). While these findings are likely based on the experience of the authors of this report, no data or reference information was provided to support this contention (George et al. 2000).

Leg color has been indicated as a potential mechanism for accurate aging of white-winged doves in hand by several authors (Cottom and Treften 1968, Uzzell, unpublished data). As detailed by Cottam and Treften (1968, pp 323-324), leg color age identification, with accuracy assessment using Bursa of Fabricius and primary molt score indicated high accuracy in aging white-winged doves, but reliability estimates using these data were never published and are thus unavailable. Recent aviary work by Texas A&M University-Kingsville (Fedynich et al. 2013) suggests primary molt sequence and presence/absence of buffy tipped primary coverts could be used in combination to potentially segregate juvenile into classes, but variability was high for the oft cited buffy-tips on primary coverts (range between 104 and 161 days based on a sample of n $\leq$20 captive individuals) lead to considerable variation in predictive accuracy. Anecdotally from several of the above authors, eye ring coloration has been suggested as a potential separator of age (pers.commun to Collier), however as eye ring color is likely most noticable during capture operations during the breeding season (Cottam and Treften 1968, George et al. 2000) and is possibly a breeding season characteristic, may not be singularly useful for predicting age. Thus, although referenced in several locations, we have found no definitive, research data which has proven useful for classifying white-winged doves to age classes (HY, AHY) and quantifying uncertainty in those estimates for use in a PCS.

The current inability to accurately quantify age of harvested white-winged doves based on wing morphology limits the ability of the USFWS PCS for predicting white-winged dove recruitment hindering development of harvest management strategies that provide for informed regulatory decision making in United States. Given these conditions, the focus of our study will be to 1) evaluate, describe, and quantitatively identify morphological characteristics that can be used to assign white-winged doves to age classes and easily incorporated into the U.S. Parts Collection Survey and 2) use those characteristics to develop an approach to aging harvested white-winged doves across the species southwestern U.S. range. Thus, the objectives of our work detailed herein are to:

1. Evaluate the relative applicability of previously described white-winged dove morphological characteristics for use in accuractely classifying individuals to age classes.
2. Evaluate and identify qualitative and quantitative morphological characteristics that can be used to in accurately identifying age of harvested white-winged doves across the southwestern U.S.

2 Methods

2.1 Project Personnel Training

As part of the project, we conducted a training for project personnel to ensure that all personnel were informed on study objectives, data collection methods, etc. We trained agency personnel from participating states in field data collection in order to maximize sample size and geographic extent across the range of white-winged doves. Personnel received live training from a principal investigator on equipment inventory and use, data entry, data collection procedure, and relevant literature pertaining to white-winged dove anatomy and physical characteristics. Each person running a check station was asked to provide personnel equipment including a camera or cell phone to record noteworthy specimens or events, a cooler for water and snacks, bug repellant, and sun screen. Check stations were provided with tarps or tents, chairs, folding tables, signs indicating the purpose of the work and asking for voluntary participation by hunters, a tool box, data sheets, specimen bags, specimen vials, specimen labels, and a specimen cooler. Tools consisted of a wing ruler, electronic scale, electronic calipers, game shears, waterproof pens, extra batteries, a standard operating procedures booklet (see Appendix), a procedural quick reference sheet (see Appendix), and copies of state agency and federal collection permits.

Each check station was manned by a minimum of 2 personnel. Check station personnel were asked to engage hunters as they left the field in a friendly manner, explaining the purpose of the research and asking for voluntary participation. Hunters who agreed to participate were asked if check station personnel could examine harvested birds and remove a wing, leg, crop, and tail. Hunters were also asked if they would be willing to donate one or more whole birds to the study. Check station personnel then examined the birds provided by each hunter, in the order of arrival and as quickly as possible. During the procedure one person recorded data while the other check station operator examined birds, called out data measurements, and bagged specimens. A brief description of the data collection procedure is as follows:

1. Fill in page number, name, date, state, and county.
2. Obtain check station name and description from host agency.
3. Collect GPS reading for location, filling in latitude and longitude.
4. Birds should first be inspected for damage to make sure all measurements can be made.
5. Record band numbers, if present.
6. Weigh the bird.
7. Check for presence/absence of blue eye rings, red irises, opaque black bill, and red legs.
8. With calipers, measure bill length, bill depth, and bill width.
9. With a ruler, measure tarsus, tail, and wing chord length.
10. Inspect wing to determine current stage of primary molt (P1–P10).
11. Inspect wing to determine presence or absence of buffy-tipped secondary coverts.
12. Obtain specimen bags (1 large, 2 small), tissue vial, and small sticker.
    (a) If this is a donated bird, check WB on datasheet and place bird in large sample bag.
    (b) If this is not a donated bird, proceed as indicated below.
13. Remove right wing and leg. Place in small bag 1.
14. Remove muscle tissue. Place in tissue vial.
15. Remove tail fan below vent. Place in bag 1 on top of leg and wing.
16. Remove crop contents and place in small bag 2.
17. Place both small bags and tissue vial into large bag.

18. Inspect data sheet, bags, and tissue vial. Ensure they contain parts and all information.
19. If all bags, vials, and data sheet are complete, seal all parts in large bag and place in cooler.

The full check station procedure is detailed within the Appendix, and the full procedure was demonstrated using whole birds for each group of check station personnel during training. Check station operators were then provided specimens to practice the procedure and ask questions of the principal investigator. Personnel were instructed that following data collection in the field, birds not donated should be returned to the hunter, and the hunter thanked for his or her willingness to participate. Check station personnel were instructed to answer questions posed by hunters as time permitted (i.e., so long as no other hunters were waiting to be processed).

Laboratory personnel received the same training as check station personnel, but received additional hands-on training in avian anatomy, anatomical data collection techniques (skull ossification and other skeletal measurements, identification and measurement of reproductive organs and bursa), and museum specimen preparation (preparation and storage of skins, wings, feathers, skeletons, and tissue samples). Laboratory personnel were also instructed in insect damage identification, insect prevention techniques, specimen lyophilization, data quality control, and database data entry. This additional training was necessary for consistent and accurate data measurements of anatomical details that were impossible to collect in the field due to time, equipment, and expertise. As such, laboratory personnel training was ongoing, specimen driven, and therefore required active participation of the principal investigators and museum staff. Due to this level of training, and the ability to cross-examine any detail or measurement, all laboratory measurements supersede similar measurements made in the field.

2.2 Study Sites

Working under the assumption that white-winged doves do not exhibit significant morphological deviations based on geographical spacing, we identified field collection sites on which we could efficiently collect and process legally harvested white-winged doves during the first week of the annual hunting season framework for each state. Although expanding in the United States (Butcher et al. 2014), the current range of the white-winged dove is primarily limited to the southwestern United States, thus we focused data collection in Texas, New Mexico, Arizona, and California. Throughout their range, white-winged doves are habitat generalists and have adapted to a variety of environments ranging from desert-dwelling to urban areas (Cottam and Trefethen 1968, George et al. 1994, Collier et al. 2012) thus our field collection sites were based primarily on frequency and accessibility to legal hunting activities such that adequate white-winged doves could be collected from hunters on a volunteer basis. Over the course of our field data collection (2011-2012) we collected data at 6 sites in Texas, 4 sites in New Mexico, 2 sites in Arizona, and 1 site in California (Table 1, Figure 1).

2.3 Field Data Acquisition

During the first week of the hunting season in each state (beginning 1 September), project personnel at each site requested that hunters who had completed hunting donate $\geq$1 legally harvested white-winged dove to our work. We examined each specimen for any significant damage or defects which would preclude accurate evaluation of the suite of morphological characteristics of interest, assigned each specimen a unique ID, conducted a field assessment of those morphological characteristics which had been previously identified as useful for classifying white-winged dove ages and bagged each specimen (or wing, tail fan, leg, and tissue sample were bagged when a whole specimen was not donated) for further laboratory evaluation.

After a preliminary evaluation of field morphological measurements from individuals collected in 2011 (N = 2,219), we subsequently reduced the suite of morphological characteristics measured on those individuals collected in 2012 (N = 1,101), to 1) reduce the data collection time in the field for metrics which could be more easily and accurately measured in the laboratory and 2) ensure that field data collection encompasses on those metrics which we deemed required field measurements for consistency with 2011 data collection (e.g., leg color, blue eye ring, which could in theory change post-mortem;). After gross morphological characteristics were collected, each specimen was bagged and frozen for transport to the Biodiveristy Research and Teaching Collections at Texas A&M Univeristy (BRTC: http://brtc.tamu.edu/) for laboratory evaluation, dissection, and to have voucher specimens of whole individuals (both skins and skeletons), wings, and tissue archived for future research needs. Note that the above sample sizes will be reduced in subsequent analyses in several places due to our inability to accurately collect measurements from harvested individuals due to either internal damage during the harvest process or lack of whole birds samples. Sample size will be denoted within each subsequent analyses.

2.4 Laboratory Data Acquisition

During our study, all morphological characteristics measured within the laboratory were completed by 4 undergraduate research assistants. Each laboratory evaluation provided a independent evaluation of each field measurement. To assist with accurate aging of birds within the laboratory, we performed a necropsy on harvested individuals to determine presence and size of the Bursa of Fabricius (Proctor and Lynch 1993), as reduction in size (and involution) can be used to age from HY to AHY after 8th primary loss (Saunders 1950, Cottam and Trefethen 1968, Kirkpatrick 1994, Mirarchi 1993, Abbate et al. 2007). Bursa of Fabricius absence implies adult (Wight 1956), although remnants ($\leq$3mm) may remain (Mirarchi 1993). During necropsy, we also inspected reproductive organs to determine sex (via testis/ovary occurrence), obtain tissue samples (pectoral muscle) for future genetic/disease evaluation, estimated frontal bone ossification (Miller 1946, Baird 1963), and collected deck feather samples for sexing white-winged doves using methods developed by Oyler-McCance and Braun (unpublished data). After the initial aging and necropsy has been completed, we collected 1 wing (left or right alternating between birds) cut at the proximal end of the humerus, tail fans (Oyler-McCance and Braun, unpublished data), and 1 leg (left or right alternating between birds) cut at the proximal end of the fibula for archiving at BRTC.

2.5 Data Description and Analysis

During field data collection in 2011 (Appendix 1), we collected measurements of the following gross morphological metrics:

- Field Gross Morphological Characteristics
  - Eye Ring Color (Blue: Y/N) (Cottam and Trefethen 1968, George et al. 1994)
  - Iris Color (Red: Y/N) (Cottam and Trefethen 1968, George et al. 1994)
  - Leg Color (Red: Y/N) (Cottam and Trefethen 1968, Uzell, unpublished data)
  - Bill Color (Black: Y/N) (Cottam and Trefethen 1968, George et al. 1994)
  - Bill Length (mm) (bill from feathers; Proctor and Lynch 1993, Loncarich and Krementz 2004)
  - Bill Depth (mm) (measured at the base; Proctor and Lynch 1993, Loncarich and Krementz 2004)
  - Tarsus Length (mm) (Proctor and Lynch 1993)
  - Tail Length (mm) (Proctor and Lynch 1993)
  - Wing Chord Length (mm) (Proctor and Lynch 1993)
  - Primary Molt Pattern (P0-P10) (Saunders 1950, Cottam and Trefethen 1968)
  - Primary Covert Molt Color (Buffy Coverts: Y/N) (Saunders 1950, Cottam and Trefethen 1968, George et al. 1994)
  - Weight (g) (Proctor and Lynch 1993)

After preliminary evaluation of the 2011 data, we determined that collecting morphological metrics in the field immediately after sample acquisition when combined with measurement of additional characteristic in the lab was more efficient and accurate when whole bird carcasses were available. Thus, in 2012, we only collected whole birds from hunters willing to donate to our study and we collected morphological metrics in the field using a reduced data collection form that was a subset of the 2011 characteristics above and then sent all whole specimens to BRTC for further evaluation. During lab data collection in both 2011 and 2012, we collected both the measurements taken in the field (above) as well as the following morphological characteristics:

- Laboratory Morphological and Physiological Characteristics
  - Primary Covert Molt (Y/N)
  - P10 Length (mm) (Right Wing In Situ)
  - P10 Length (mm) (Left Wing Ex Vivo)
  - Brown Deck Feathers (Brown: Y/N)
  - Deck Feather Molt (Y/N)
  - Deck Feather Length (mm) (In Situ)
  - Deck Feather Length (mm) (Ex Vivo)
  - Deck Feather Vane Length (mm)
  - Deck Feather Van Width (mm)
  - Deck Feather Damage (Y/N)
  - Right Tarsus Length (mm)

- Pubic Spread (mm)
- Skeletal Pubic Spread (mm)
- Skeletal Ilium Spread (mm)
- Skull Ossification (%)
- Ovaries or Testes (O/T)
- Ovaries or Testes Size (Length * Width)
- Bursa of Fabricius Size (Diameter * Width)
- Secondary Molt (S0-S10)
- Alular Molt (A0-A3)
- Primary Covert Molt Location (PC0-PC10)
- Alular Count (0-3)
- A1 Color (Black/White)
- A2 Color (Black/White)
- A3 Color (Black/White)
- Girth to S1 (mm)
- Girth to P5 (mm)

3 Results

3.1 Summary Statistics 2011

The focus of our preliminary evaluation was to determine whether any discriminatory capability was readily noticable when evaluating the suite of morphological metrics above to the aging standard of primary covert color (e.g., buffy coverts) currently used for Mourning doves. Our initial expectation was that if all those morphological metrics that have been previously suggested to be indicators of age are correct (True = 1), then the white-winged dove in hand should by definition be an adult and should have no buffy coverts present. It follows that if all those morphological metrics are false (False = 0), the white-winged dove in hand should be a juvenile and should have buffy coverts present. Based on the available literature on white-winged dove aging, when used together the metrics of eye ring color, iris color, leg color, and bill color should allow for near 100% accuracy in initial aging. Individuals that are neither all 1's, or all 0's (118 possible permutations) are technically unknowns and the thrust of our work.

First, based on the 2011 data, we collected 2,099 white-winged doves of which 524 were assumed adults (indicating that they had metrics which were all present (1's)) and 731 white-winged doves that were assumed juveniles, indicating that they had metrics which were all absent (0's)), respectively. Thus, based on a sample of 2,099, the number of white-winged doves that were not classified to one of the 'known' categories was 844, giving an approximate unclassifiable percentage based on whole-bird measurements of 0.4020962. Based on the assumed adults (N = 524), we found no evidence that separation using these four characteristics occured when compared to the presence (N= 241) or absence (N = 283) of buffy coverts. Juvenile classification indicated more based on the sample (N = 731) wherein when these four characteristrics were absent there was more separation in the presence (N= 562) or absence (N = 169) of buffy coverts.

Using the entire 2011 sample (N = 2,099), simple classification tables in indicated little to no obvious separation between the morphological characteristics of blue eye ring (Table 2), red iris (Table 3), black bill (Table 4) and red leg (Table 5) when compared to the presence or absense of Buffy Coverts as identified in the field. There was uncertainty in the classification of whether primary coverts were considered to have 'buffy' tips (white or discolored edges) when comparing 2001 field measurements to 2011 lab measurements (Table 6). Potentially, there could have been various misclassification errors regarding the presence of buffy primary coverts during our field analysis as over 50 observers were trained and actively involved in field data collection during the 2 years of the study. However, our laboratory estimates were intended to be more liberal (e.g., if there was any hint of discoloration along the distal edge of the covert it was classified by the research assistants as buffy), thus as expected classification of buffy coverts based on the laboratory data tended to show more positive buffy coverts than field measurements (Table 6).

In general, primary molt pattern based on both the field (Table 7) and lab (Table 8) evaluation was in general consisent with dove molt patterns for the southwestern United States for similar time periods (Figure 2). We did notice, however, that primary molt measurements were not equivalent between field and laboratory measurements (Tables 7 & 8; Figure 2) with laboratory measurements being skewed slightly towards later primary molt scores, likely an artifact of the laboratory measurements being more thorough and thus more likely to identify primary molt in an early stage of feather eruption. As expected, when comparing primary molt score between doves identified as having buffy coverts from field samples (Figure 3), field and lab comparisons (Figure 4), and lab comparisons (Figure 5) we start to see a relationship between the distribution of primary molt and the presence or absence of buffy coverts, conforming to previous expections on dove age.

Bursa of Fabricius presence or absence may be used to estimate age as the bursa are expected to regress with age. To assist with aging of birds in hand, and to evaluate whether bursa regression in white-winged doves occurs, we performed a necropsy on all whole individuals to determine presence and size of the Bursa of Fabricius (Proctor and Lynch 1998), as reduction in size (and involution) can be used to age from HY to AHY after 8th primary loss (Saunders 1950, Cottam and Trefethen 1968, Kirkpatrick 1994, Mirarchi 1993, Abbate et al. 2007). Bursa of Fabricius absence implies adult (Wight 1956), although remnants (<3mm) may remain (Mirarchi 1993). Across the range of primary molt measurements and buffy covert classification there was little noticable variation in Bursa of Fabricius size (diameter and width, Figure 7). However, there was evidence of separation in occurrence of and size of bursa when categorized by primary molt and buffy covert classifications in the field (Figure 8 and Figure 9). Interestingly, Figure 8 and Figure 9 both identify several interesting relationships in that when looking at our sample of those molting ≤P5 that did not have buffy coverts, our sample was small (and hence few bursa's were measured), yet the vast majority of birds that were molting ≥P6 and did not have buffy coverts had measureable bursa. For those white-winged doves that had buffy coverts, the vast majority of our sample were molting between P2 and P7, thus the majority of bursa measurements for white-winged doves with buffy coverts fell within that range. Interestingly, there seem to be 2 distinct groups of white-winged doves molting ≥P7, in that there were white-winged doves with bursa that could be measured as well as white-winged doves that had no measureable bursa present, leading us to suggest that perhaps we are are dealing with 2 distinct adult age classes, first year breeders (second year (SY) birds that had measureable bursa) and ≥2nd year breeders wherein total involution of the bursa has occurred.

Both body feather and wing molts have been used to categorize juvenile from adults for a variety of avian species. With this in mind, we collected information on the alular covert molt and color (white or black) as we had noted from samples collected during previous banding studies (Collier 2012a, 2012b) that known adults typically had alular feathers with limited coloration (e.g, all black) when compared to known juveniles that typically had alular feathers that had white patches or edges on them. This was borne out during our preliminary morphological evaluation of white-winged dove wings collected in 2011 as we noticed a trend in alular feathers wherein alular feathers tended to show 2 distinct patterns: those that had a distinct white colortion and those that had no white coloration (e.g., were entirely black). Thus far we have been unable to find any molt timing information on alula feathers for white-winged doves in the published literature, but given our evaluation there seemed to be a link between alular feather color and buffy covert occurrence. For our purposes, we designated alular feathers as A1, A2 and A3, with A1 being the most proximal to the body and A3 being the most distal. Alular molt is determined either by the presence of a sheath, a single missing feather or the sharp change in color from black to brown on adjacent alulars (Table 9). Based on our preliminary evaluation, there was no strong relationship between alular molt score and buffy covert occurrence (Tables 10 & 14). However, when looking at buffy covert occurrence, we did begin to detect some evidence of general trends when categorizing by Alular 1 (Tables 11 & 15), Alular 2 (Tables 12 & 16) and Alular 3 (Tables 13 & 17) wherein as one moved from Alular 1 to Alular 3 we saw increased reduced occurrence of white and increased occurrence of all black coloration on those without buffy coverts and increased occurrence of white and decreased occurrence of black coloration on those with buffy coverts.

Next, we evaluated the suggested use of aging based on primary replacement (Saunders 1950) across the range of buffy covert occurrence and alular colors as primary replacement has been suggested as one potential method supporting age classification in doves (Swank 1955, Bivings and Silvy 1980). First, the vast majority of birds without buffy coverts were molting P6 or higher (Tables 18 & 19; Figures 2, 3, 4& 5) while those doves with buffy coverts present were primarily molting between P2-P3 and P7-P8 (Tables 18 & 19; Figures 2, 3, 4& 5). Using primary molt score as a classification factor with buffy covert occurrence and alular feather color, we saw that for Alular 1, those individuals without buffy coverts typically had higher molt scores, but no variation based on alular color (Figures 12 & 15). For Alular 2, those individuals without buffy coverts still had higher molt scores, but now we begin to see variation in alular color with more individuals without buffy coverts having black A2 feathers (Figures 13 & 16). For Alular 3, separation was significantly more evident, with individuals without buffy coverts rarely having white A3 feathers and in those cases where white A3 occurs, primary molt scores were skewed towards lower values than in those individuals with buffy coverts and white A3 feathers (Figures 14 & 17).

3.2 Summary Statistics 2012

During 2012 we processed all birds (N =1,101), in the field using a reduced data collection form that was a subset of the 2011 characteristics and we only processed and collected whole bird specimens which were subsequently sent to Texas A&M University for further evaluation and incorporation into the BRTC. The metrics we collected during our 2012 field season included:

- Field Gross Morphological Characteristics
  - Eye Ring Color (Cottam and Trefethen 1968, George et al. 1994)
  - Iris Color (Cottam and Trefethen 1968, George et al. 1994)
  - Leg Color (Cottam and Trefethen 1968, Uzell, unpublished data)
  - Bill Color (Cottam and Trefethen 1968, George et al. 1994)
  - Primary Covert Molt Color (Saunders 1950, Cottam and Trefethen 1968, George et al. 1994)
  - Primary Molt Pattern (Saunders 1950, Cottam and Trefethen 1968)
  - Wing Chord Length (Proctor and Lynch 1993)
  - Weight (Proctor and Lynch 1993)
  - Age Categorization (Adult or Juvenile; unpublished data-conducted in laboratory)

Following our 2011 preliminary analysis, we determined the relative frequency of known and unknowns and then use the first year's information/knowledge gathered to inform a structured approach to better ensuring data collecting in year 2 would reduce the uncertainty associated with the birds in the 'middle' of the extremes. During 2012, we collected 1,101 white-winged doves of which 134 were assumed adults (indicating that they had metrics which were all present (1's)) and 453 white-winged doves that were assumed juveniles, indicating that they had metrics which were all absent (0's)), respectively. Thus, based on a sample of 1,101, the number of white-winged doves that were not classified to one of the 'known' categories was 514, giving an approximate unclassifiable percentage based on whole-bird measurements of 0.4668483, similar to our 2011 results. Based on the assumed adults (N = 134), we found no evidence that separation using these four characteristics occured when compared to the presence (N= 30) or absence (N = 104) of buffy coverts. Juvenile classification indicated more based on the sample (N = 453) wherein when these four characteristrics were absent there was more separation in the presence (N= 327) or absence (N = 126) of buffy coverts and when looking over primary molt score (Figure 18).

Additionally, based on the combination of gross morphological and phenological characteristics we categorized each bird as either an adult or juvenile. Following our classification of adult or juvenile, we additionally collected information on the alular covert molt and color (white or black) as we had noted from our 2011 samples as well as individuals collected during previous banding operations (Collier, unpublished data) that known adults typically had alular feathers with no coloration (e.g, all black) when compared to known juveniles that typically had alular feathers that had white patches or edges on them.

Similar to our 2011 data, simple classification tables in indicated little to no obvious separation between the morphological characteristics of blue eye ring (Table 20), red iris (Table 21), black bill (Table 22) and red leg (Table 23) when compared to the presence or absense of Buffy Coverts as identified in the field. Additionally, our 2012 data showed similar uncertainty in the field classification of whether primary coverts were considered to have 'buffy' tips when comparing 2012 field measurements to 2012 lab measurements (Table 24). However, as observers for 2012 were drawn from the same group of biologists used in 2011 and underwent additional training, in general the misclassification rate was slightly lower than in 2011. However, as expected our laboratory estimates were intended to be more liberal (e.g., if there was any hint of discoloration along the distal edge of the covert it was classified by the research assistants as buffy), thus classification of buffy coverts occurring based on the laboratory data tended to show more positive buffy coverts than field measurements (Table 24). As expected based on our 2011 descriptive results, when evaluating primary molt score based on presence or absense of buffy coverts (lab measurement) we saw the same general trend wherein those individuals with no buffy coverts tended to have larger primary molt scores (Figure 20). We note that when comparing distribution of primary molt score by age classification (Figure 21), we see a similar trend to that shown by buffy coverts (Figure 20) for the 2012 data indicating that buffy coverts do provide some explanatory information for again white-winged doves.

Across the range of primary molt scores and buffy covert classification there was little noticable variation in Bursa of Fabricius size (diameter and width, Figure 22). However, there was evidence of separation in occurrence of and size of bursa when categorized by primary molt and buffy covert classifications in the field (Figure 23 and Figure 24). Figure 23 and Figure 24 both continue to support the relationships identified in 2011. Our sample of birds, when looking at those molting ≤P5 that did not have buffy coverts, was small (and hence few bursa's were measured), yet the vast majority of birds that were molting ≥P6 and did not have buffy coverts had measureable bursa. For those white-winged doves that had buffy coverts, the vast majority of our sample was molting between P2 and P7, thus the majority of bursa measurements for white-winged doves with buffy coverts fell within that range. Interestingly, our 2012 data also suggest that there are 2 distrinct groups of white-winged doves molting ≥P7, in that there were white-winged doves with bursa that could be measured as well as white-winged doves that had not bursa present, leading us to again suggest that perhaps we are are dealing with 2 distinct adult age classes, first year breeders (second year birds those with measureable bursa) and ≥2nd year breeders wherein total involution of the bursa has occurred.

As with our 2011 data, primary molt scores (Tables 25 & 26 ; Figure 19) indicated that molt patterns were consistent with those found elsewhere in the southwestern United States. We did again see some variation in primary molt scores between the field and laboratory measurement (Tables 25 & 26 ; Figure 19). Alular molt was evenly spread across alular feathers, with approximately half of our sample not molting (Table 27). Based on our preliminary evaluation, there was no strong relationship between alular molt score and buffy covert occurrence (Tables 28 & 32). However, when looking at buffy covert occurrence, we did begin to detect some evidence of general trends when categorizing by Alular 1 (Tables 29 & 33), Alular 2 (Tables 30 & 34) and Alular 3 (Tables 31 & 35) wherein as one moved from Alular 1 to Alular 3 we saw increased reduced occurrence of white and increased occurrence of all black coloration on those without buffy coverts and increased occurrence of white and decreased occurrence of black coloration on those with buffy coverts. As seen with primary molt score classification (Figure 21), buffy coverts as measured in the field (Table 36) and lab (Table 37) for the 2012 data indicating that buffy coverts do provide some explanatory information for again white-winged doves.

The vast majority of birds without buffy coverts were molting P6 or higher while those doves with buffy coverts present were primarily molting between P2-P3 and P7-P8 (Table 38). Using primary molt score as a classification factor with buffy covert occurrence and alular feather color, we saw that for Alular 1, those individuals without buffy coverts typically had higher molt scores, but no variation based on alular color (Figure 25). For Alular 2, those individuals without buffy coverts still had higher molt scores, but now we begin to see variation in alular color with more individuals without buffy coverts having black A2 feathers (Figures 26). For Alular 3, separation was significantly more evident, with individuals without buffy coverts rarely having white A3 feathers and in those cases where white A3 occurs, primary molt scores were skewed towards lower values than in those individuals with buffy coverts and white A3 feathers (Figures 27). Using our age classification (adult or juvenile) we saw similar trends as in 2011 in both the field (Figure 28) and lab (Figure 29) evaluations. Inclusion of alular color (white or black) into the categorization indicated similar results as seen with buffy covert occurrence, in that there was little separation for A1 (Figure 30) yet much more noticable separation into adult and juvenile classes based on the A2 (Figure 31) and A3 (Figure 32) alular colors.

3.3 Discrimination and Regression Modeling

Combining our descriptive analysis based on body size and wing morphology with our age categorization, we initially used logistic regression to estimate the probability of belonging to either the adult (A) or juvenile (J) age class based on the set of morphological characteristics we collected. As metrics such as eye ring color, bill color, buffy covert occurrence, etc. were used in the laboratory for classification into adult or juvenile classes, we provide those estimates only in a supporting role and instead focus on estimates based on primary molt score, alular feather color, bursa size. We found little evidence for separation of adults and juveniles based on the A1 alular color (white or black; Table 39) or resultant logistic predictions for the probability of being an adult (success) given the bird has a white A1 (0.4603421) or black A1 (0.6428571) alular feather. There was greater separation with very few adults having evidence of a white A2 alular (Table 40) which was borne out when looking at the logistic regression predictions for the probability of being an adult (success) given a white (0.120155) or black (0.6428571) A2 alular feather. However, separation become very evident (Table 41) when looking at predictions for the A3 alular where the predicted probability of the bird being a adult, given it had a white A3 alular was very low (0.0597484) while the probability that it was adult given that it had a black A3 alular was high (0.8283379).

We used principal component analysis (pca) for verification of our selection of causal model factors. Based upon previous research, the combined presence of four gross morphological characteristics should be indicative of adult status: red iris, blue eye ring, hardened black bill, and red legs (Cottam and Trefethen 1968, George et al. 1994, Uzzell, unpublished data). Conversely, our data suggests the presence of buffy coverts and white distal alular feathers is indicative of juvenile age status. For the 2011 data with no missing values (Table 44), the first 2 principal components explain 55.62% and 16.23% of the total variance (71.85% of the cumulative variance combined; Figure 39). For the 2012 data with no missing values (Table 47), the first 2 principal components explain 54.74% and 15.3% of the total variance in the 2012 data (70.04% of the cumulative variance combined; Figure 40). In both years the presence of red iris, blue eye ring, hardened black bill, red legs, and primary molt score are positively correlated with pca dimension 1, while the presence of buffy coverts and white distal alular feathers are negatively correlated with pca dimension 1. The variable loadings and correlations for both the 2011 and 2012 data sets support our selection of primary molt score, presence of buffy coverts, and distal alular color as factors for use in development of casual models.

3.4 Causal Modeling

In order to quantify uncertainty relative to age classification of white-winged doves as well as to provide a tool to assist biologists with quantification and uncertainty evaluation, we developed a Bayesian belief network implemented in Netica (Norsys Software Corp.) to assist biologists in estimating white-winged dove age. Graphical models are a depiction of the biological system under study and the causal relationships between parameters within this system (Pearl 1988, Marcot et al. 2001, Borsuk et al. 2004, Marcot et al. 2006). Thus, each data point included in the model defines a segment of the graphical model structure (Lee and Rieman 1997, Peterson and Evans 2003). Model depiction is composed of nodes (boxes) which represent individual model parameters (population parameter or state variables) (Clemen 1996, Peterson and Evans 2003). Nodes having no predecessors (root nodes) are parameterized by a prior (unconditional) probability, or the probability that the input parameter is in a specific state(s) (Charniak 1991), while non-root (child) nodes are parameterized by conditional probabilities of specific states, given the state of the parent nodes (Pearl 1988, Charniak 1991, Marcot et al. 2001, Lee 2002, Marcot et al. 2006). Bayesian belief networks use probabilistic expressions to describe relationships between components conditional on knowledge (evidence) contained in other variables within the system (Peterson and Evans 2003, Borsuk et al. 2004). Causal relationships are defined by specification of a conditional probability matrix (CPM) (Pearl 1988, Morawski 1989, Marcot et al. 2001, Marcot et al. 2006), which characterizes the probability of an event occurring conditional on the state of immediate parent nodes in the network. The model is solved by using Bayesian learning to calculate the output or posterior probabilities (Pearl 1988, Charniak 1991). Because the "true" state of a variable is rarely known, uncertainty is indicated by assigning belief to each range of values within a node (Lee and Rieman 1997). As belief can never be >1, the allocation of belief within each node, given bin-width size, is used to show certainty (or uncertainty) associated with the state of each biological variable.

We based our causal model on the 3 factors that we and others have identified as potential metrics for aging doves: primary molt score, occurrence of buffy coverts, and coloration of the most distal alular (A3) feather. Note that as the most discrimination seemed to occur with the most distal alular we have only included that alular color into our causal model (Figures 30 & 31 & 32). Using a sample of known age individuals ($N = 683$) with complete measurements on the 3 characteristics above, we developed a BBN which can be used to probabilistically quantify the likelihood that a white-winged dove falls within a particular age class based on our identified characteristics. The underlying data used to parameterize the BBN's is provided, raw, in Tables 43-49. As an example, consider Figure 34, which shows the initial parameterized Bayesian belief network based on the sample of 683 as detailed above. Based on the uninformed parameterization, there is approximately a 55:45 chance that a dove is a juvenile, based on the data at hand. However, the strength of this modeling approach shows when information is added to the network system. For instance, in Figure 35, the addition of knowledge about the state of the wing, e.g., that the wing does have evidence of a buffy edge on the primary coverts, changes the expectation of the age classification as a HY from 54.9% to 73.5%. Similar adjustments occur when information on alular color is added (Figure 36) and the same holds true for alternative scenarios shown in Figure 37 and Figure 38).

4 Preliminary Conclusions

Based on our results, age-specific classification of white-winged doves exhibits more variability than that currently ascribed to mourning doves on the use of a single metric (buffy cover presence). Our work indicates that a suite of wing metrics seem to provide a plausible classification scheme for white-winged doves that will be useful for inclusion into the UWFWS Parts Collection Survey. The primary focus in the near term should be on determining what the appropriate classification is for initial use, under the expectation that refinements will be necessary. First, as rarely were any birds classified as HY molting P7 or greater, we suggest that if the specimen has buffy coverts and non-black distal alular and is molting <P7 is should be classified as a HY (classified as a HY 94.5% or greater across all lower molt classes). Next, we suggest that if the specimen has no buffy coverts and a black distal alular and is molting P7 or greater, it should be classified as an adult (classified as an AHY 85% or greater across all higher molt classes). Further refinements using recaptured birds from banding operations where age is known will be beneficial and are ongoing at this time.

Tables

Table 1: WWDO PCS Data Collection Locations

Sample Sites	County	Latitude	Longitude
Arizona: Milligan Road	Maricopa	32.735	-111.495
Arizona: Robins Butte WMA	Maricopa	33.370	-112.668
California: CA6F BREA	Imperial	33.125	-115.534
New Mexico: Viega Dairy	Dona Ana	31.895	-106.655
New Mexico: Santa Teresa Port of Entry Livestock Crossing Stockyard	Dona Ana	31.787	-106.659
New Mexico: DeRutyer Dairy	Dona Ana	32.165	-106.676
New Mexico: Woodcrest Dairy	Chaves	33.350	-104.438
Texas: Midland Private Land	Martin	32.105	-101.469
Texas: Carol/Sealy Private Land	Austin	29.743	-96.092
Texas: Pflugerville	Travis	30.474	-97.661
Texas: Temple	Bell	31.053	-97.303
Texas: Nooner Ranch	Medina	29.353	-99.112
Texas: Las Palomas WMA-Anacua Unit	Cameron	26.054	-99.112

Table 2: Buffy coverts (field measurements) relative to occurrence of blue eye ring (BER) based on the 2011 sample of white-winged doves

	Blue Eye Ring = No	Blue Eye Ring = Yes
Buffy Coverts = No	414	537
Buffy Coverts = Yes	788	360

Table 3: Buffy coverts (field measurements) relative to occurrence of red iris (RI) based on the 2011 sample of white-winged doves

	Red Iris = No	Red Iris = Yes
Buffy Coverts = No	603	348
Buffy Coverts = Yes	848	300

Table 4: Buffy coverts (field measurements) relative to occurrence of black bill (BB) based on the 2011 sample of white-winged doves

	Black Bill = No	Black Bill = Yes
Buffy Coverts = No	336	615
Buffy Coverts = Yes	752	396

Table 5: Buffy coverts (field measurements) relative to occurrence of red leg (RL) based on the 2011 sample of white-winged doves

	Red Leg = No	Red Leg = Yes
Buffy Coverts = No	267	684
Buffy Coverts = Yes	658	490

Table 6: Buffy covert (field measurement) relative to buffy coverts (lab measurement) for the 2011 sample of white-winged doves

	Buffy Coverts (Field) = No	Buffy Coverts (Field) = Yes
Buffy Coverts (Lab) = No	535	110
Buffy Coverts (Lab) = Yes	414	1037

Table 7: Primary molt score (field measurement) during 2011.

	Primary Molt Score: Field
P0	44
P1	55
P2	99
P3	109
P4	92
P5	137
P6	149
P7	173
P8	162
P9	159
P10	118

Table 8: Primary molt score (lab measurement) during 2011.

	Primary Molt Score: Lab
P0	43
P1	53
P2	102
P3	105
P4	102
P5	141
P6	147
P7	184
P8	171
P9	169
P10	130

Table 9: Alular molt score for all 2011 sample white-winged doves.

	Alular Molt Score
No Molt	672
Alular 1 Molt	276
Alular 2 Molt	282
Alular 3 Molt	114

Table 10: Alular molt score categorized by buffy coverts (field measurement) for all 2011 sample white-winged doves.

	Field: Buffy Coverts Absent	Field: Buffy Coverts Present
No Molt	335	337
Alular 1 Molt	77	199
Alular 2 Molt	121	161
Alular 3 Molt	77	37

Table 11: Alular 1 Color (Black or White) categorized by buffy coverts (field measurement) using the 2011 sample of white-winged doves

	Alular 1 Color = Black	Alular 1 Color = White
Field: Buffy Coverts Absent	27	584
Field: Buffy Coverts Present	32	706

Table 12: Alular 2 Color (Black or White) categorized by buffy coverts (field measurement) using the 2011 sample of white-winged doves

	Alular 2 Color = Black	Alular 2 Color = White
Field: Buffy Coverts Absent	462	149
Field: Buffy Coverts Present	215	523

Table 13: Alular 3 Color (Black or White) categorized by buffy coverts (field measurement) using the 2011 sample of white-winged doves

	Alular 3 Color = Black	Alular 3 Color = White
Field: Buffy Coverts Absent	453	158
Field: Buffy Coverts Present	95	643

Table 14: Alular molt score categorized by buffy coverts (lab measurement) for all 2011 sample white-winged doves.

	Lab: Buffy Coverts Absent	Lab: Buffy Coverts Present
No Molt	288	383
Alular 1 Molt	29	247
Alular 2 Molt	74	208
Alular 3 Molt	49	65

Table 15: Alular 1 Color (Black or White) categorized by buffy coverts (lab measurement) using the 2011 sample of white-winged doves

	Alular 1 Color = Black	Alular 1 Color = White
Lab: Buffy Coverts Absent	22	419
Lab: Buffy Coverts Present	37	870

Table 16: Alular 2 Color (Black or White) categorized by buffy coverts (lab measurement) using the 2011 sample of white-winged doves

	Alular 2 Color = Black	Alular 2 Color = White
Lab: Buffy Coverts Absent	378	63
Lab: Buffy Coverts Present	298	609

Table 17: Alular 3 Color (Black or White) categorized by buffy coverts (lab measurement) using the 2011 sample of white-winged doves

	Alular 3 Color = Black	Alular 3 Color = White
Lab: Buffy Coverts Absent	389	52
Lab: Buffy Coverts Present	158	749

Table 18: Buffy covert (field measurement) categorization by primary molt (lab measurement) during 2011.

	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Field: Buffy Coverts Absent	11	5	13	11	16	31	46	74	122	159	121
Field: Buffy Coverts Present	32	48	89	94	86	110	101	110	49	10	9

Table 19: Buffy covert (lab measurement) categorization by primary molt (lab measurement) during 2011.

	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab: Buffy Coverts Absent	9	3	3	1	3	9	14	40	76	158	125
Lab: Buffy Coverts Present	34	50	99	104	99	132	133	144	95	11	5

Table 20: Buffy coverts (field measurements) relative to occurrence of blue eye ring (BER) based on the 2012 sample of white-winged doves

	Blue Eye Ring = No	Blue Eye Ring = Yes
Buffy Coverts = No	294	299
Buffy Coverts = Yes	421	87

Table 21: Buffy coverts (field measurements) relative to occurrence of red iris (RI) based on the 2012 sample of white-winged doves

	Red Iris = No	Red Iris = Yes
Buffy Coverts = No	464	129
Buffy Coverts = Yes	467	41

Table 22: Buffy coverts (field measurements) relative to occurrence of black bill (BB) based on the 2012 sample of white-winged doves

	Black Bill = No	Black Bill = Yes
Buffy Coverts = No	197	396
Buffy Coverts = Yes	393	115

Table 23: Buffy coverts (field measurements) relative to occurrence of red leg (RL) based on the 2012 sample of white-winged doves

	Red Leg = No	Red Leg = Yes
Buffy Coverts = No	245	348
Buffy Coverts = Yes	377	131

Table 24: Buffy covert (field measurement) relative to buffy coverts (lab measurement) for the 2012 sample of white-winged doves

	Buffy Coverts (Field) = No	Buffy Coverts (Field) = Yes
Buffy Coverts (Lab) = No	396	56
Buffy Coverts (Lab) = Yes	174	439

Table 25: Primary molt score (field measurement) during 2012.

	Primary Molt Score: Field
P0	4
P1	25
P2	37
P3	42
P4	42
P5	50
P6	64
P7	84
P8	95
P9	139
P10	95

Table 26: Primary molt score (lab measurement) during 2012.

	Primary Molt Score: Lab
P0	4
P1	28
P2	36
P3	33
P4	35
P5	52
P6	63
P7	87
P8	102
P9	148
P10	97

Table 27: Alular molt score for 2012 sample white-winged doves.

	Alular Molt Score
No Molt	342
Alular 1 Molt	108
Alular 2 Molt	141
Alular 3 Molt	91

Table 28: Alular molt score categorized by buffy coverts (field measurement) for all 2012 sample white-winged doves.

	Field: Buffy Coverts Absent	Field: Buffy Coverts Present
No Molt	211	131
Alular 1 Molt	38	70
Alular 2 Molt	78	63
Alular 3 Molt	64	27

Table 29: Alular 1 Color (Black or White) categorized by buffy coverts (field measurement) using the 2012 sample of white-winged doves

	Alular 1 Color = Black	Alular 1 Color = White
Field: Buffy Coverts Absent	33	360
Field: Buffy Coverts Present	9	283

Table 30: Alular 2 Color (Black or White) categorized by buffy coverts (field measurement) using the 2012 sample of white-winged doves

	Alular 2 Color = Black	Alular 2 Color = White
Field: Buffy Coverts Absent	325	68
Field: Buffy Coverts Present	102	190

Table 31: Alular 3 Color (Black or White) categorized by buffy coverts (field measurement) using the 2012 sample of white-winged doves

	Alular 3 Color = Black	Alular 3 Color = White
Field: Buffy Coverts Absent	453	158
Field: Buffy Coverts Present	95	643

Table 32: Alular molt score categorized by buffy coverts (lab measurement) for all 2012 sample white-winged doves.

	Lab: Buffy Coverts Absent	Lab: Buffy Coverts Present
No Molt	207	134
Alular 1 Molt	13	94
Alular 2 Molt	40	101
Alular 3 Molt	55	36

Table 33: Alular 1 Color (Black or White) categorized by buffy coverts (lab measurement) using the 2012 sample of white-winged doves

	Alular 1 Color = Black	Alular 1 Color = White
Lab: Buffy Coverts Absent	25	293
Lab: Buffy Coverts Present	16	349

Table 34: Alular 2 Color (Black or White) categorized by buffy coverts (lab measurement) using the 2012 sample of white-winged doves

	Alular 2 Color = Black	Alular 2 Color = White
Lab: Buffy Coverts Absent	287	31
Lab: Buffy Coverts Present	139	226

Table 35: Alular 3 Color (Black or White) categorized by buffy coverts (lab measurement) using the 2012 sample of white-winged doves

	Alular 3 Color = Black	Alular 3 Color = White
Field: Buffy Coverts Absent	310	83
Field: Buffy Coverts Present	57	235

Table 36: Adult or juvenile categorized by presence or absence of buffy coverts (field measurement) using the 2012 sample of white-winged doves

	A	J
Field: Buffy Coverts Absent	280	113
Field: Buffy Coverts Present	43	249

Table 37: Adult or juvenile categorized by presence or absence of buffy coverts (lab measurement) using the 2012 sample of white-winged doves

	A	J
Lab: Buffy Coverts Absent	295	23
Lab: Buffy Coverts Present	28	337

Table 38: Buffy covert (a) and age (b) categorization based on primary molt (lab measurement) during 2012.

(a) Primary molt (lab measurement) categorized by buffy covert occurrence using the 2012 sample of white-winged doves.

	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab: Buffy Coverts Absent	3	1	1	0	1	2	6	15	57	141	91
Lab: Buffy Coverts Present	1	27	35	33	34	50	56	72	45	7	5

(b) Primary molt (lab measurement) categorized by specimen age using the 2012 sample of white-winged doves.

	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Adult	3	0	0	0	0	3	6	24	65	134	88
Juvenile	1	28	36	33	35	49	57	63	37	14	9

Table 39: Age categorization (a) and logistic regression parameter estimates (b) for the model predicting the probability of a bird being an adult (where adult is designated as a success) based on the color (W=white or B=black) of the distal alular (A1) feather.

(a) Alular 1 Color (Black or White) categorized by specimen age using the 2012 sample of white-winged doves

	Black A1	White A1
Adult	27	296
Juvenile	15	347

(b) Logistic regression model parameter estimates (SE) relating A1 color to specimen age.

	Estimate	Std. Error
(Intercept)	0.588	0.322
A1ColorWhite A1	-0.747	0.332

Table 40: Age categorization (a) and logistic regression parameter estimates (b) for the model predicting the probability of a bird being an adult (where adult is designated as a success) based on the color (W=white or B=black) of the distal alular (A2) feather.

(a) Alular 2 Color (Black or White) categorized by specimen age using the 2012 sample of white-winged doves

	Black A2	White A2
Adult	292	31
Juvenile	135	227

(b) Logistic regression model parameter estimates (SE) relating A2 color to specimen age.

	Estimate	Std. Error
(Intercept)	0.771	0.104
A2ColorWhite A2	-2.762	0.218

Table 41: Age categorization (a) and logistic regression parameter estimates (b) for the model predicting the probability of a bird being an adult (where adult is designated as a success) based on the color (W=white or B=black) of the distal alular (A3) feather.

(a) Alular 3 Color (Black or White) categorized by specimen age using the 2012 sample of white-winged doves

	Black A3	White A3
Adult	304	19
Juvenile	63	299

(b) Logistic regression model parameter estimates (SE) relating A3 color to specimen age.

	Estimate	Std. Error
(Intercept)	1.574	0.138
A3ColorWhite A3	-4.330	0.274

Table 42: Age categorization (a) and logistic regression parameter estimates (b) for the model predicting the probability of a bird being an adult (where adult is designated as a success) based on the presence or absence of buffy coverts as measured in the lab.

(a) Buffy coverts (lab measurement) categorized by specimen age using the 2012 sample of white-winged doves.

	Lab: Buffy Coverts Absent	Lab: Buffy Coverts Present
Adult	295	28
Juvenile	23	337

(b) Logistic regression model parameter estimates (SE) relating buffy covert presence/absense to specimen age using the 2012 sample of white-winged doves.

	Estimate	Std. Error
(Intercept)	2.551	0.216
BCLLab: Buffy Coverts Present	-5.039	0.292

Table 43: Summary counts by group for 2011 sample of white-winged doves.

	Laboratory Primary Molt	Buffy Coverts	Distal Alular Color	Frequency
1	P0	0	B	10
2	P0	0	W	1
3	P0	1	B	4
4	P0	1	W	36
5	P0	1		1
6	P1	0	B	2
7	P1	0	W	4
8	P1	0		1
9	P1	1	W	52
10	P1	1		2
11	P2	0	W	3
12	P2	1	B	4
13	P2	1	W	119
14	P2	1		2
15	P3	0	W	1
16	P3	1	B	6
17	P3	1	W	144
18	P3	1		7
19	P4	0	W	4
20	P4	0		2
21	P4	1	B	5
22	P4	1	W	156
23	P4	1		8
24	P5	0	B	4
25	P5	0	W	12
26	P5	0		1
27	P5	1	B	18
28	P5	1	W	192
29	P5	1		11
30	P5		B	1
31	P6	0	B	12
32	P6	0	W	15
33	P6	0		1
34	P6	1	B	28
35	P6	1	W	209
36	P6	1		13
37	P7	0	B	47
38	P7	0	W	23
39	P7	0		3
40	P7	1	B	80
41	P7	1	W	143
42	P7	1		8
43	P8	0	B	120
44	P8	0	W	16
45	P8	0		1
46	P8	1	B	148
47	P8	1	W	25
48	P8	1		5
49	P9	0	B	209
50	P9	0	W	3
51	P9	0		7
52	P9	1	B	17
53	P10	0	B	132
54	P10	0	W	2
55	P10	0		3
56	P10	1	B	1
57	P10	1	W	6
58		0		6
59		1	B	1
60			B	1
61				1

Table 44: Summary counts by group for 2011 sample of white-winged doves with empty data cells removed.

	Laboratory Primary Molt	Buffy Coverts	Distal Alular Color	Frequency
1	P0	0	B	10
2	P0	0	W	1
3	P0	1	B	4
4	P0	1	W	36
5	P1	0	B	2
6	P1	0	W	4
7	P1	1	W	52
8	P2	0	W	3
9	P2	1	B	4
10	P2	1	W	119
11	P3	0	W	1
12	P3	1	B	6
13	P3	1	W	144
14	P4	0	W	4
15	P4	1	B	5
16	P4	1	W	156
17	P5	0	B	4
18	P5	0	W	12
19	P5	1	B	18
20	P5	1	W	192
21	P6	0	B	12
22	P6	0	W	15
23	P6	1	B	28
24	P6	1	W	209
25	P7	0	B	47
26	P7	0	W	23
27	P7	1	B	80
28	P7	1	W	143
29	P8	0	B	120
30	P8	0	W	16
31	P8	1	B	148
32	P8	1	W	25
33	P9	0	B	209
34	P9	0	W	3
35	P9	1	B	17
36	P10	0	B	132
37	P10	0	W	2
38	P10	1	B	1
39	P10	1	W	6

Table 45

Table 46: Summary counts by group for 2012 sample of white-winged doves.

	Laboratory Primary Molt	Buffy Coverts	Distal Alular Color	Frequency
1	P0	0.00	B	4
2	P0	1.00	W	1
3	P1	0.00	W	1
4	P1	1.00	W	29
5	P1	1.00		1
6	P2	0.00	W	1
7	P2	1.00	W	44
8	P2	1.00		1
9	P3	0.00	B	2
10	P3	1.00	B	2
11	P3	1.00	W	45
12	P3	1.00		1
13	P4	0.00	W	2
14	P4	1.00	B	2
15	P4	1.00	W	62
16	P5	0.00	B	2
17	P5	1.00	B	5
18	P5	1.00	W	79
19	P5	1.00		1
20	P5		B	1
21	P6	0.00	B	5
22	P6	0.00	W	4
23	P6	0.00		1
24	P6	1.00	B	7
25	P6	1.00	W	83
26	P6	1.00		7
27	P6		B	1
28	P7	0.00	B	17
29	P7	0.00	W	3
30	P7	1.00	B	45
31	P7	1.00	W	90
32	P7	1.00		3
33	P7		B	1
34	P8	0.00	B	106
35	P8	0.00	W	7
36	P8	0.00		3
37	P8	1.00	B	75
38	P8	1.00	W	12
39	P8	1.00		4
40	P8			1
41	P9	0.00	B	183
42	P9	0.00	W	11
43	P9	0.00		1
44	P9	1.00	B	5
45	P9	1.00	W	2
46	P10	0.00	B	97
47	P10	0.00	W	1
48	P10	0.00		1
49	P10	1.00	B	1
50	P10	1.00	W	6
51	P10		W	1
52				31

Table 47: Summary counts by group for 2012 sample of white-winged doves with empty data cells removed.

	Laboratory Primary Molt	Buffy Coverts	Distal Alular Color	Frequency
1	P0	0.00	B	4
2	P0	1.00	W	1
3	P1	0.00	W	1
4	P1	1.00	W	29
5	P2	0.00	W	1
6	P2	1.00	W	44
7	P3	0.00	B	2
8	P3	1.00	B	2
9	P3	1.00	W	45
10	P4	0.00	W	2
11	P4	1.00	B	2
12	P4	1.00	W	62
13	P5	0.00	B	2
14	P5	1.00	B	5
15	P5	1.00	W	79
16	P6	0.00	B	5
17	P6	0.00	W	4
18	P6	1.00	B	7
19	P6	1.00	W	83
20	P7	0.00	B	17
21	P7	0.00	W	3
22	P7	1.00	B	45
23	P7	1.00	W	90
24	P8	0.00	B	106
25	P8	0.00	W	7
26	P8	1.00	B	75
27	P8	1.00	W	12
28	P9	0.00	B	183
29	P9	0.00	W	11
30	P9	1.00	B	5
31	P9	1.00	W	2
32	P10	0.00	B	97
33	P10	0.00	W	1
34	P10	1.00	B	1
35	P10	1.00	W	6

Figures

Figure 1: 2011 and 2012 White-winged dove collection locations.

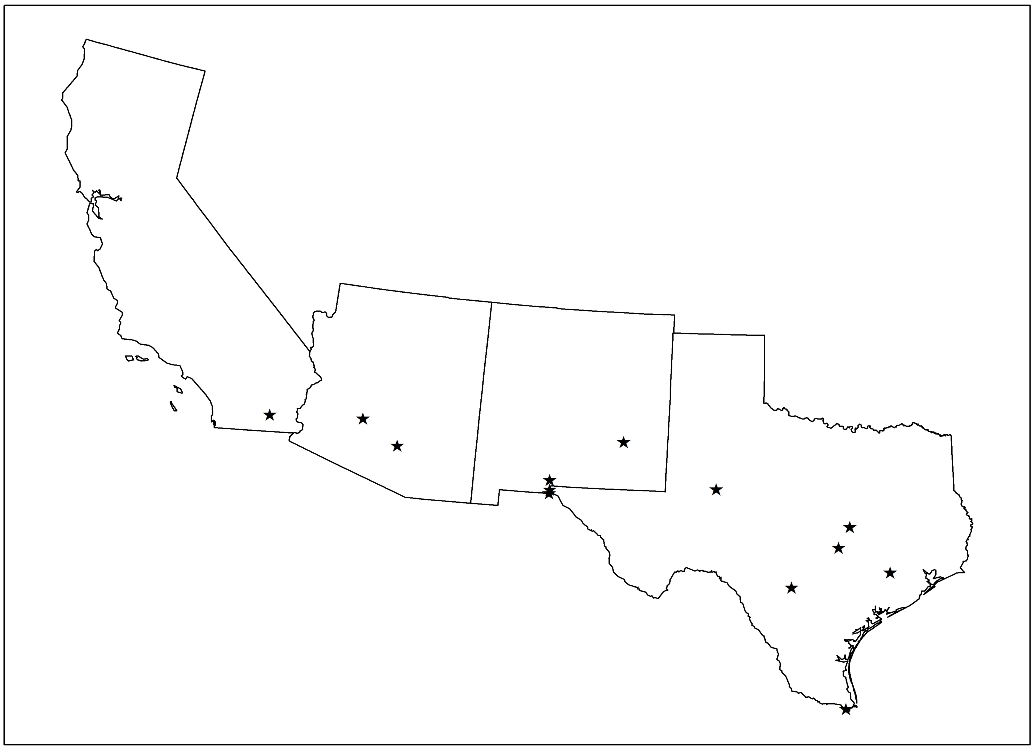


Figure 2: Primary molt score measured in field and lab settings using the 2011 sample of white-winged doves.

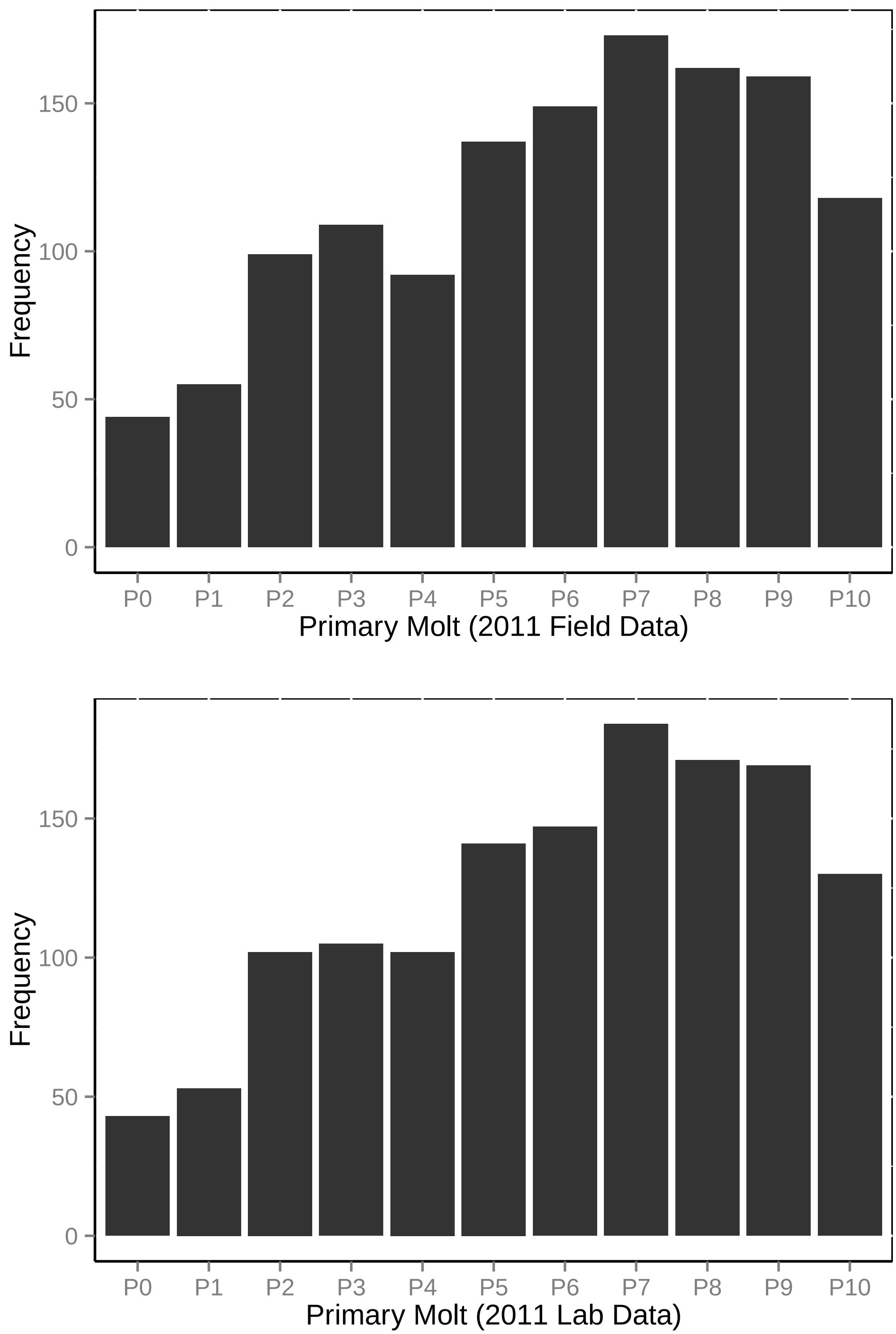


Figure 3: Primary molt score (field measurement) by buffy coverts (field measurement) using the 2011 sample of white-winged doves.

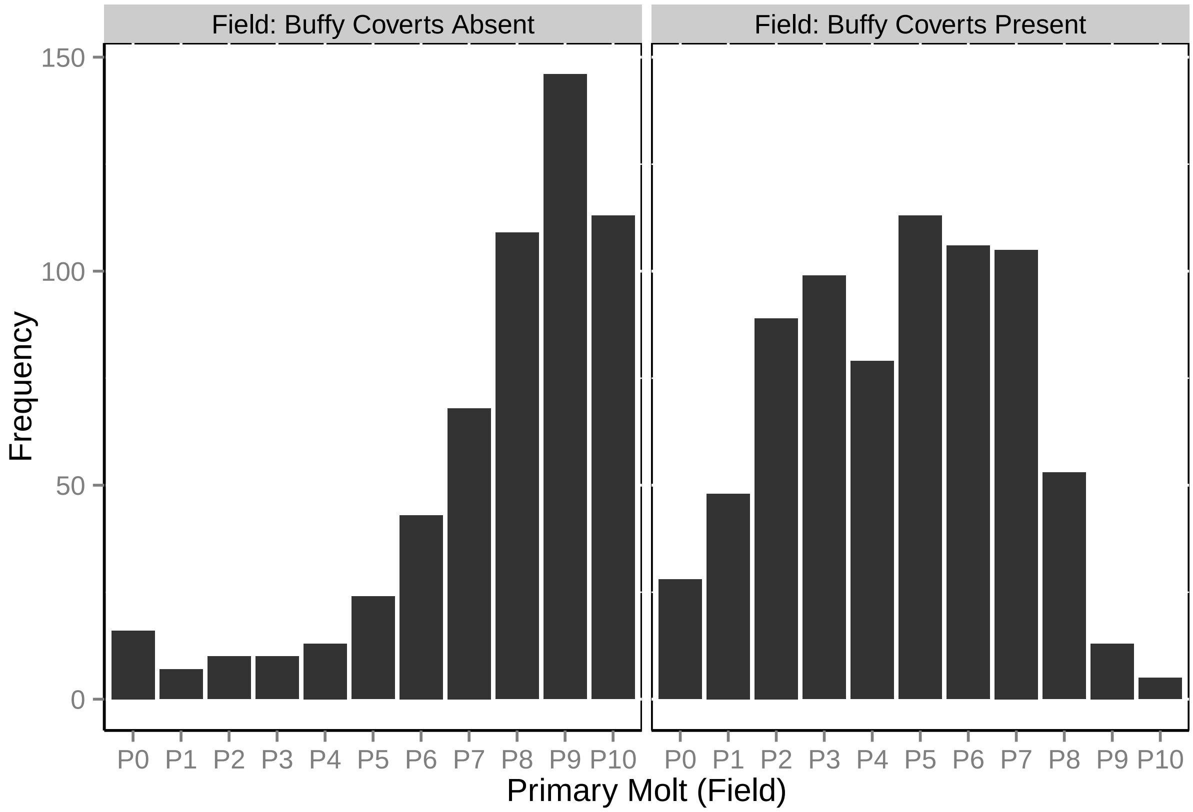


Figure 4: Primary molt score (lab measurement) by presence/absense of buffy coverts (field measurement) using the 2011 sample of white-winged doves.

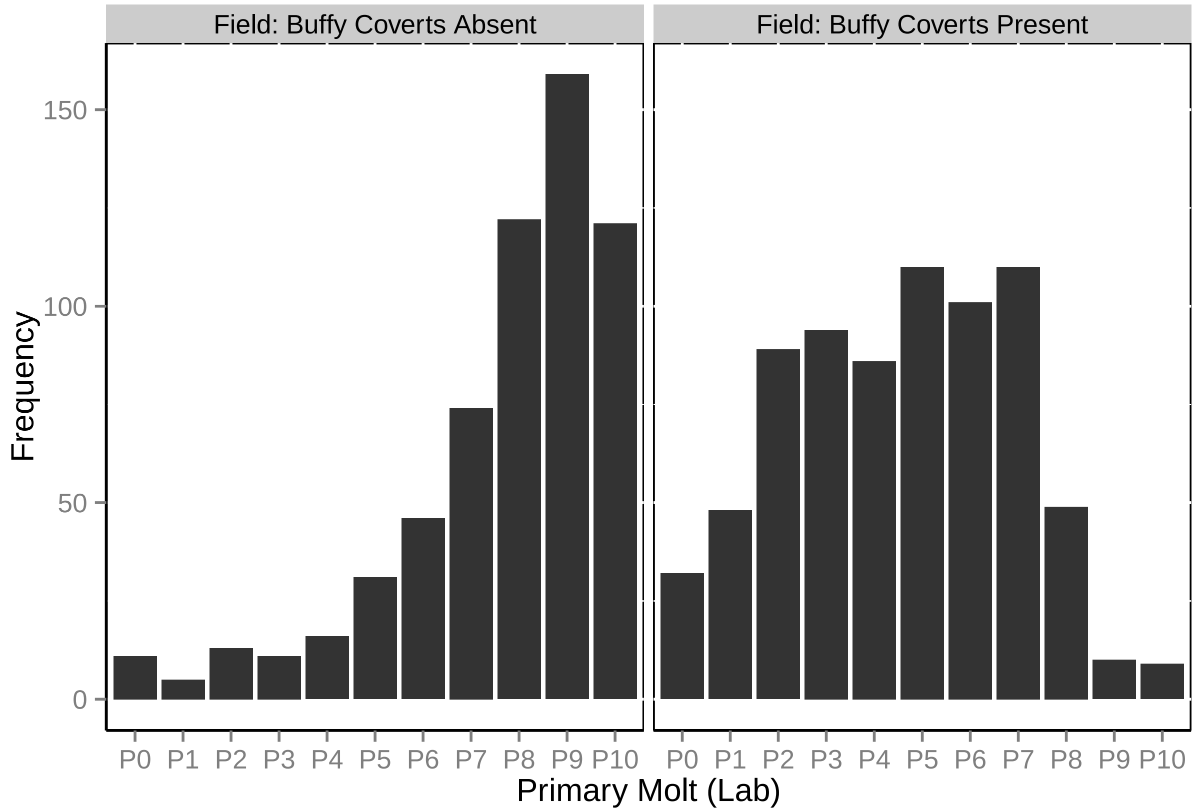


Figure 5: Primary molt score (lab measurement) by presence/absense of buffy coverts (lab measurement) using the 2011 sample of white-winged doves.

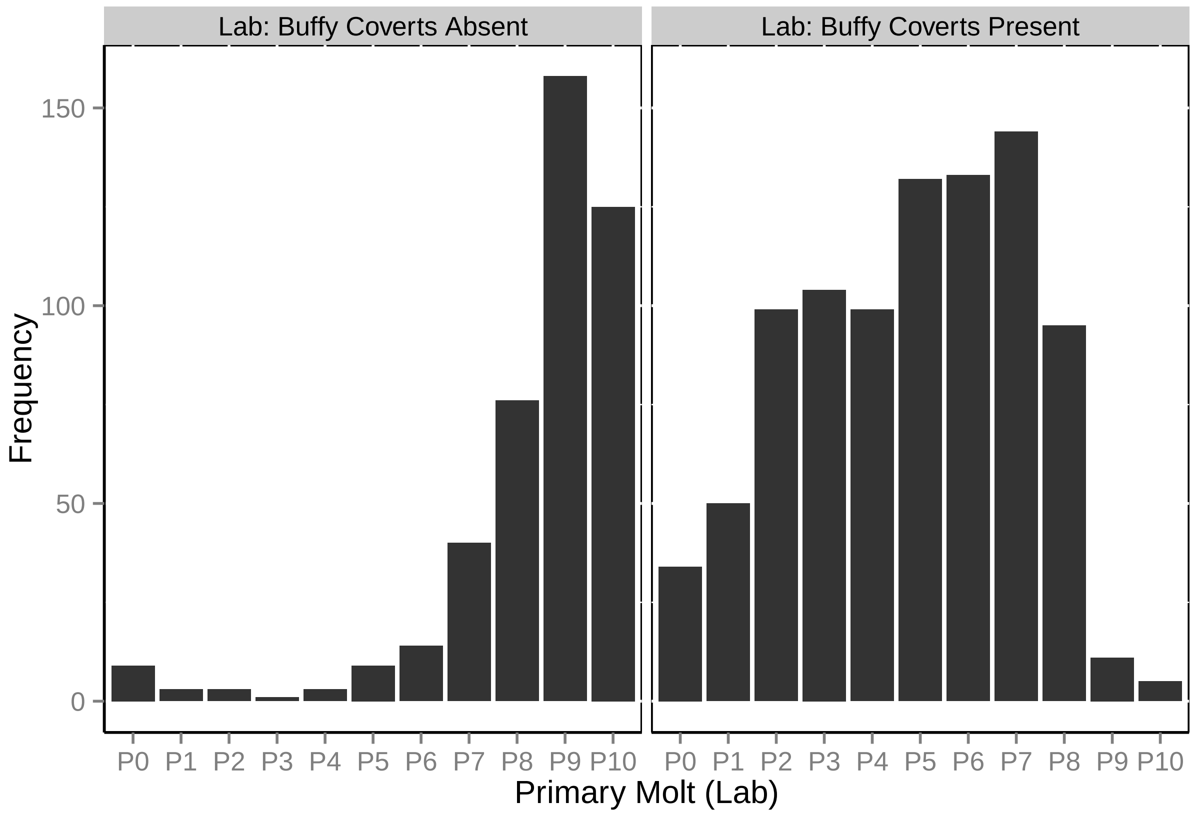
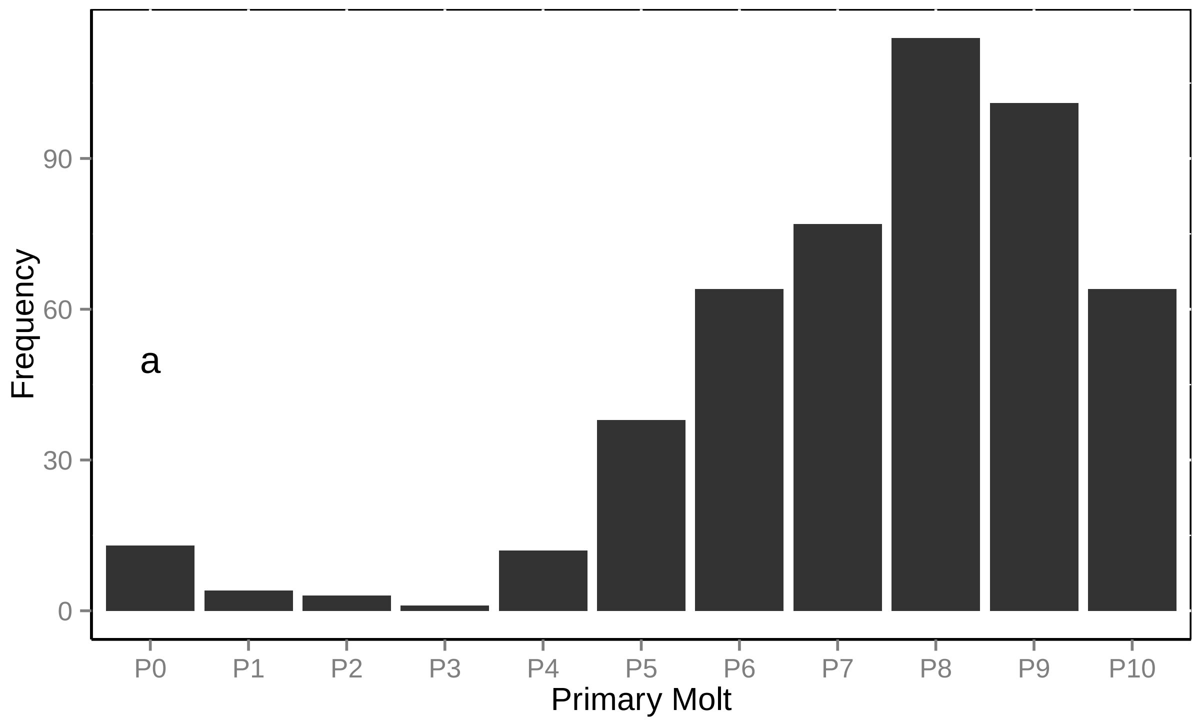


Figure 6: Primary molt score (field measurement) for harvested doves that had all 4 metrics assumed to describe age (a) and those with none of the 4 metrics (b) based on 2011 sampling.



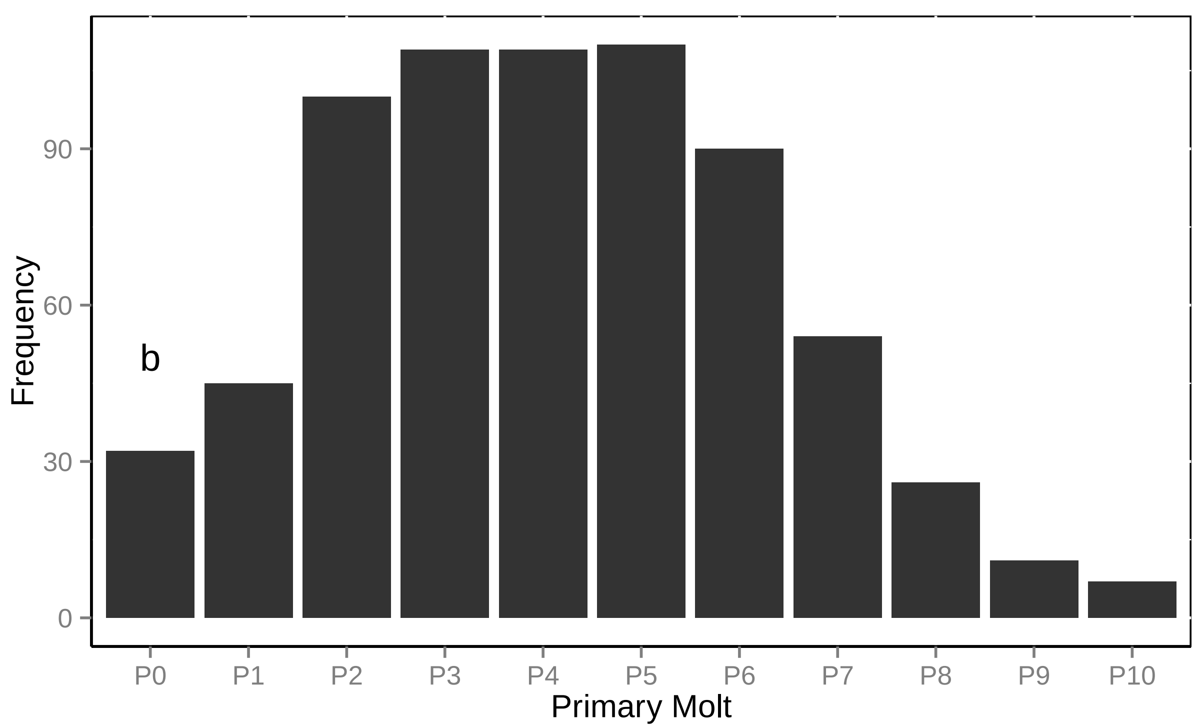
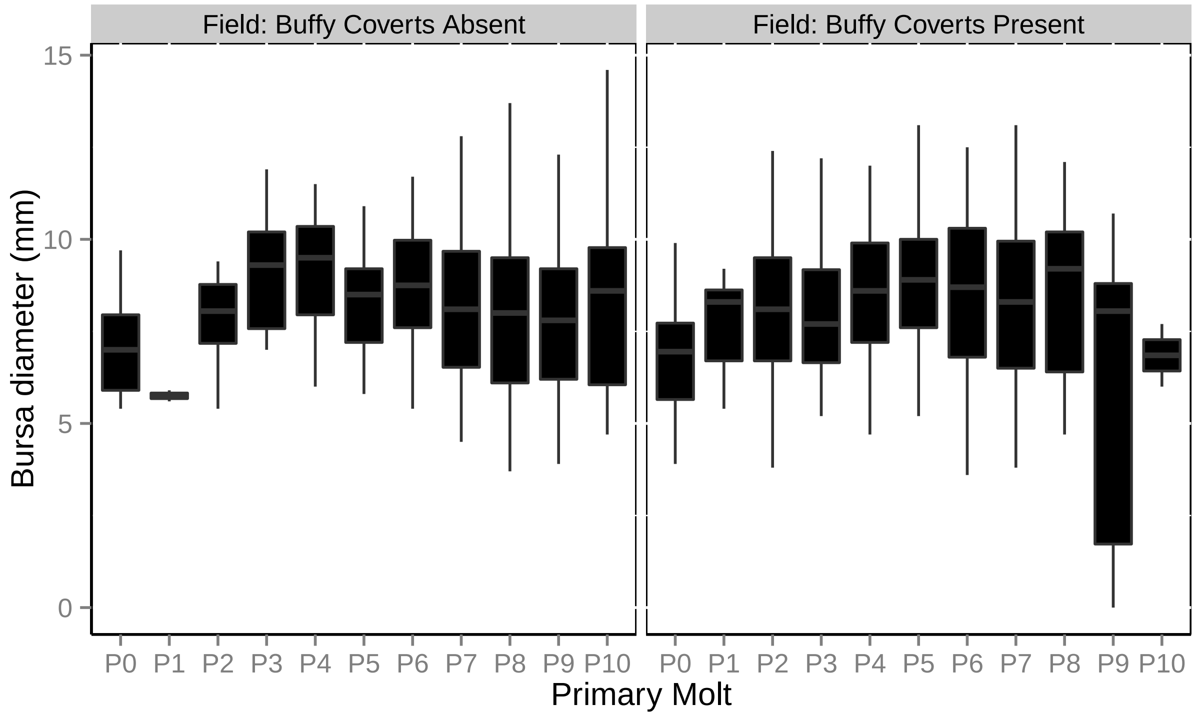


Figure 7: Bursa of Fabricus measurements by primary molt score (field measurement) and buffy coverts (field measurement) for harvested doves based on 2011 sampling.



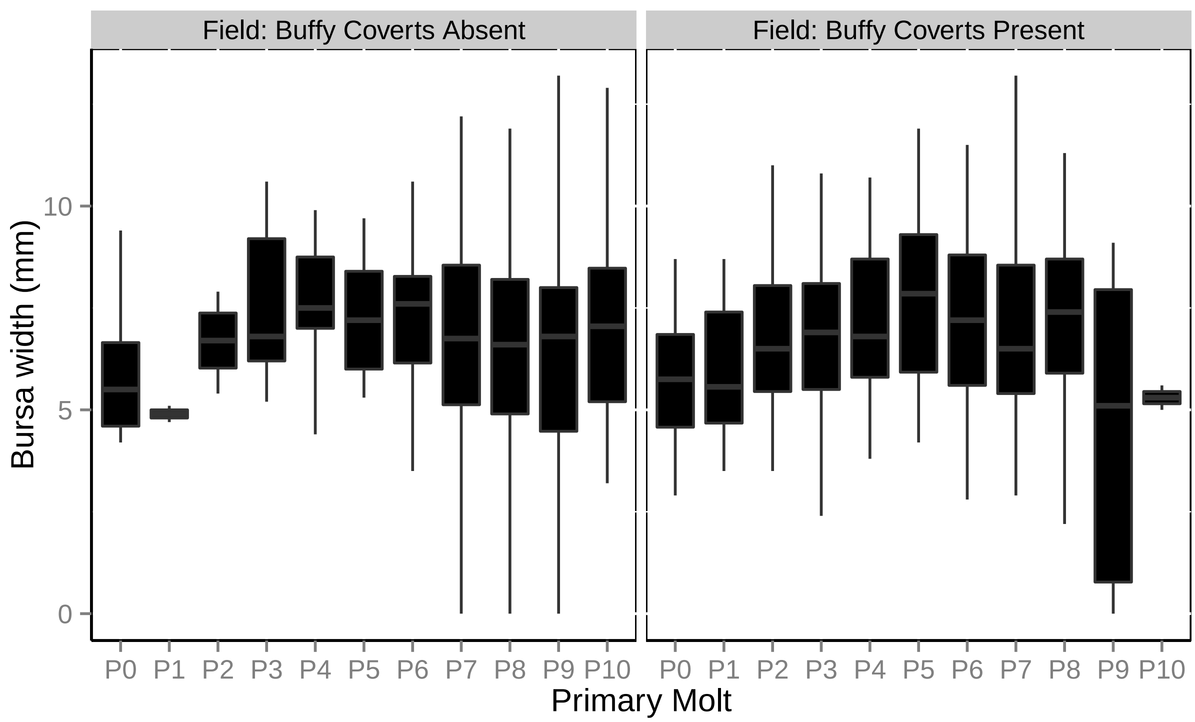


Figure 8: Bursa of Fabricus diameter relative to primary molt score (field measurement) and buffy coverts (field measurement) for 2011 harvested white-winged doves.

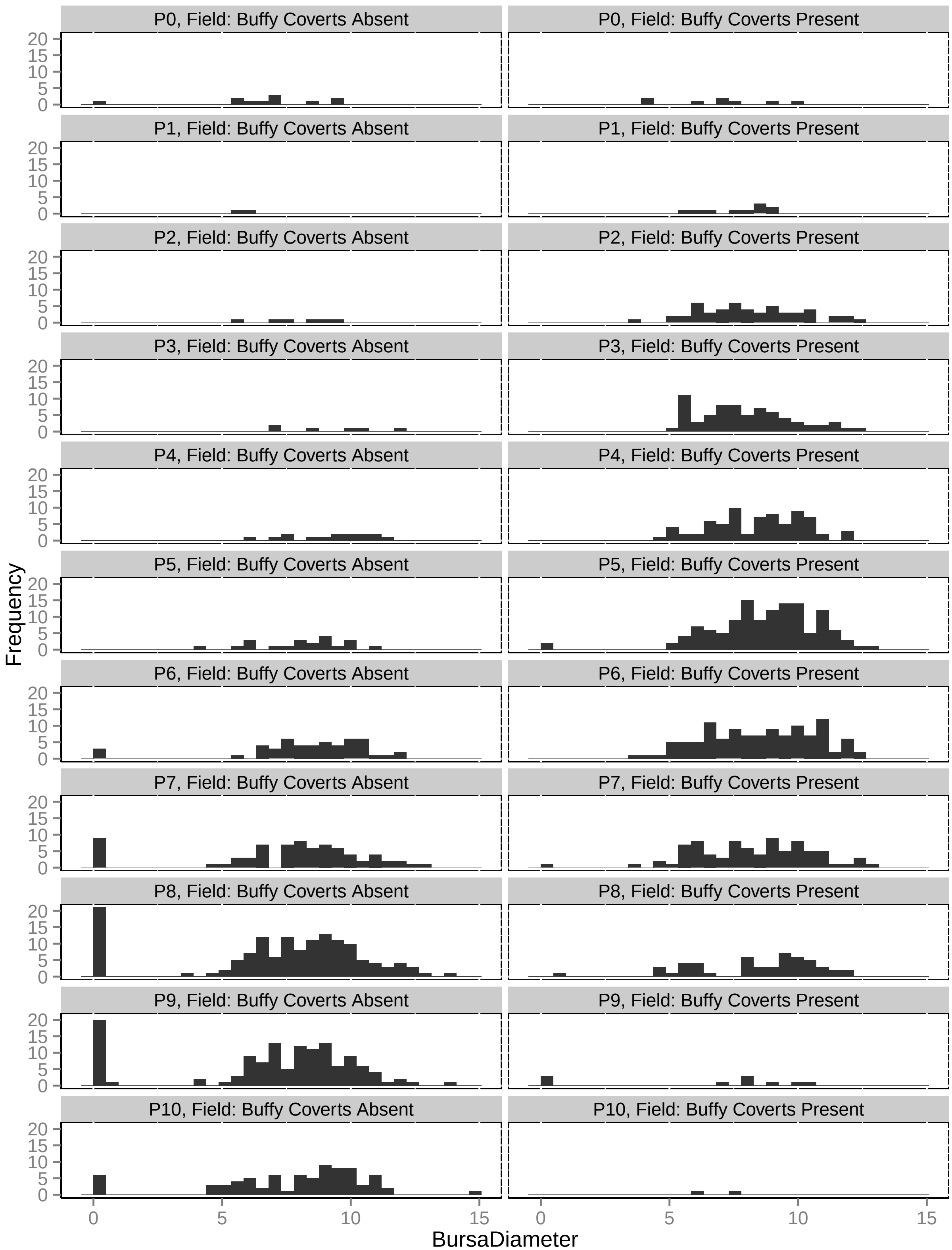


Figure 9: Bursa of Fabricus width relative to primary molt score (field measurement) and buffy coverts (field measurement) for 2011 harvested white-winged doves.

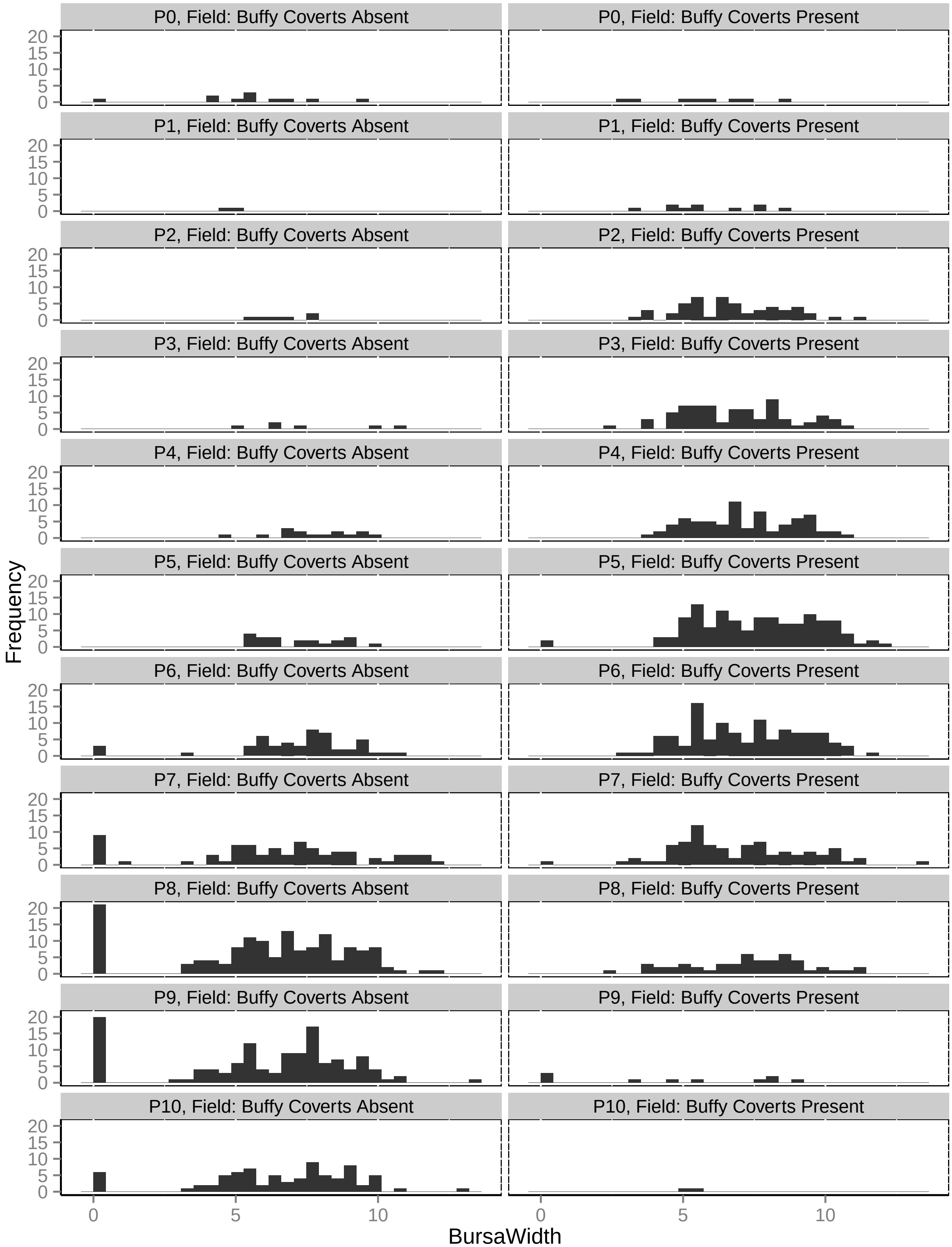


Figure 10: Bursa of Fabricus diameter relative to primary molt score (lab measurement) and buffy coverts (lab measurement) for 2011 harvested white-winged doves.

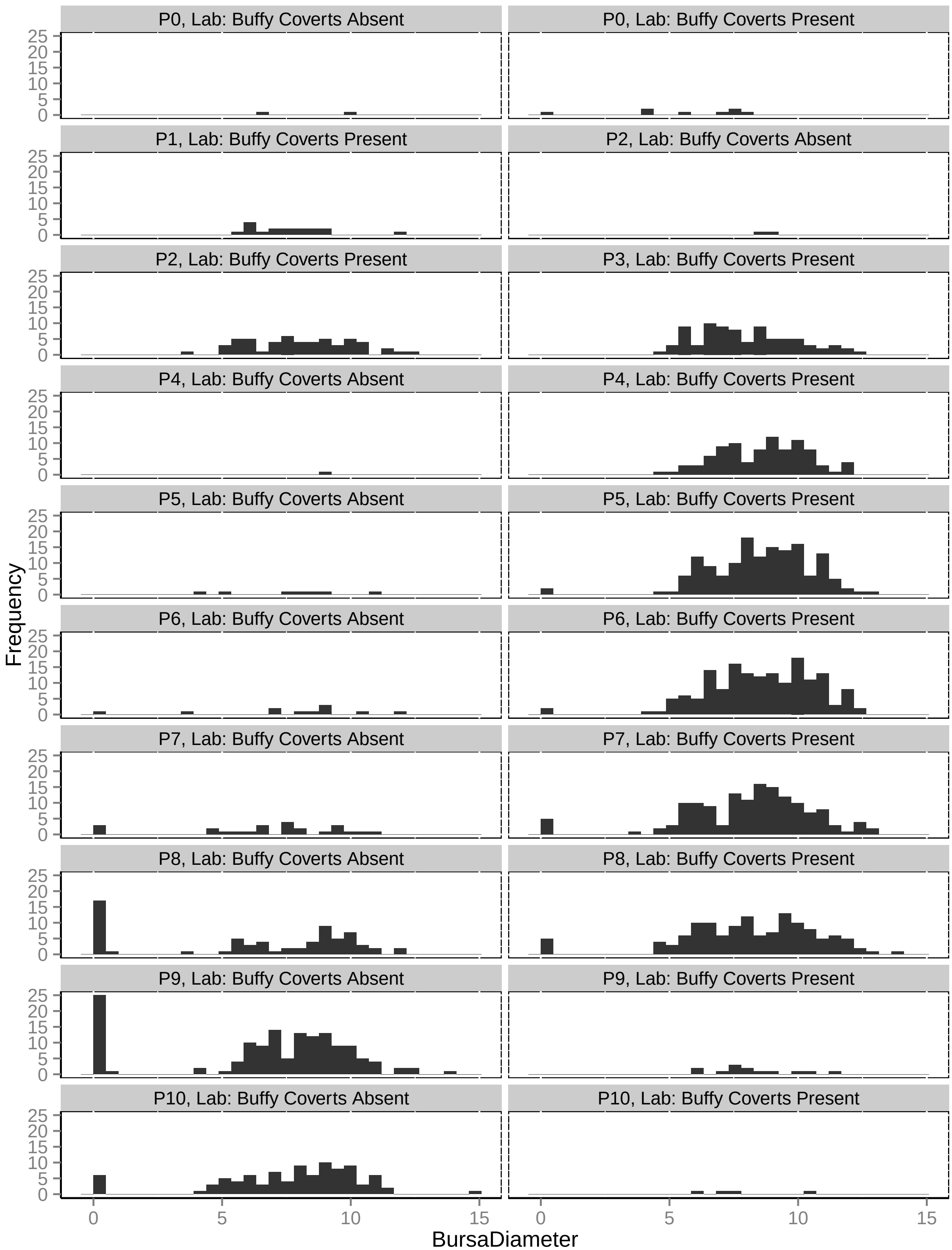


Figure 11: Bursa of Fabricus width relative to primary molt score (lab measurement) and buffy coverts (lab measurement) for 2011 harvested white-winged doves.

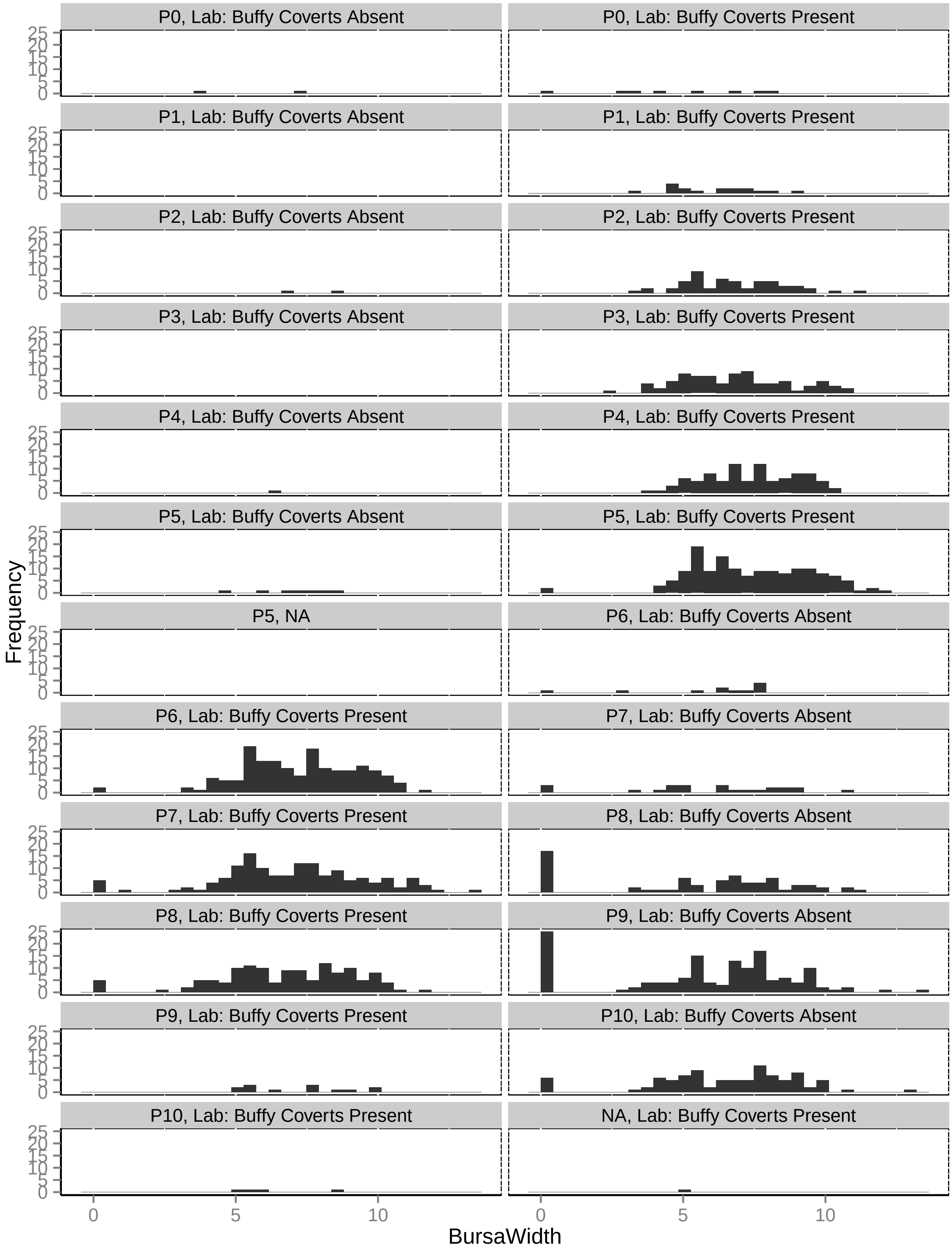


Figure 12: Primary molt score relative to buffy coverts (field measurement) and A1 alulur feather color using the 2011 sample of white-winged doves.

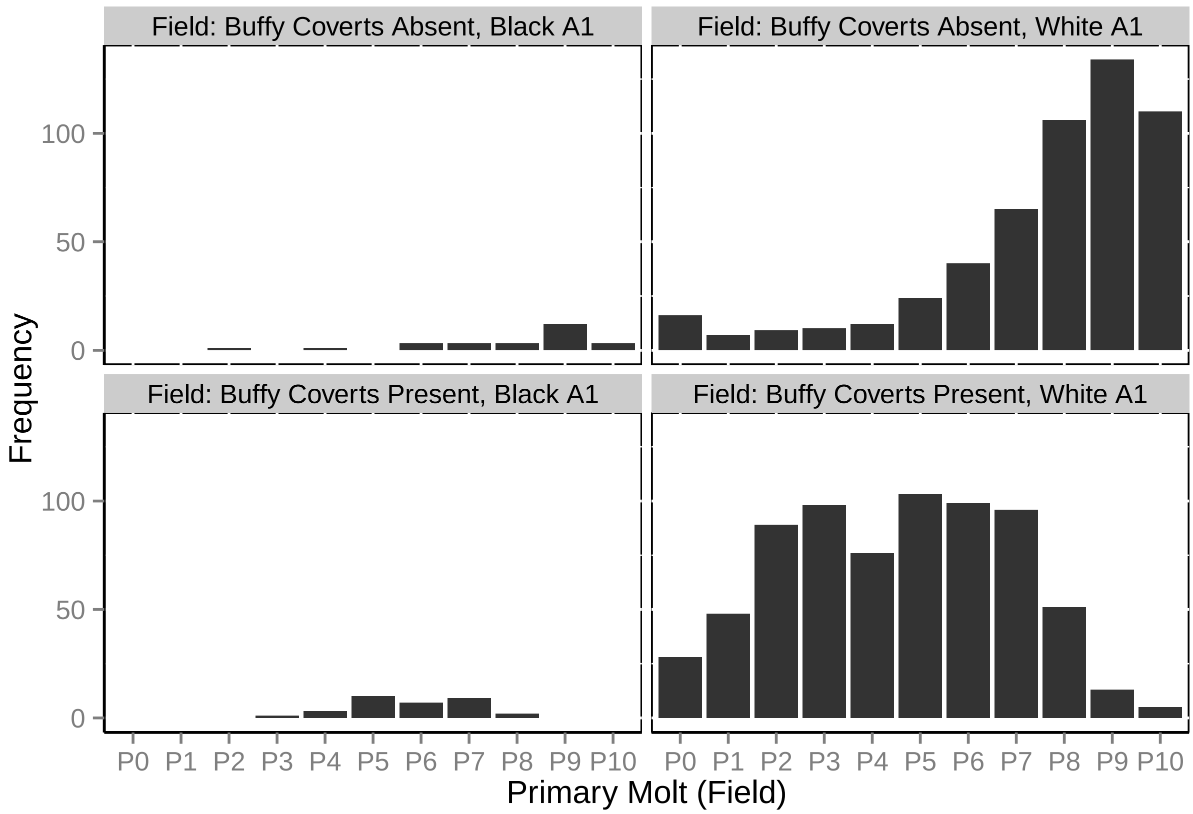


Figure 13: Primary molt score relative to buffy coverts (field measurement) and A2 alulur feather color using the 2011 sample of white-winged doves

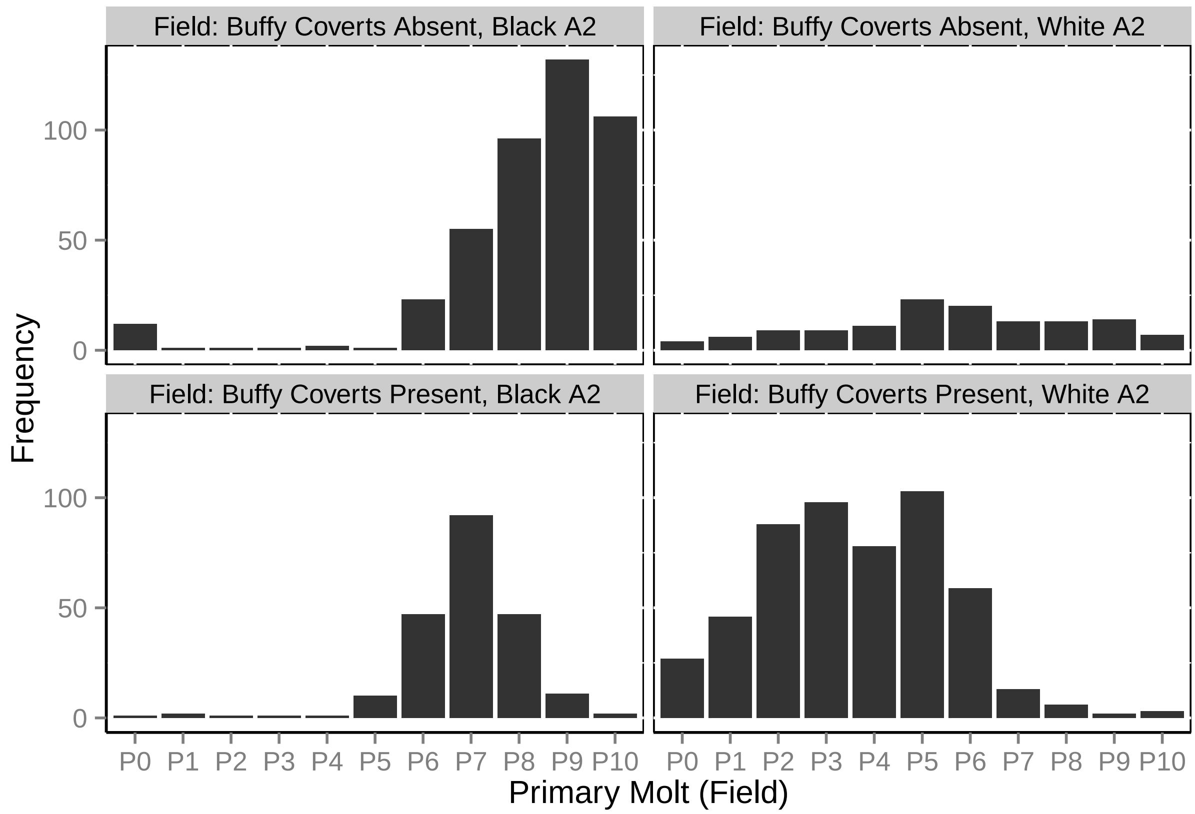


Figure 14: Primary molt score relative to buffy coverts (field measurement) and A3 alulur feather color using the 2011 sample of white-winged doves

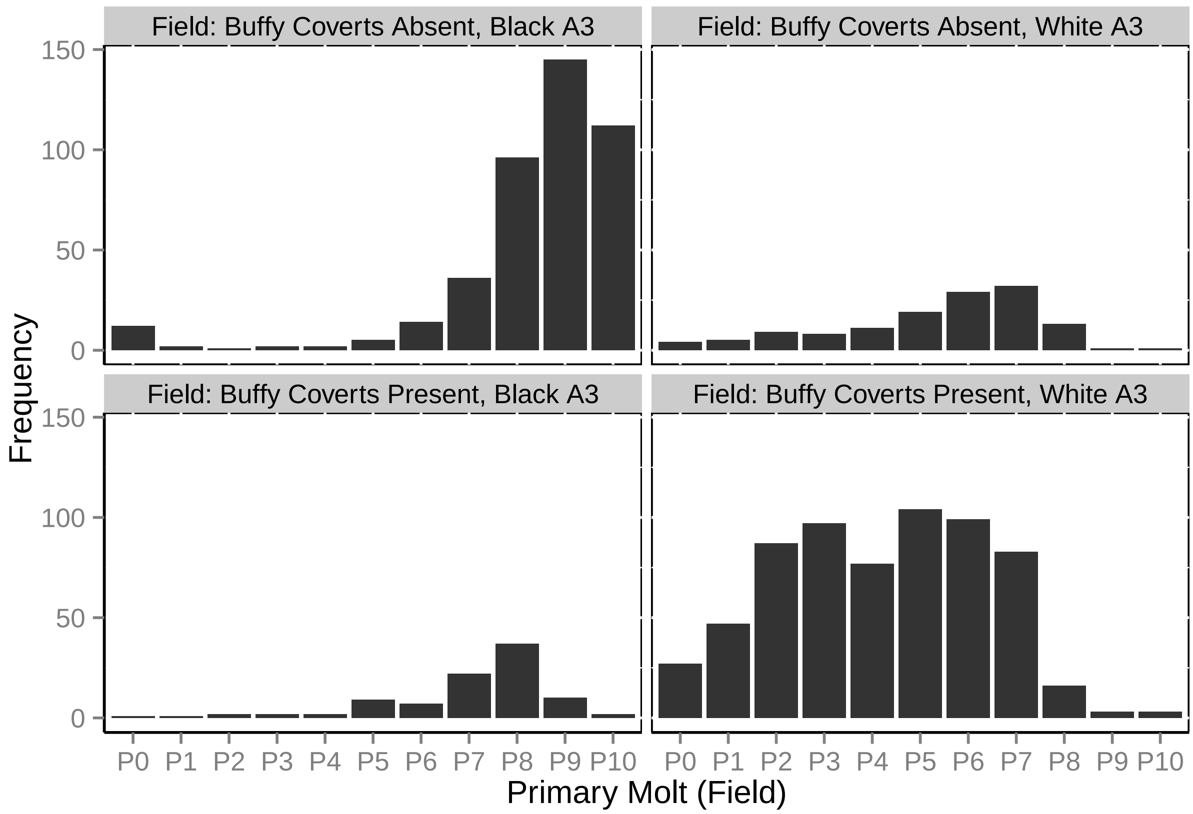


Figure 15: Primary molt score relative to buffy coverts (lab measurement) and A1 alulur feather color using the 2011 sample of white-winged doves.

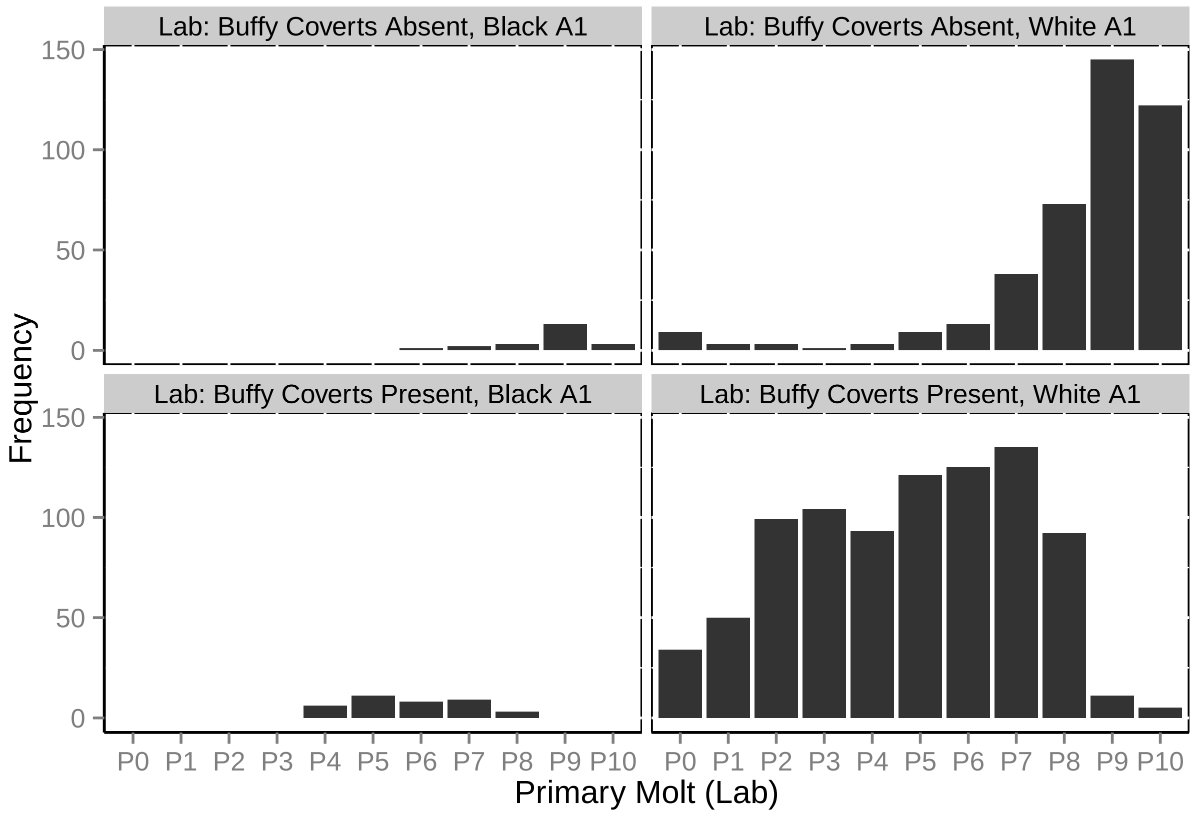


Figure 16: Primary molt score relative to buffy coverts (lab measurement) and A2 alulur feather color using the 2011 sample of white-winged doves

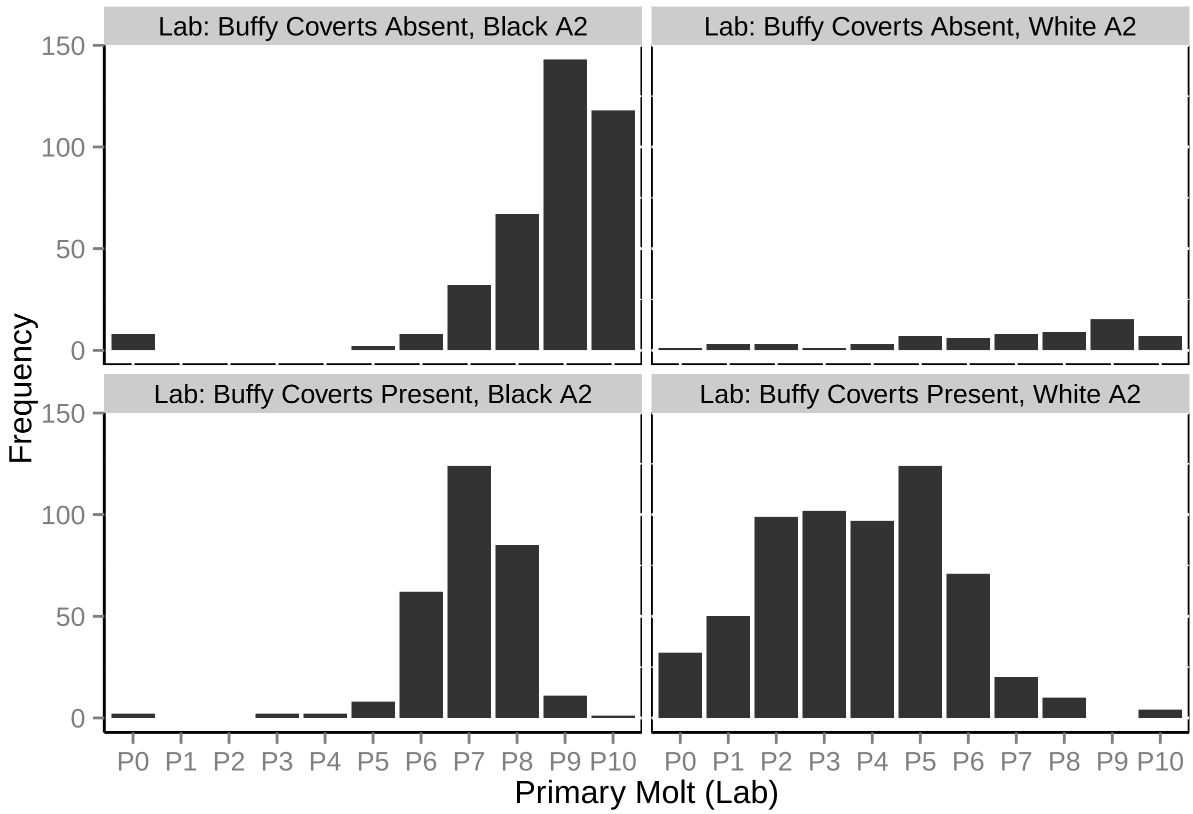


Figure 17: Primary molt score relative to buffy coverts (field measurement) and A3 alulur feather color using the 2011 sample of white-winged doves

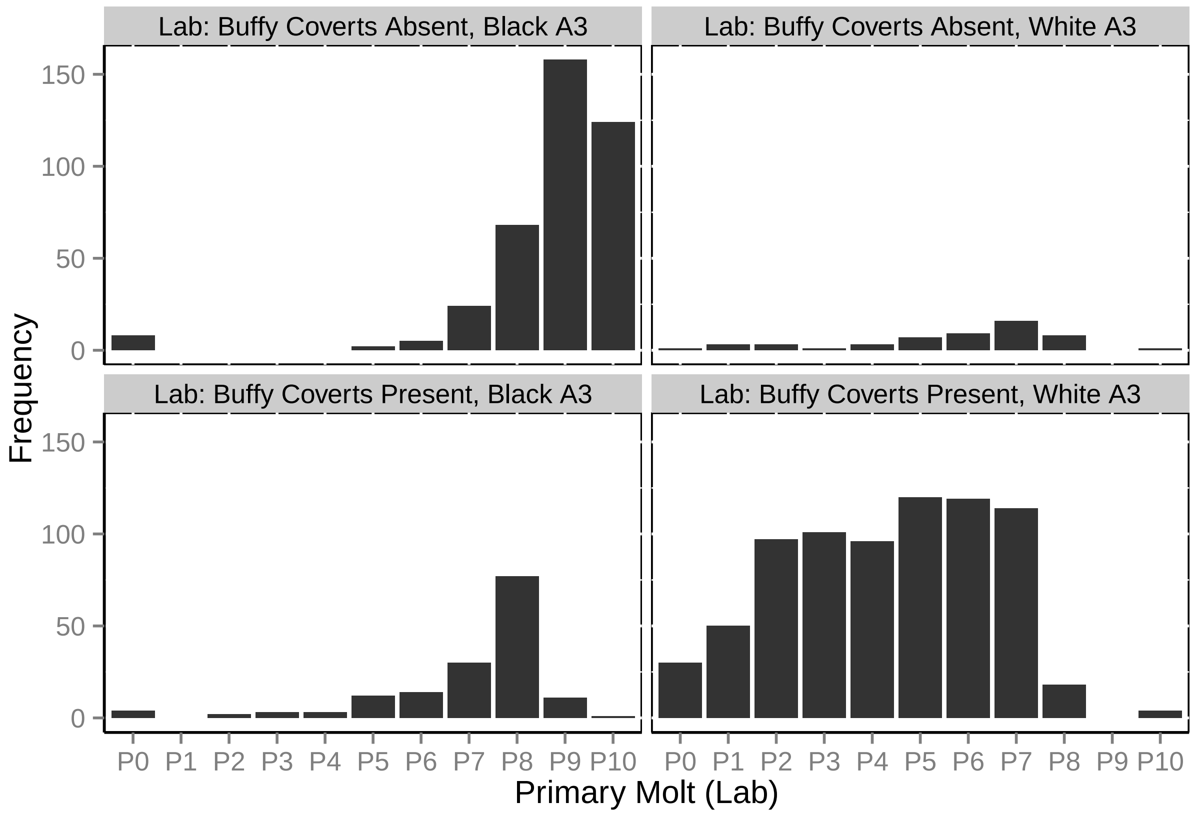


Figure 18: Primary molt score (field measurement) for harvested doves that had all 4 metrics assumed to describe age (a) and those with none of the 4 metrics (b) based on 2012 sampling.

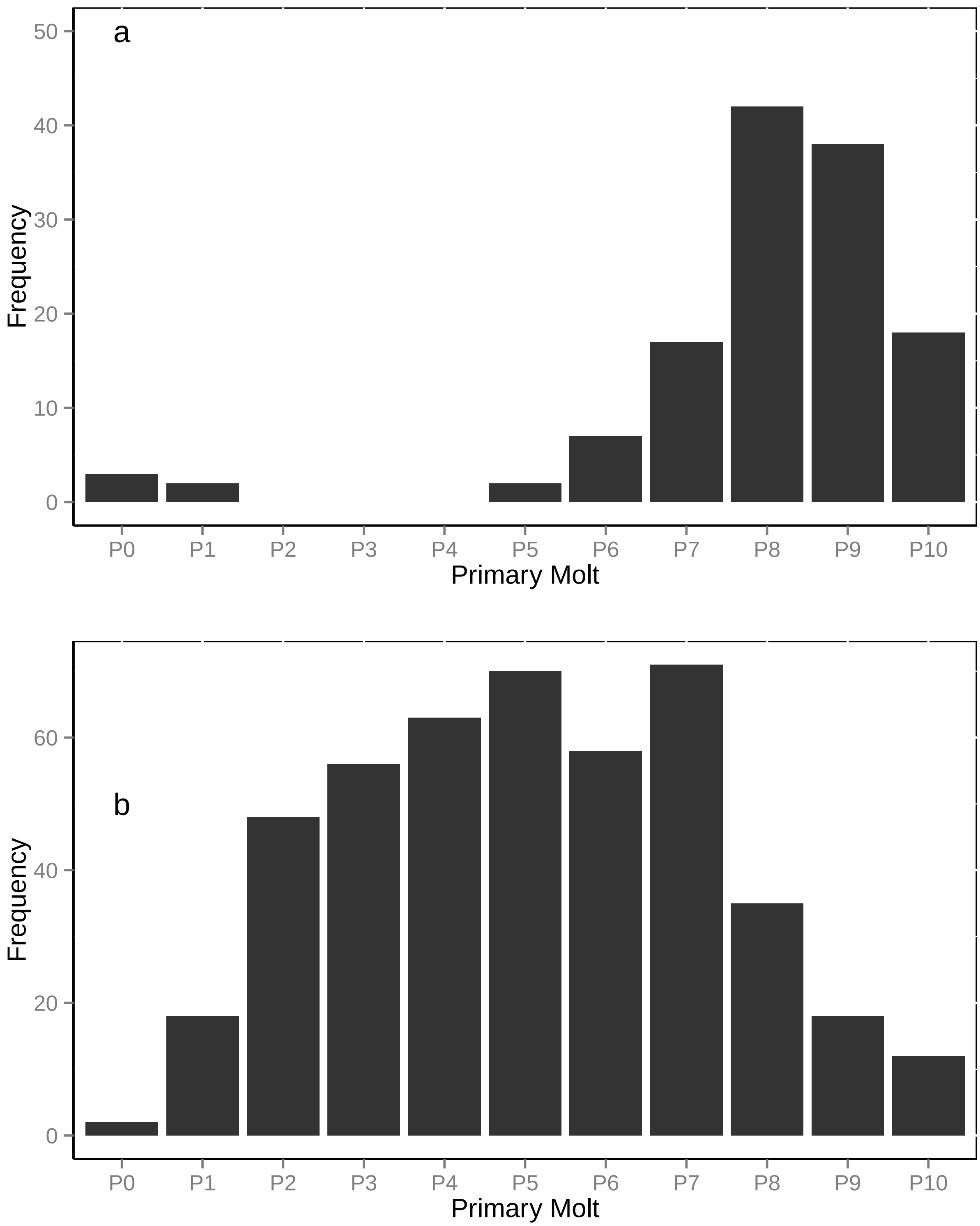
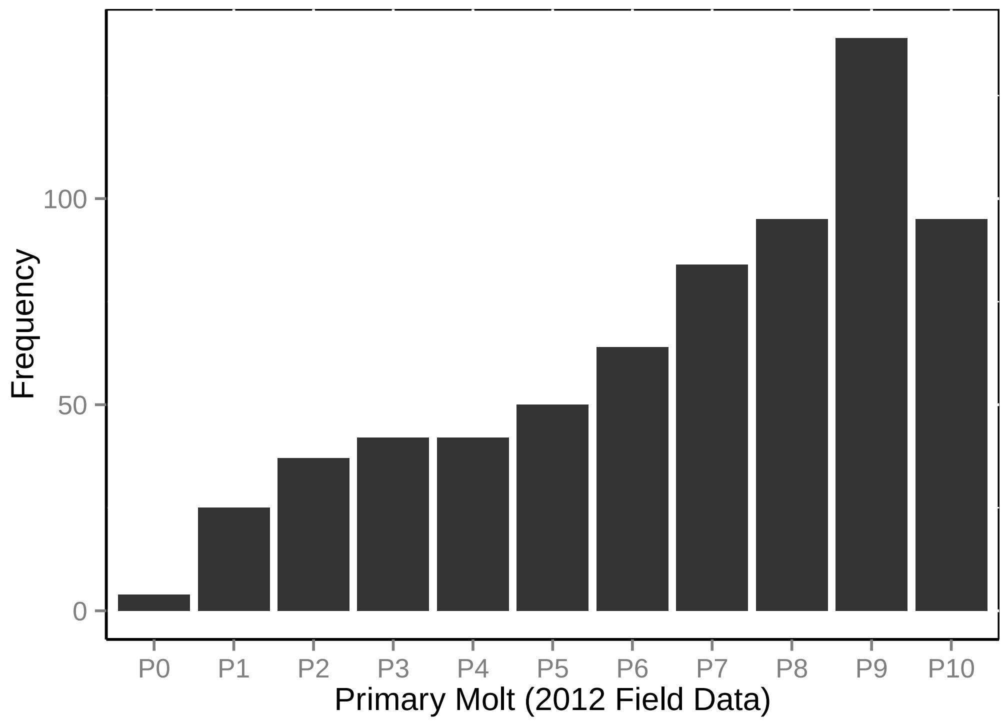


Figure 19: Primary molt score measured in field and lab settings using the 2012 sample of white-winged doves.



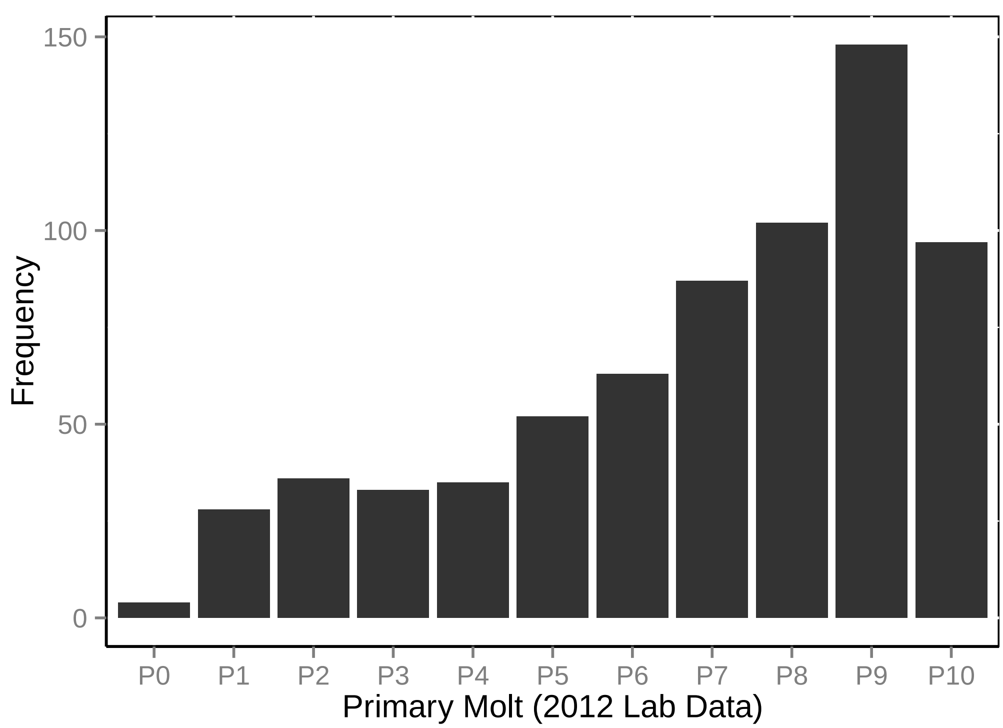


Figure 20: Primary molt score (lab measurement) by presence/absense of buffy coverts (lab measurement) using the 2012 sample of white-winged doves.

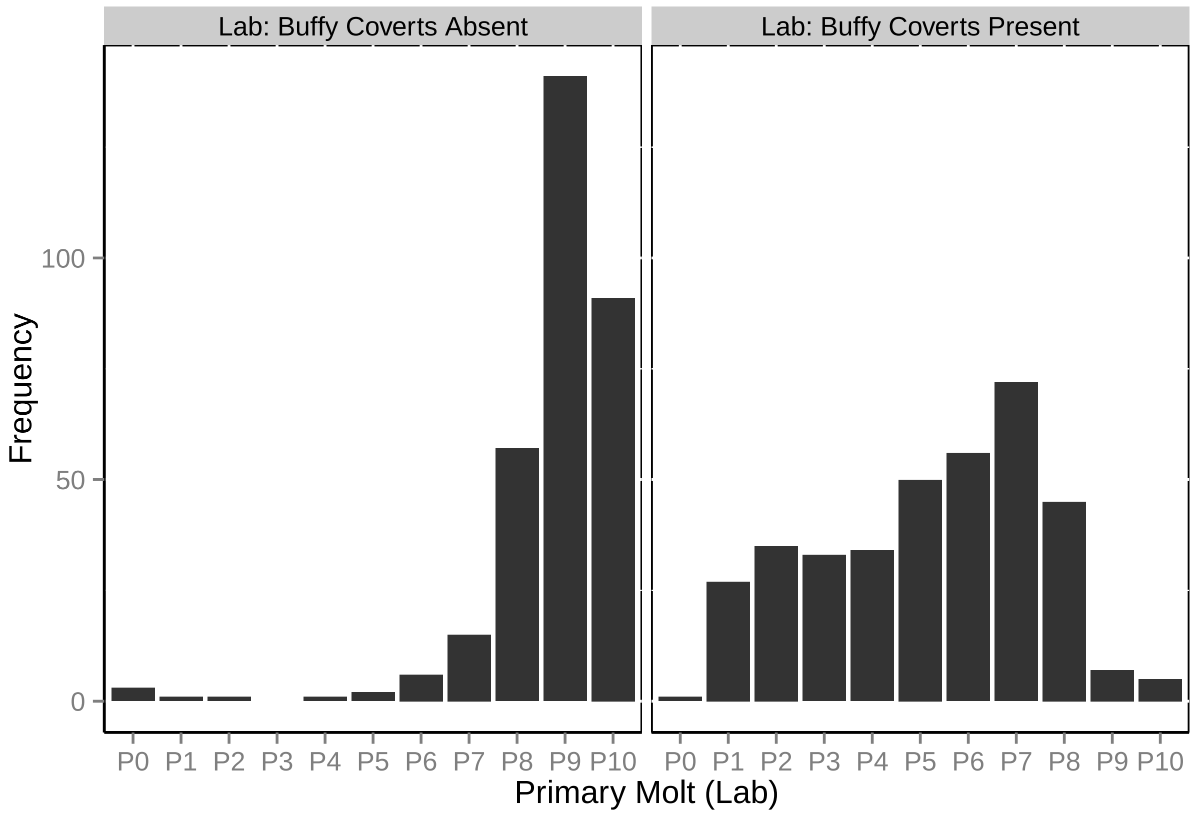


Figure 21: Primary molt score (lab measurement) by categorization of adult or juvenile using the 2012 sample of white-winged doves.

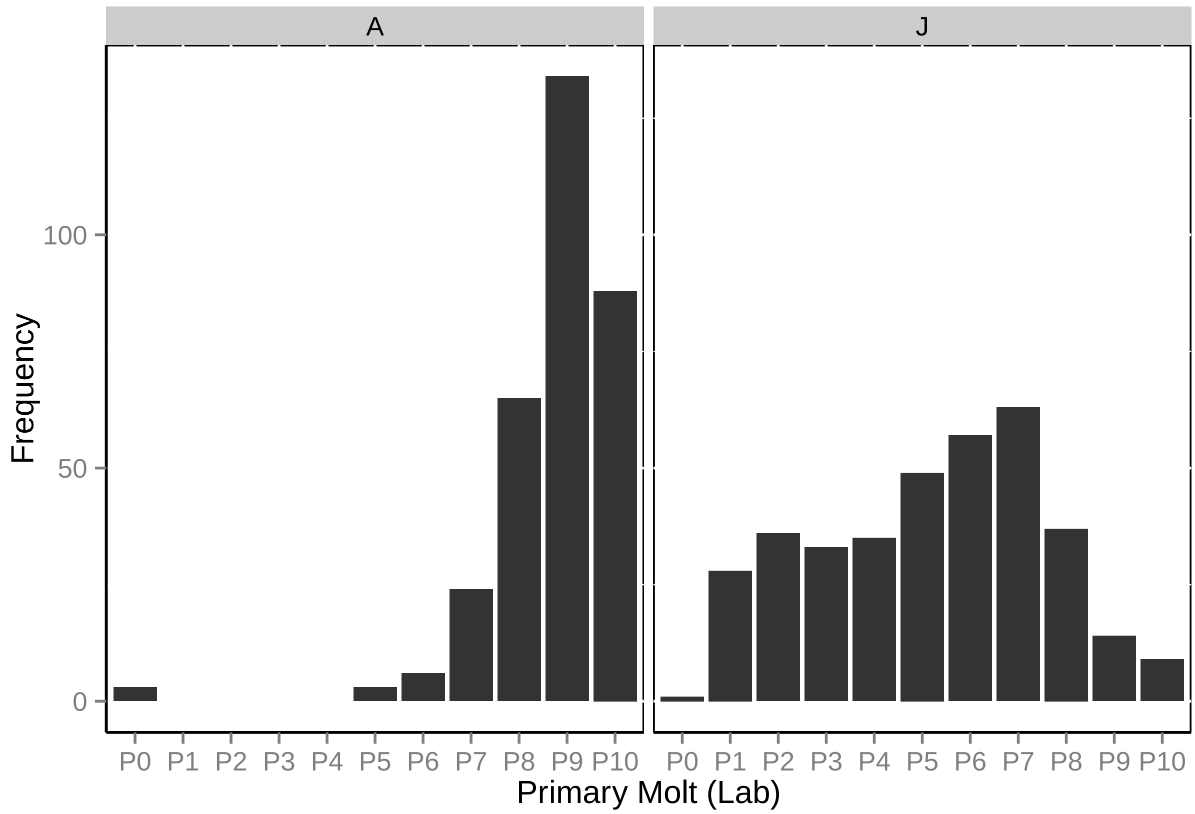


Figure 22: Bursa of Fabricus measurements by primary molt score (field measurement) and buffy coverts (field measurement) for harvested doves based on 2012 sampling.

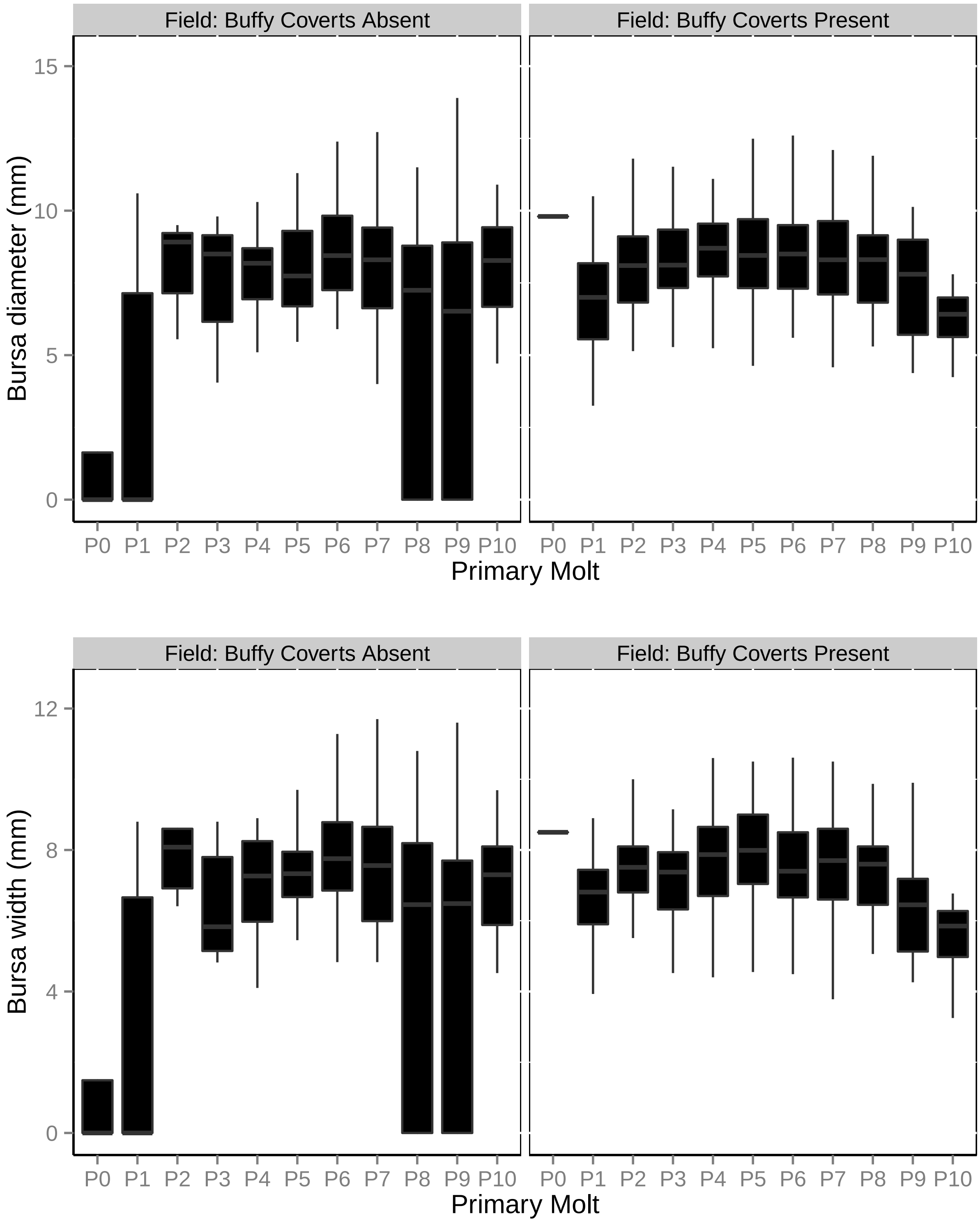


Figure 23: Bursa of Fabricus diameter relative to primary molt score (field measurement) and buffy coverts (field measurement) for 2012 harvested white-winged doves.

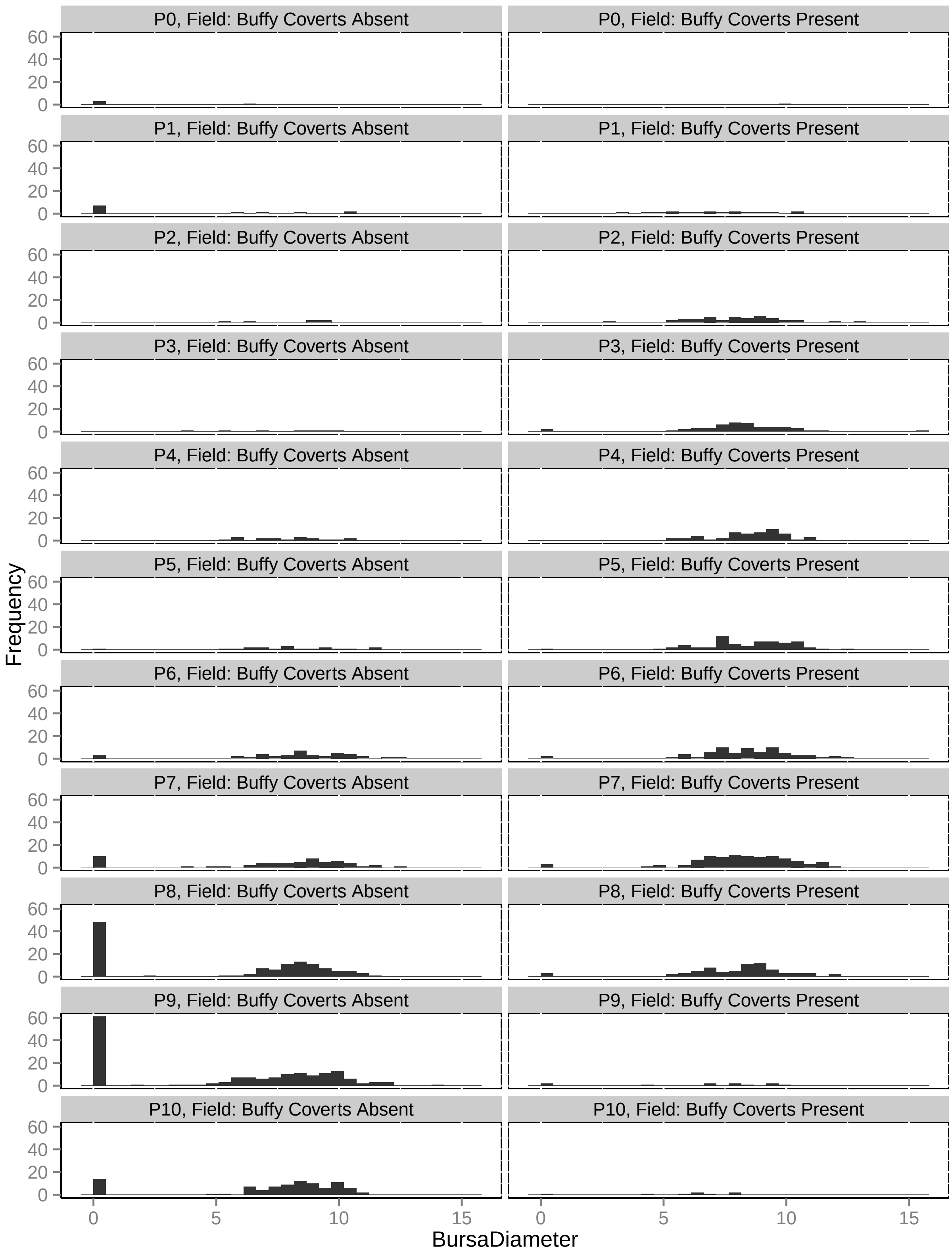


Figure 24: Bursa of Fabricus width relative to primary molt score (field measurement) and buffy coverts (field measurement) for 2012 harvested white-winged doves.

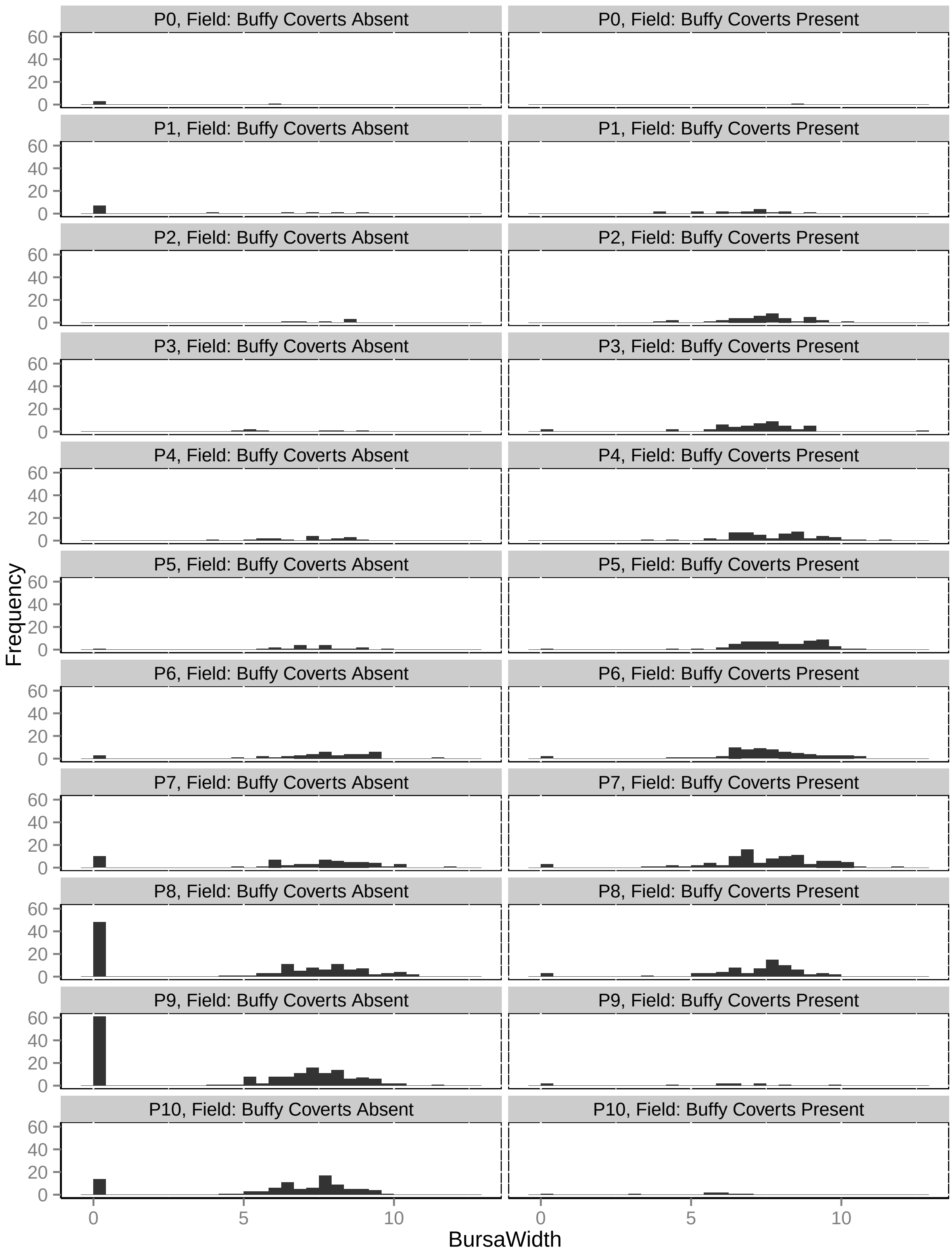


Figure 25: Primary molt score relative to buffy coverts (field measurement) and A1 alulur feather color using the 2012 sample of white-winged doves.

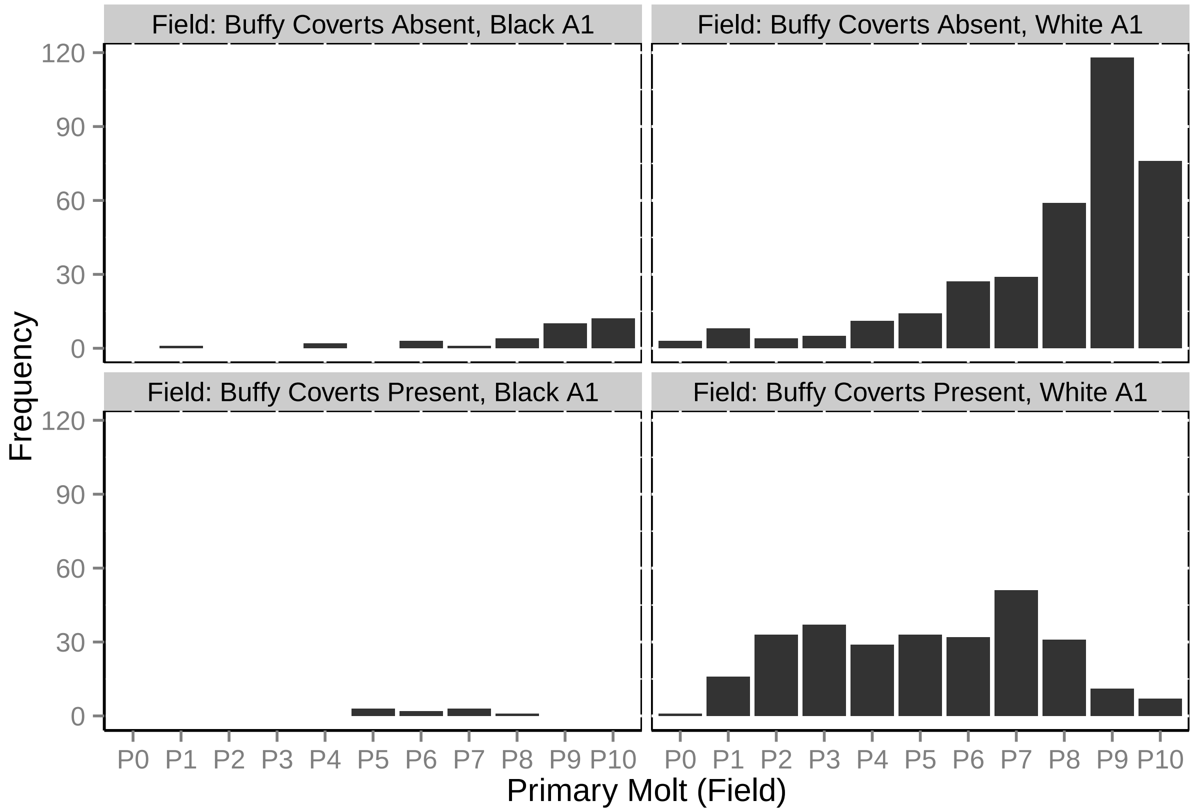


Figure 26: Primary molt score relative to buffy coverts (field measurement) and A2 alulur feather color using the 2012 sample of white-winged doves

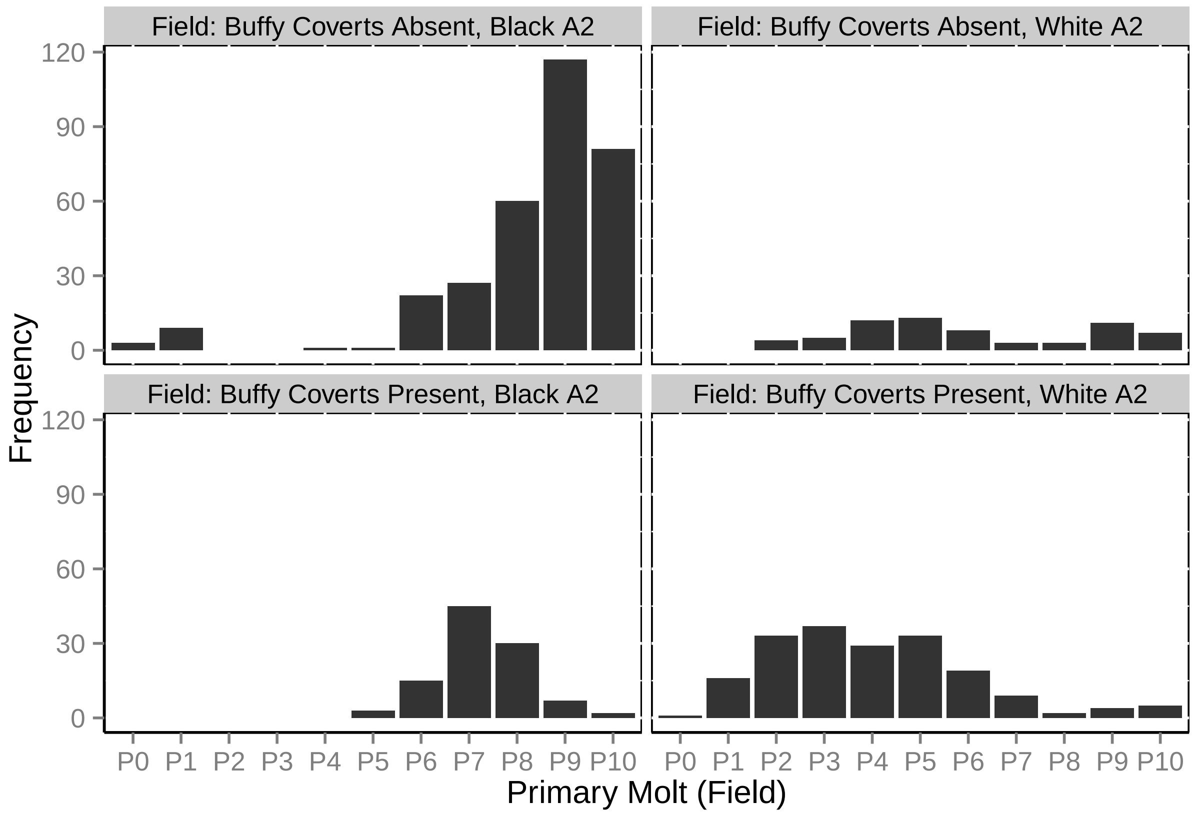


Figure 27: Primary molt score relative to buffy coverts (field measurement) and A3 alulur feather color using the 2012 sample of white-winged doves

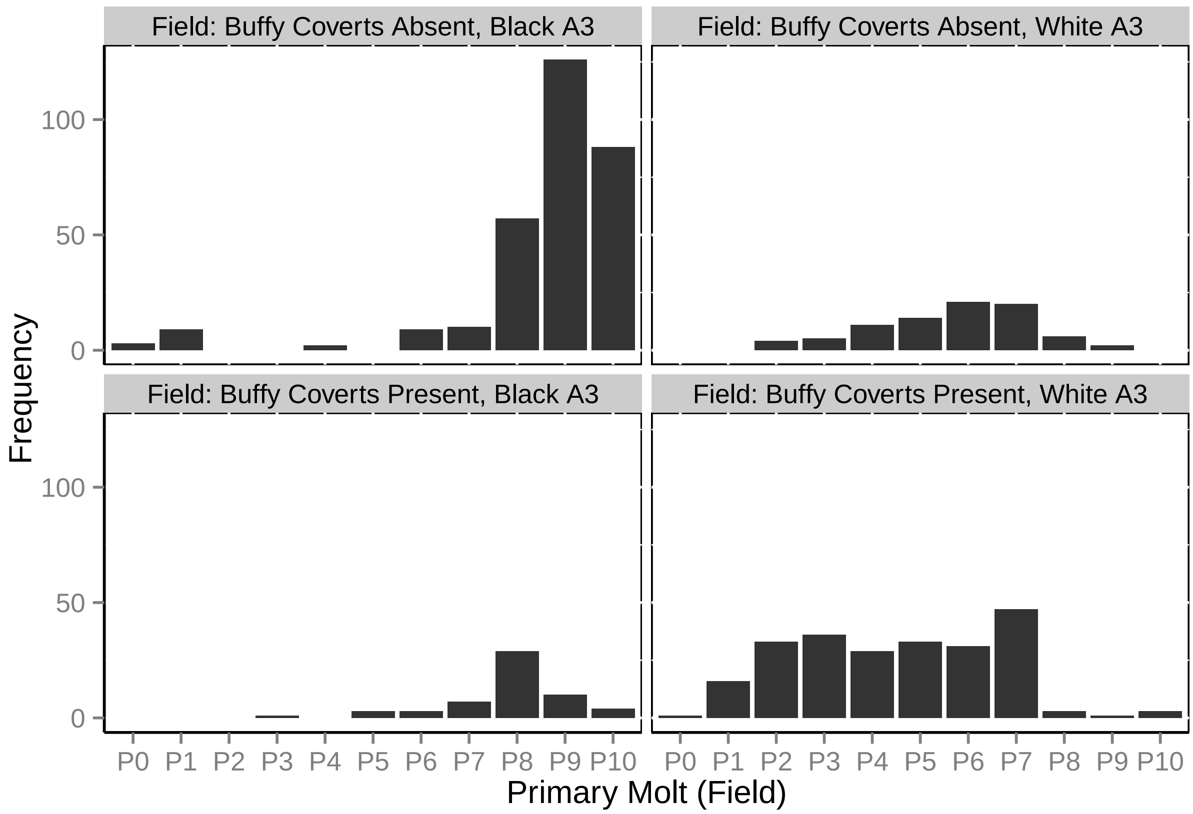


Figure 28: Primary molt score (field) relative to buffy coverts (lab measurement) and adult (A) or juvenile (J) classification 2012 sample of white-winged doves

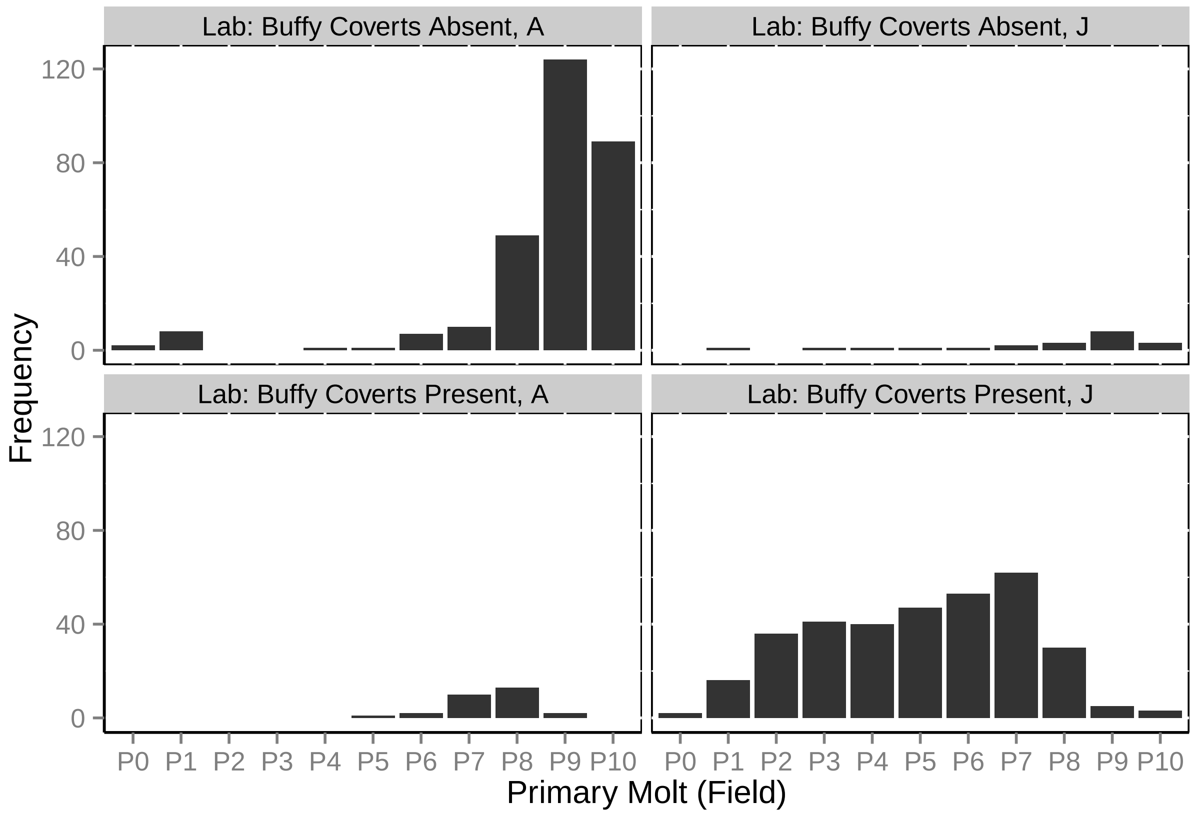


Figure 29: Primary molt score (lab) relative to buffy coverts (lab measurement) and adult (A) or juvenile (J) classification 2012 sample of white-winged doves

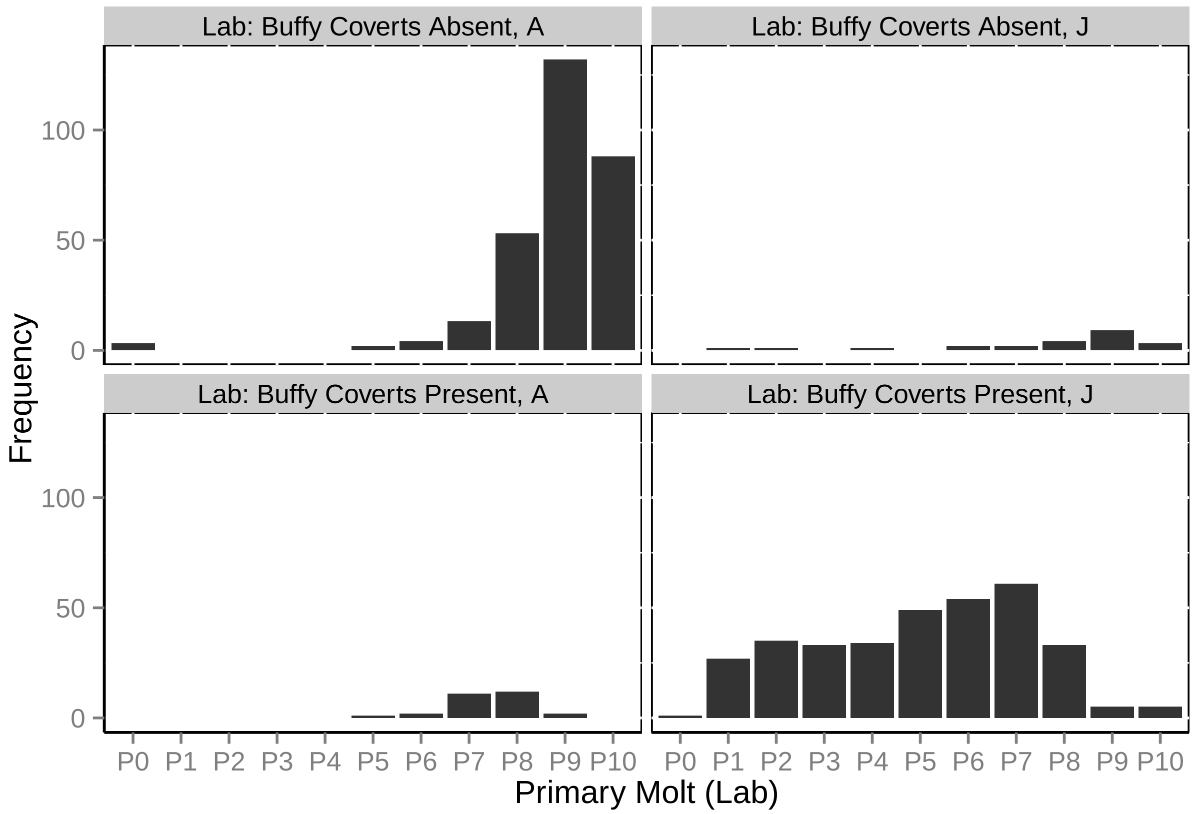


Figure 30: Primary molt score relative to age classification and A1 alulur feather color using the 2012 sample of white-winged doves.

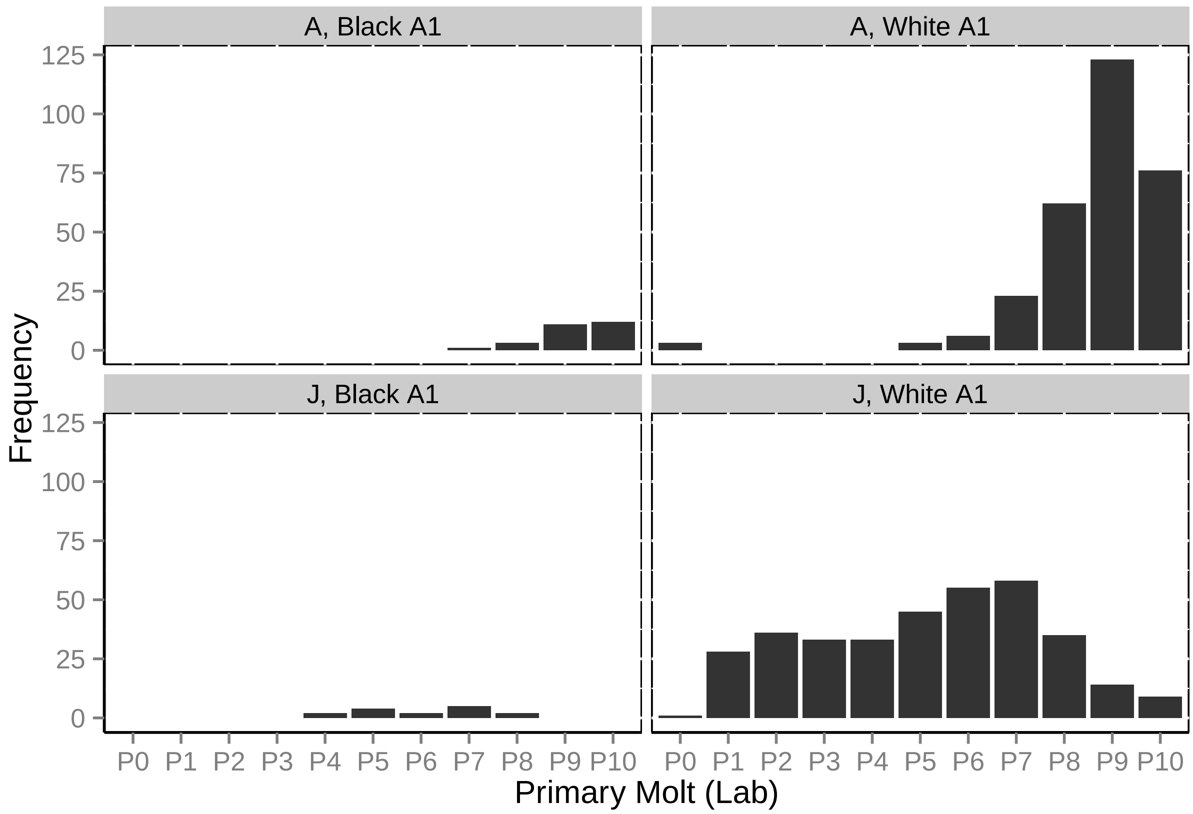


Figure 31: Primary molt score relative to age classification and A2 alulur feather color using the 2012 sample of white-winged doves

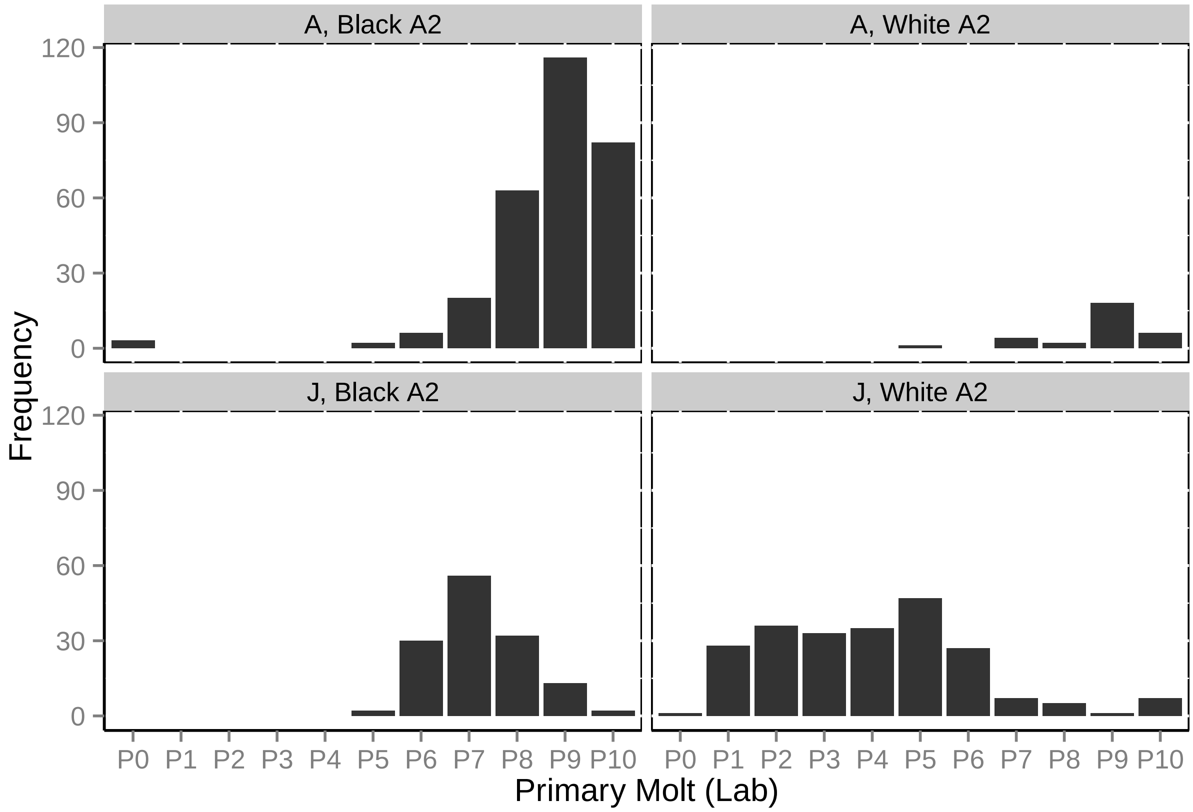


Figure 32: Primary molt score relative to age classification and A3 alulur feather color using the 2012 sample of white-winged doves

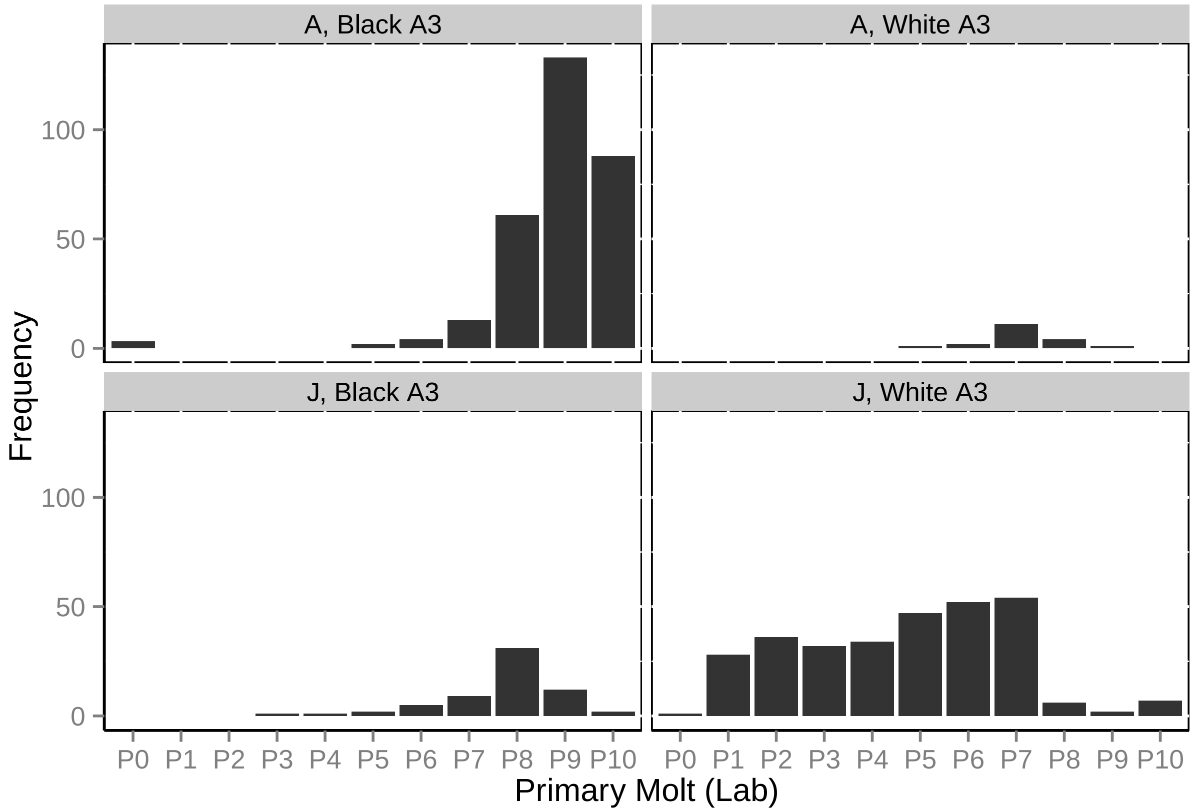
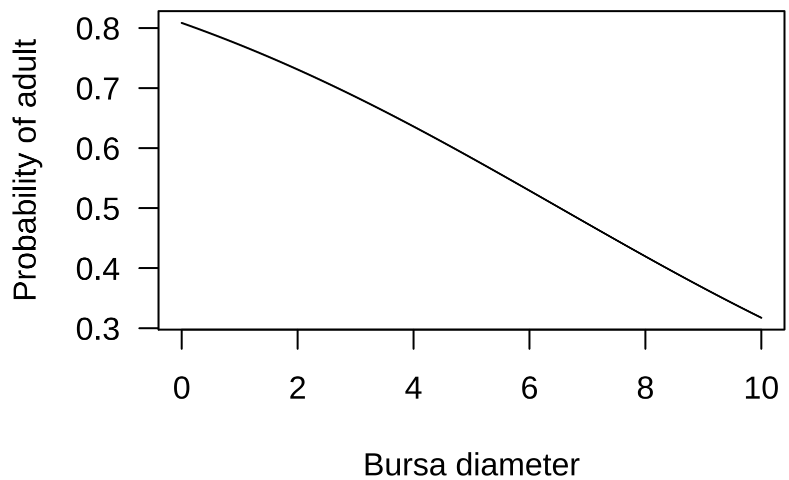


Figure 33: Predicted probability of being an adult white-winged doves based on bursa diameter (a) and bursa width (b) based on the 2012 sample of white-winged doves.

(a) Bursa diameter



(b) Bursa width

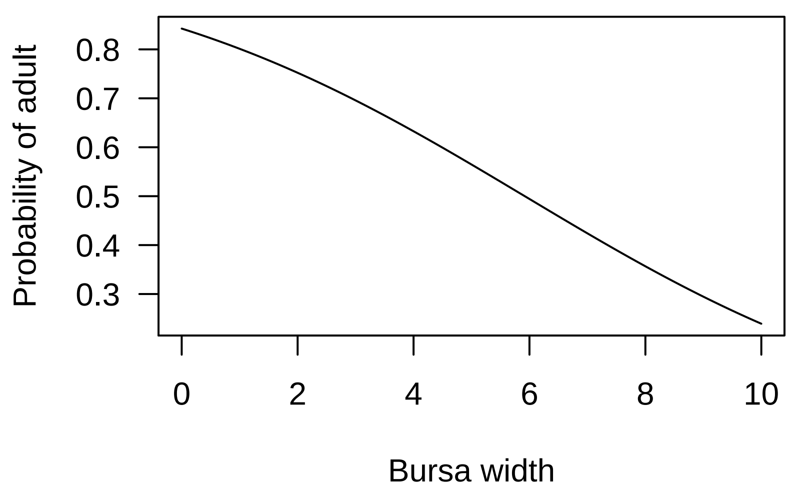


Figure 34: Initial parameterization of the base Baysian belief network using white-winged dove primary molt score, occurrence of buffy coverts, and coloration of the most distal alular based off a sample of 683 individuals.

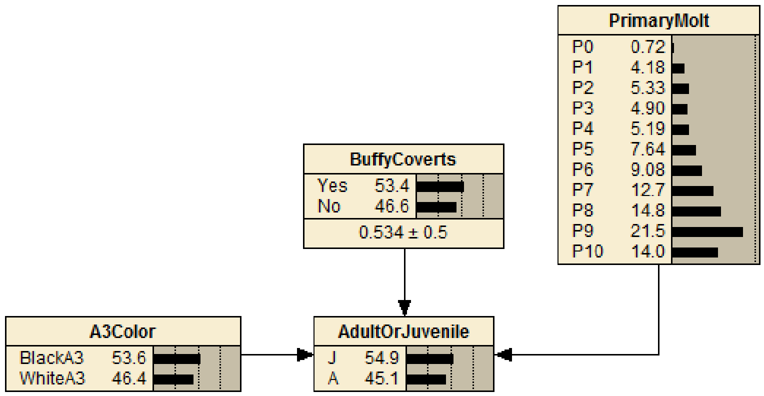


Figure 35: Data included parameterization of the Baysian belief network using white-winged dove primary molt score, buffy coverts being found (BuffyCoverts=YES), and coloration of the most distal alular based off a sample of 683 individuals.

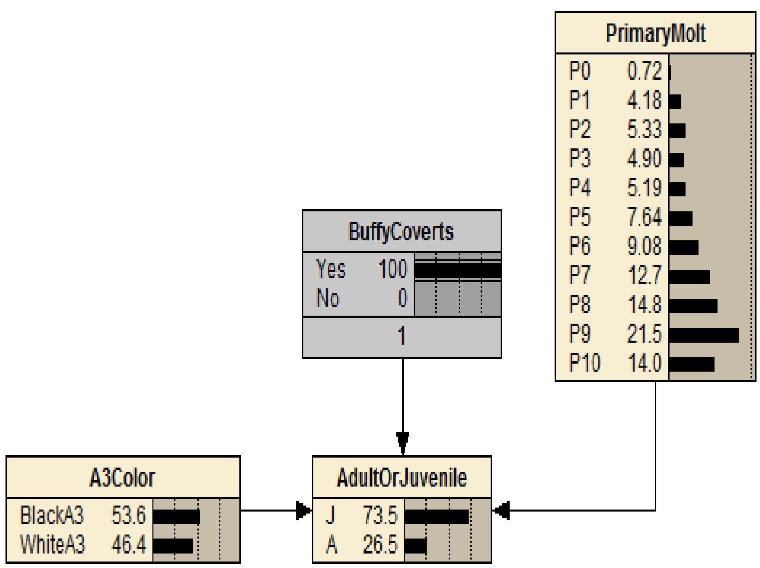


Figure 36: Data included parameterization of the Baysian belief network using white-winged dove primary molt score, buffy coverts being found (BuffyCoverts=YES), and coloration of the most distal alular (White) based off a sample of 683 individuals.

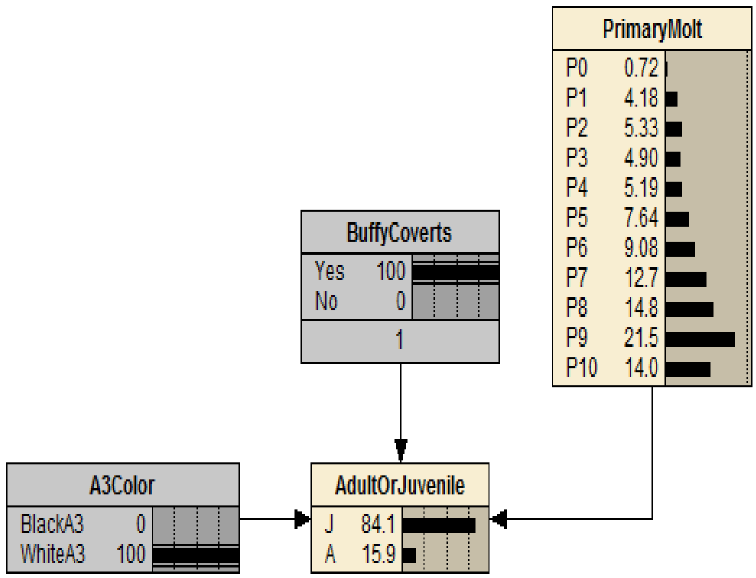


Figure 37: Data included parameterization of the Baysian belief network using white-winged dove primary molt score, buffy coverts being found (BuffyCoverts=No), and coloration of the most distal alular (Black) based off a sample of 683 individuals.

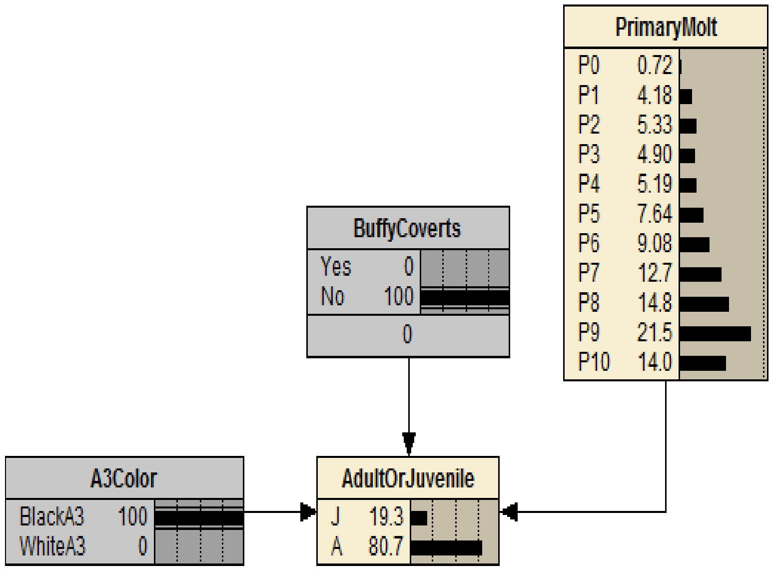


Figure 38: Data included parameterization of the Baysian belief network using white-winged dove primary molt score (PM = 8), buffy coverts being found (BuffyCoverts=No), and coloration of the most distal alular (Black) based off a sample of 683 individuals.

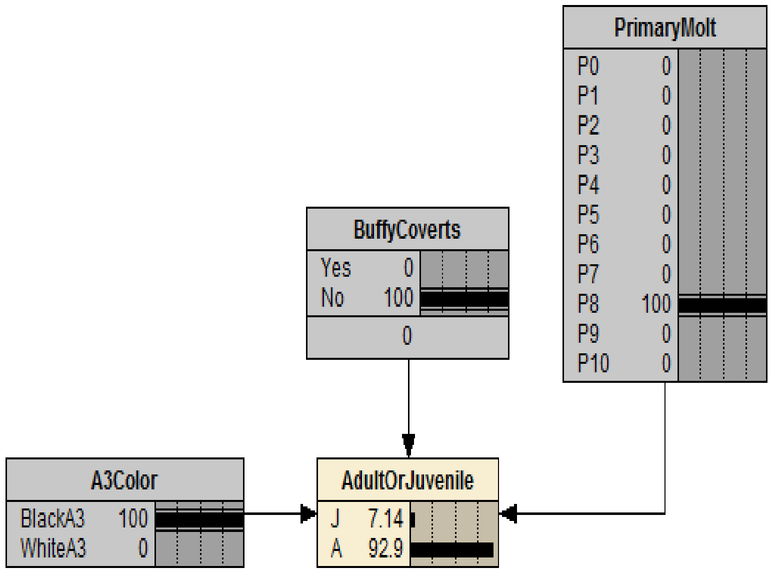


Figure 39: Plot of variable loadings on principal component dimensions 1 and 2 for the 2011 white-winged dove specimens.

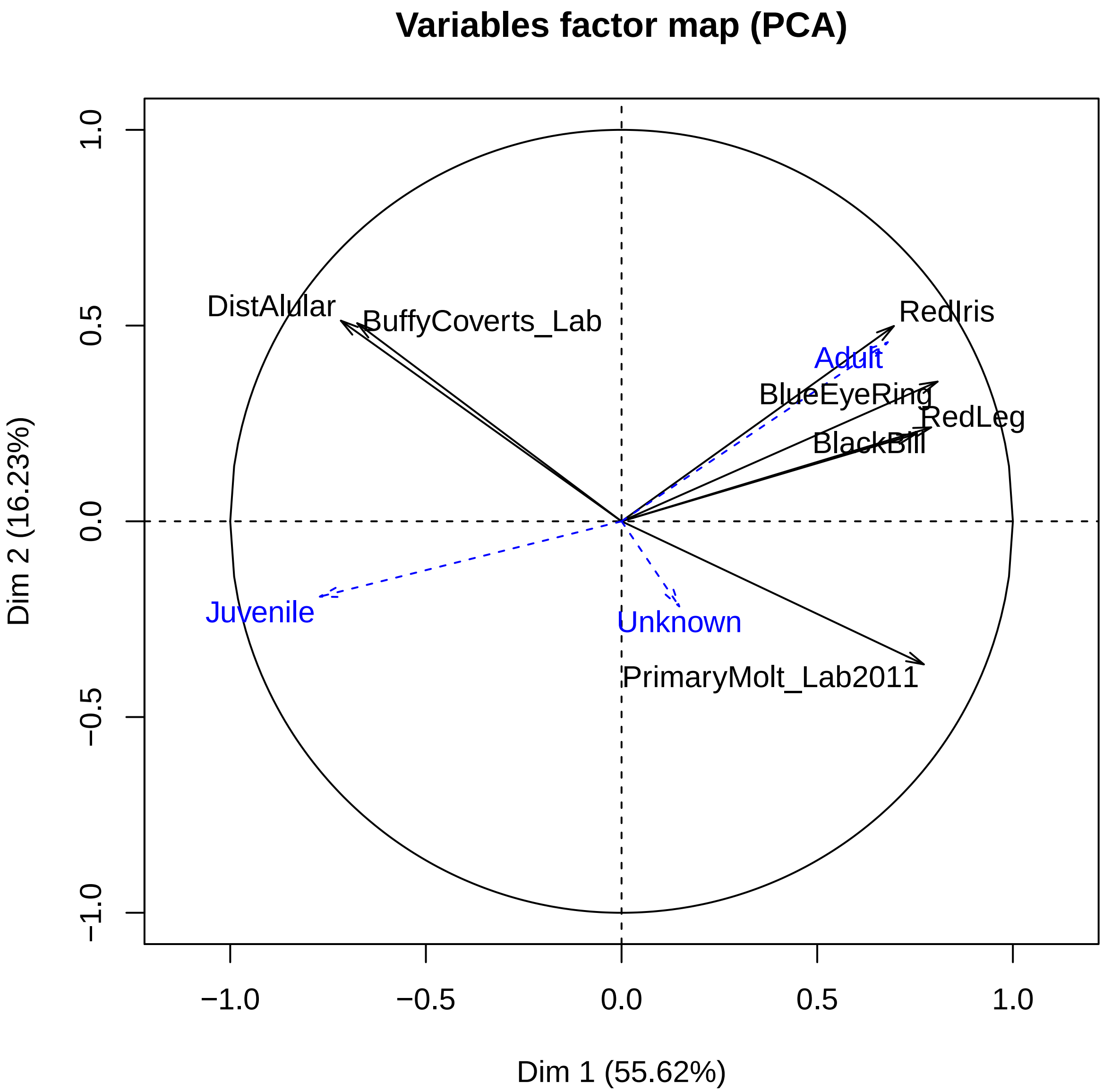
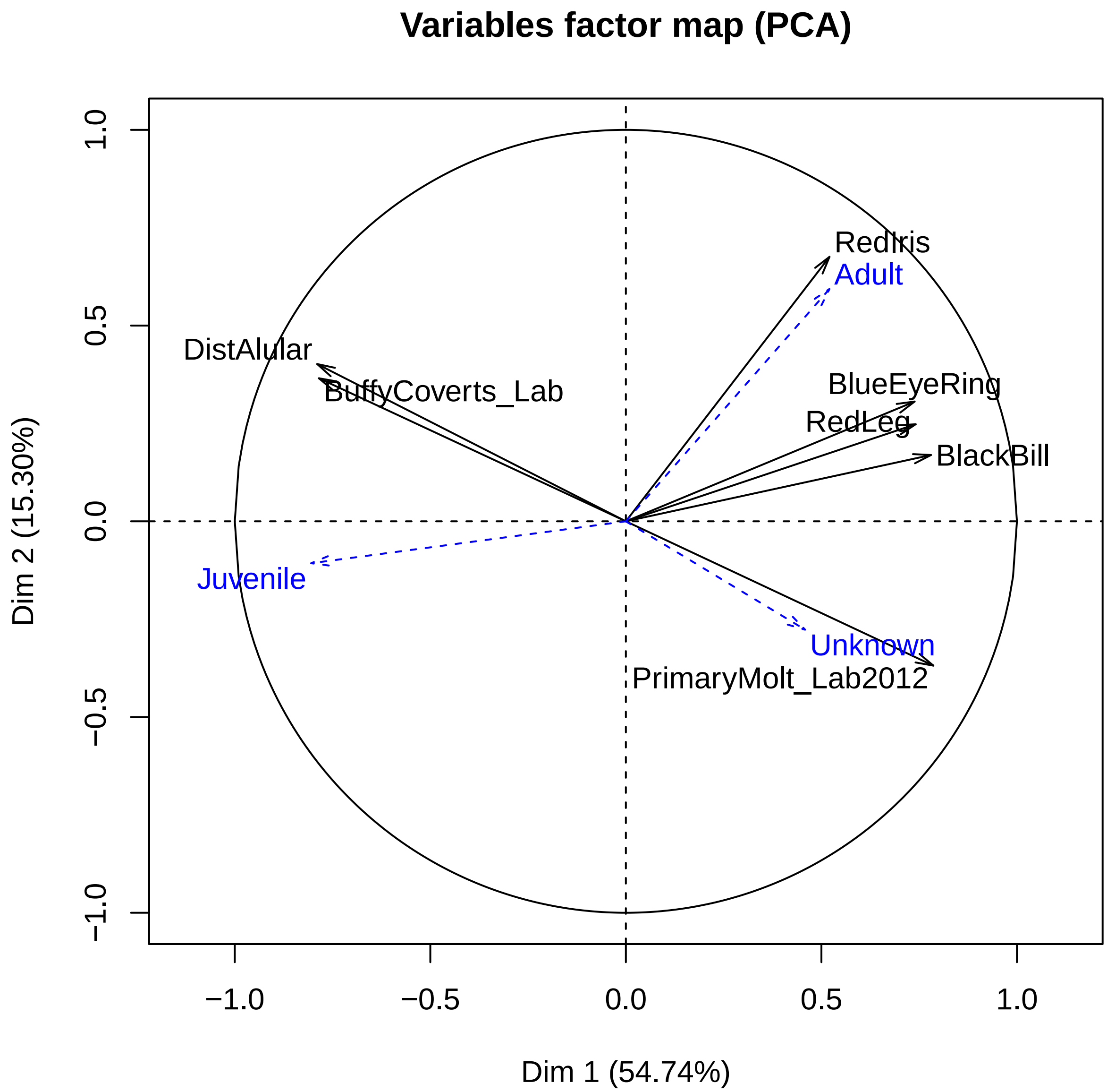


Figure 40: Plot of variable loadings on principal component dimensions 1 and 2 for the 2012 white-winged dove specimens.



Appendix

WWDO Phenology Project

Check Station Standard Operating Procedures

Check Station Sign Example

Table of Contents

Personal Equipment

- Cell phone and camera
- Small cooler with water, drinks & snacks
- Bug repellent & sun screen
- Tarp or netting & rope
- Tables & chairs
- Take photos and send them to Corey

Project Equipment

- Toolbox
- Data Forms
- Bags, Vials, & Labels
- Cooler
- Table & Chairs
- Tent

Toolbox Contents

- Wing ruler
- Scale & calipers
- Game shears
- Sharpie pens & pencils
- Vials, Bags, & Labels
- Data forms & extra batteries
- SOP booklet

Data Sheet

Page No. _______ of _______

White-winged Dove Parts Collection Morphology Data Sheet

Name: ______________________________

Date: ______________________________

State: ______________________________

County: ______________________________

TEXAS PARKS & WILDLIFE

Check Station Name/Description: ______________________________

Latitude (DD.ddd; WGS84): ______________________________

Longitude (DD.ddd; WGS84): ______________________________

	Band	Wt.	Blue Eye Ring	Red Iris	Black Bill	Red Leg	Bill Length	Bill Depth	Bill Width	Tarsus Length	Tail Length	Wing Length	Primary Molt	Buffy Coverts	Skull Ossified	Ovaries Testes	Bursa of Fabricius	Parts Bagged						Bag Number
	(Band# or N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	MD, MU, FD, FU, Unknown	(Y/N)	WB	W	L	T	C	TV	Affix Sticker from Tag
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Texas A&M IRNR WWDO Parts Collection Morph Data Form 20110702.6

The Data Collection Procedure

White-winged Phenology Data Collection Procedure

Equipment:

Electronic Scales (2)	Pre-labeled Large Zip Lock Bags (500)
Extra Batteries for scale (2)	Pre-labeled Small Zip Lock Bags (1000)
Calipers (2)	Pre-labeled Sample Vials (500)
Extra Batteries for calipers (2)	Fine Tipped Sharpie Pens (4)
Rulers (2)	Pencils (4)
Game Shears (2)	Digital Camera (1)
Folding Tables (2)	Extra Batteries for camera (1)
Data Sheets (50)	Ice Chest (1)
Labels for Data Sheets (500)	Chairs (3)

Procedure:

Talk to the hunter. Ask to do measurements on all birds, and if he/she would be interested in donating one or more whole birds. If they wish to participate, inform them that all returned birds will be missing a wing, leg, crop, and tail.

1. Fill in page number, name, date, state, and county.
2. Obtain check station name and description from host agency personnel.
3. Collect GPS reading for location. Fill in Latitude & Longitude.
4. Birds should first be inspected for damage. Make sure all measurements can be made.
5. Record band numbers if present.
6. Weigh the bird.
7. Check for presence/absence of blue eye rings, red irises, opaque black bill, and red legs.
8. With calipers, measure bill length, bill depth, and bill width.
9. With a ruler, measure tarsus, tail, and wing chord length.
10. Inspect wing to determine current stage of primary molt (P1 – P10).
11. Inspect wing to determine presence/absence of buffy-tipped secondary coverts.
12. Obtain specimen bags (1 lg, 2 sm), tissue vial, and small sticker.

If this is a donated bird, check "WB" on datasheet and place bird in large sample bag.
If this is not a donated bird, proceed as indicated below.

13. Remove wing & leg. Place in small bag#1.
14. Remove muscle tissue. Place in tissue vial.
15. Remove tail fan below vent. Place in bag#1 on top of leg & wing.
16. Remove crop contents. Place in small bag#2.
17. Place both small bags and tissue vial into large bag.
18. Inspect data sheet, bags, and tissue vial. Ensure they contain parts & all information.
19. If all bags, vials, & data sheet are complete, seal all parts in large bag & place in cooler.

Use the columns under **Parts Bagged** to annotate which wing and leg are used (we prefer right on both). Make any notes on the back of the data sheet and annotate their presence with an asterisk beside the bag number.

I suggest 2 people.

1 records
1 measures

White-winged Phenology Data Collection Procedure

Equipment:

Electronic Scales (2)	Pre-labeled Large Zip Lock Bags (500)
Extra Batteries for scale (2)	Pre-labeled Small Zip Lock Bags (1000)
Calipers (2)	Pre-labeled Sample Vials (500)
Extra Batteries for calipers (2)	Fine Tipped Sharpie Pens (4)
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Folding Tables (2)	Extra Batteries for camera (1)
Data Sheets (50)	Ice Chest (1)
Labels for Data Sheets (500)	Chairs (3)

Procedure:

Talk to the hunter. Ask to do measurements on all birds, and if he/she would be interested in donating one or more whole birds. If they wish to participate, inform them that all returned birds will be missing a wing, leg, crop, and tail.

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4. Birds should first be inspected for damage. Make sure all measurements can be made.
5. Record band numbers if present.
6. Weigh the bird.
7. Check for presence/absence of blue eye rings, red irises, opaque black bill, and red legs.
8. With calipers, measure bill length, bill depth, and bill width.
9. With a ruler, measure tarsus, tail, and wing chord length.
10. Inspect wing to determine current stage of primary molt (P1 – P10).
11. Inspect wing to determine presence/absence of buffy-tipped secondary coverts.
12. Obtain specimen bags (1 lg, 2 sm), tissue vial, and small sticker.

If this is a donated bird, check "WB" on datasheet and place bird in large sample bag.
If this is not a donated bird, proceed as indicated below.

13. Remove right wing & leg. Place in small bag#1.
14. Remove muscle tissue. Place in tissue vial.
15. Remove tail fan below vent. Place in bag#1 on top of leg & wing.
16. Remove crop contents. Place in small bag#2.
17. Place both small bags and tissue vial into large bag.
18. Inspect data sheet, bags, and tissue vial. Ensure they contain parts & all information.
19. If all bags, vials, & data sheet are complete, seal all parts in large bag & place in cooler.

Use the columns under **Parts Bagged** to annotate which wing and leg are used (we prefer right on both). Make any notes on the back of the data sheet and annotate their presence with an asterisk beside the bag number.

Page No. 2 of ___ *Fill this out when done

White-winged Dove Parts Collection Morphology Data Sheet

Name: Brian L. Pierce

Date: 1 September 2011

State: Texas

County: Hays

TEXAS PARKS & WILDLIFE

Check Station Name/Description: TPWD Office San Marcos

Latitude (DD.ddd; WGS84): 29.877636

Longitude (DD.ddd; WGS84): -97.935649

	Band	Wt.	Blue Eye Ring	Red Iris	Black Bill	Red Leg	Bill Length	Bill Depth	Bill Width	Tarsus Length	Tail Length	Wing Length	Primary Molt	Buffy Coverts	Skull Ossified	Ovaries Testes	Bursa of Fabricius	Parts Bagged						Bag Number
	(Band# or N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	MD, MU, FD, FU, Unknown	(Y/N)	WB	W	L	T	C	TV	Affix Sticker from Tag
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Step 1 – Page#, Name, Date, State,..... Lat/Long

Step 2 – Check Station Name, and description

Step 3 – Lat/Long

Steps 4-5

Inspect the bird to make sure all measurements and samples can be taken!

Make sure birds have both wings!

Look for a band! Record# if present.

Steps 6

Tare or Zero your digital scale.

Weigh the bird.

Page No. 2 of ____ *Fill this out when done

White-winged Dove Parts Collection Morphology Data Sheet

Name: Brian L. Pierce

Date: 1 September 2011

State: Texas

County: Hays

Check Station Name/Description: TPWD Office San Marcos

Latitude (DD.ddd; WGS84): 29.877636

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	(Band# or N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	MD, MU, FD, FU, Unknown	(Y/N)	WB	W	L	T	C	TV	Affix Sticker from Tag
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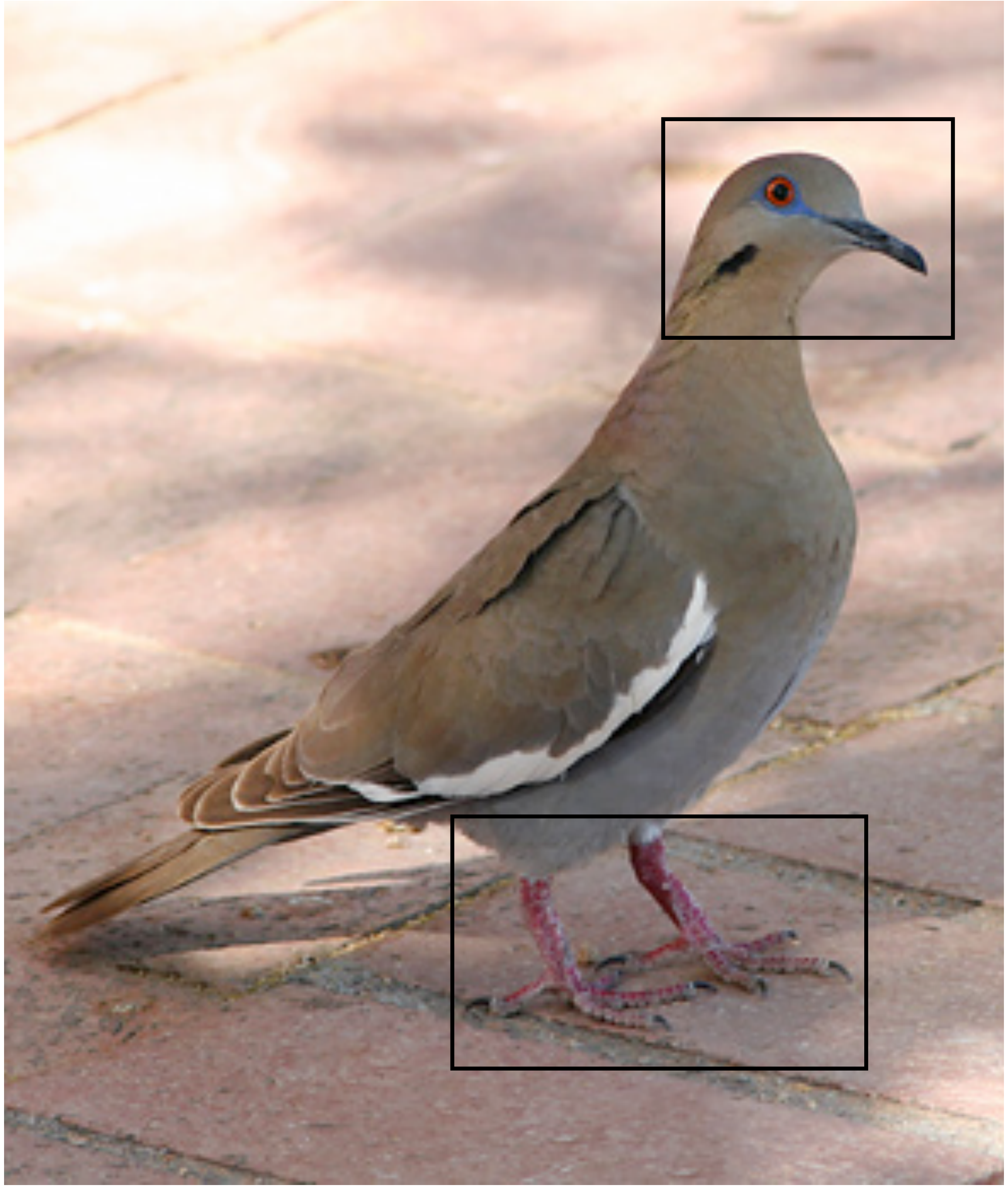
Step 5 – Band Present? (Band# or N)

Step 6 – Weight (grams)

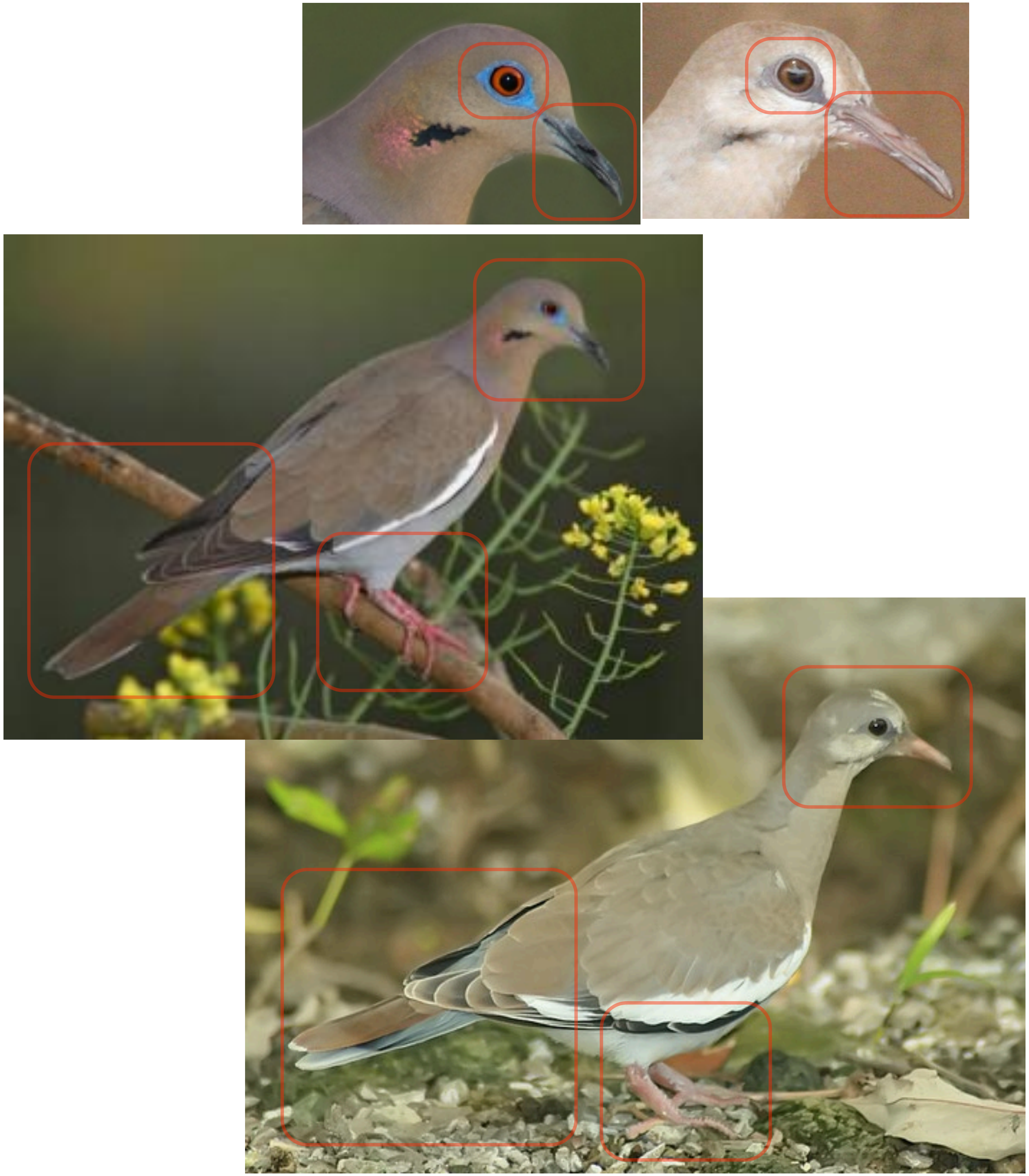
Step 7

Check for:

Blue Eye Ring
Red Iris
Black Bill
Red Legs



Step 7



Check for:

Blue Eye Ring
Red Iris
Black Bill
Red Legs

Page No. 2 of *Fill this out when done

White-winged Dove Parts Collection Morphology Data Sheet

Name: Brian L. Pierce

Date: 1 September 2011

State: Texas

County: Hays

TEXAS PARKS & WILDLIFE

Check Station Name/Description: TPWD Office San Marcos

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	(Band# or N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	MD, MU, FD, FU, Unknown	(Y/N)	WB	W	L	T	C	TV	Affix Sticker from Tag
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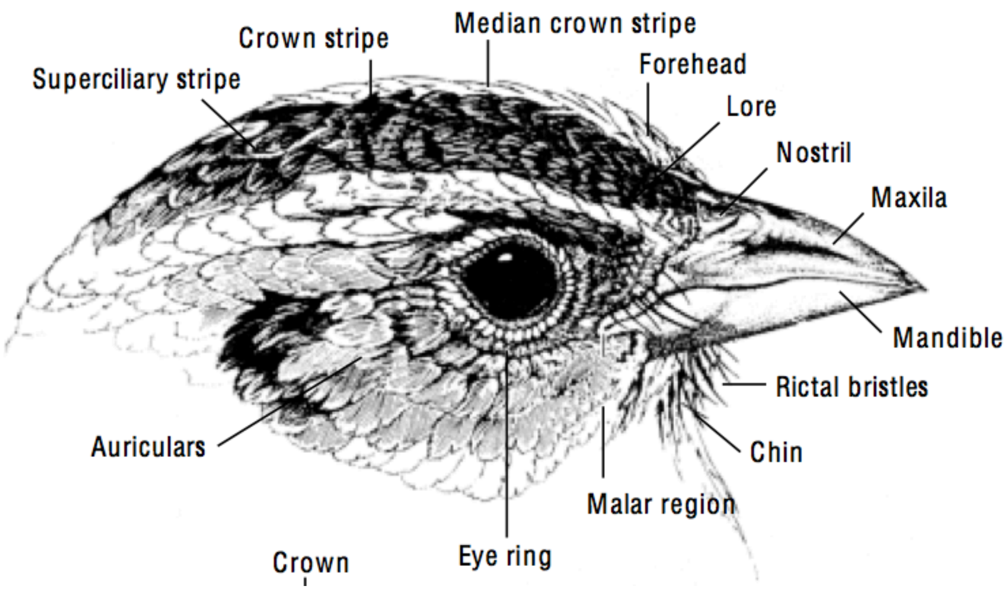
Step 7 – Blue Eye Ring (Y or N)
Red Iris (Y or N)
Black Bill (Y or N)
Red Legs (Y or N)

"Y" or "Yes" means full adult characteristic!!!

If you feel a characteristic (eye ring, iris color,...) is not representative of the full adult stage, then answer "N"

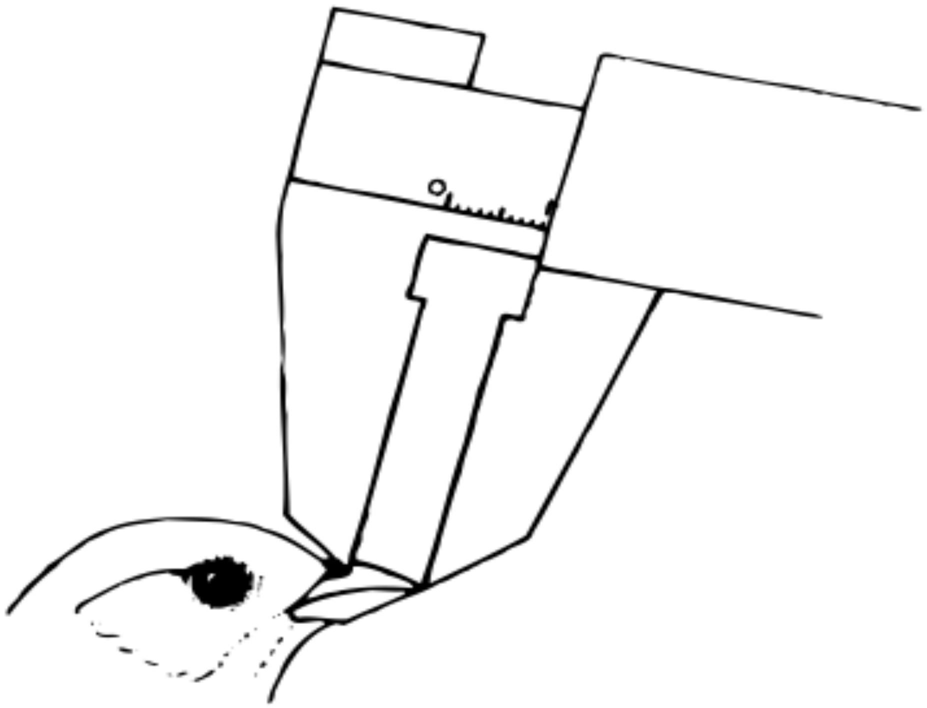
Steps 8



Measure Bill Length

Measure Bill Depth

Measure Bill Width




Tip to Nostril- this is the
least variable method of
measuring bill length

Bill Depth- from base to the top.
Note were base of the lower mandible begins.

Also, note the variation among birds.

The “chin” is covered with feathers. So the measurement starts where the feathers end.

Measure bill width at this same point (i.e., turn the calipers 90º).

*Fill this out when done

White-winged Dove Parts Collection Morphology Data Sheet

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County: Hays

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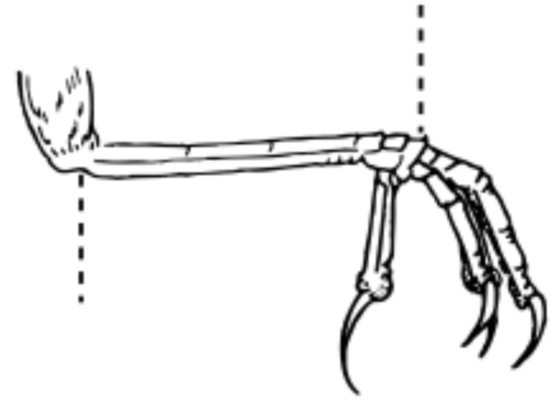
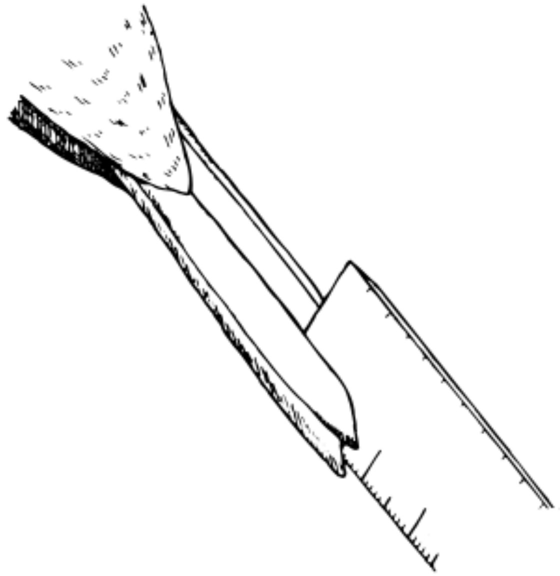
Step 8 – Bill Length (mm)
Bill Depth (mm)
Bill Width (mm)

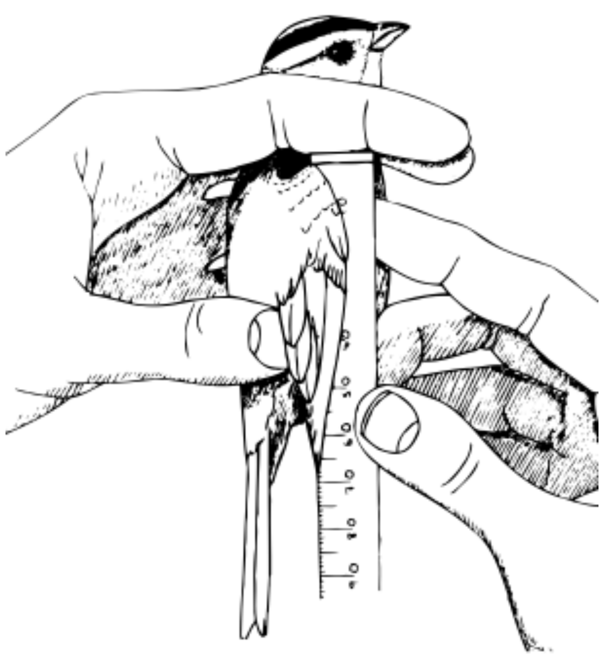
Step 9

Measure with Ruler:

Tarsus Length
Tail Length
Wing Chord Length

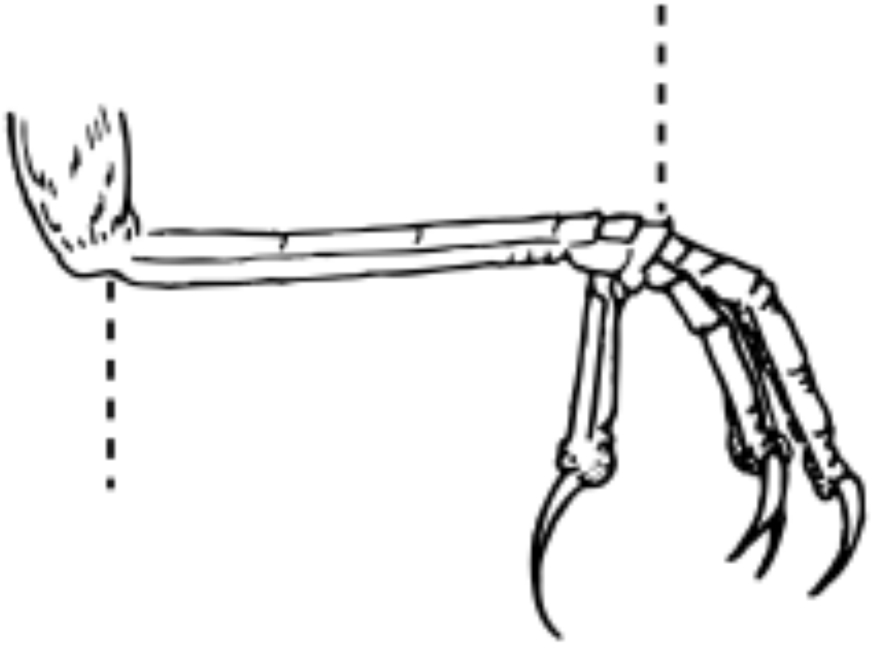




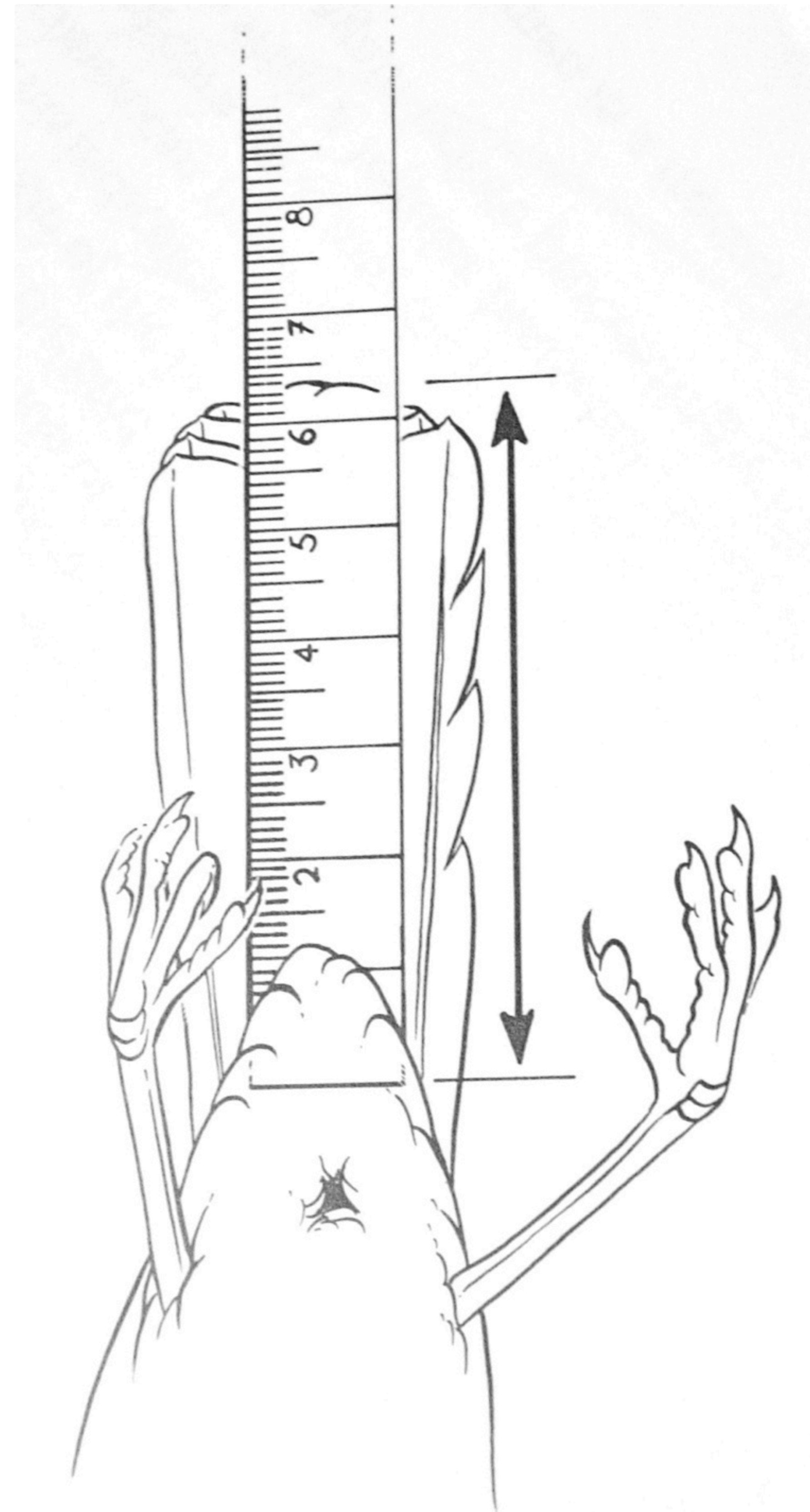


Tarsus Length

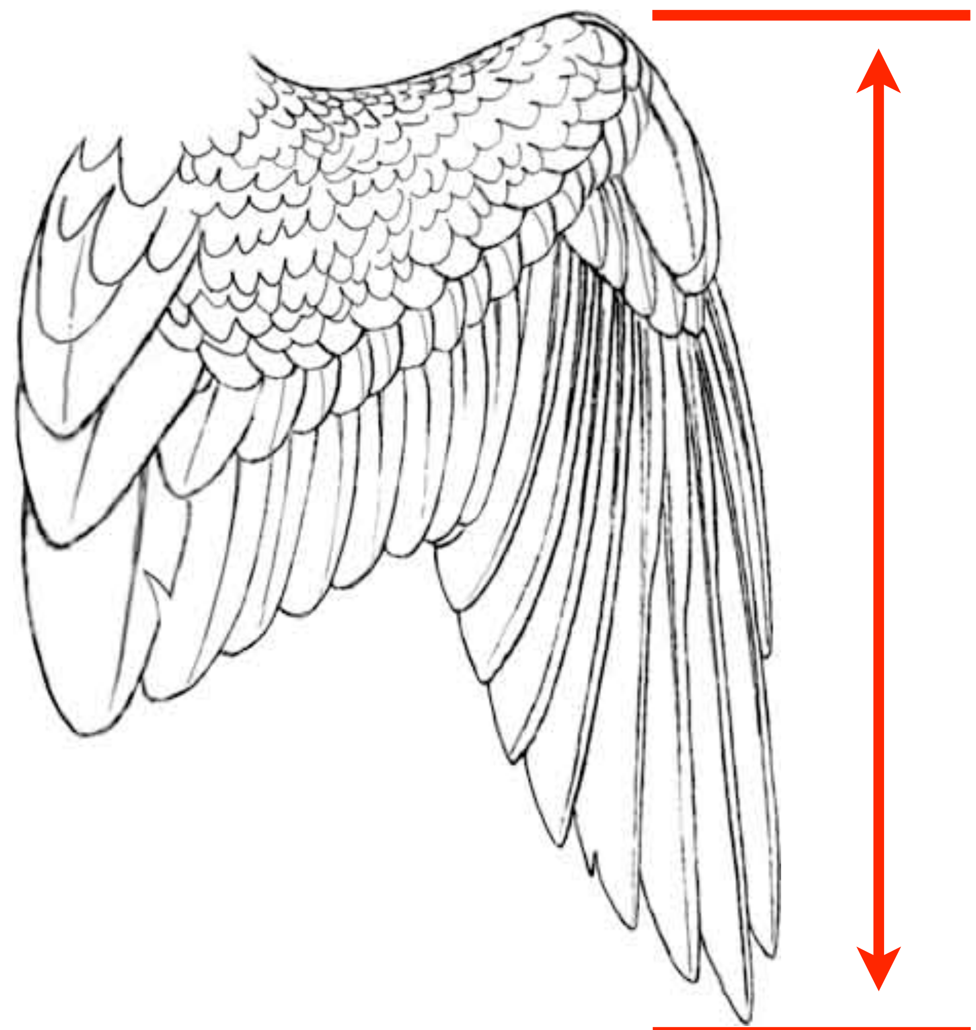
Middle of joint to last scale before toes



Tail Length



Tail length is the distance from the tip of the longest rectrix to the insertion of the two central rectrices



Use the wing ruler to measure the folded wing as indicated.

Nomenclature: Failure to Communicate

The Auk 121(3):973–976, 2004

CONFLICTING TERMINOLOGY FOR WING MEASUREMENTS IN ORNITHOLOGY AND AERODYNAMICS

F. GARY STILES[1,2,4] AND DOUGLAS L. ALTSHULER[3]

[1]*Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Apartado 7495, Bogotá D.C., Colombia;* [2]*Academy of Natural Sciences, 1900 Benjamin Franklin Parkway, Philadelphia, Pennsylvania 19103, USA; and* [3]*Bioengineering, California Institute of Technology, Mail Code 138-78, 1200 East California Boulevard, Pasadena, California 91125, USA*

IT HAS COME to our attention that certain frequently used terms describing wing dimensions refer to different morphological features when used by ornithologists, as opposed to physiologists or physicists working in aerodynamics. Potential for confusion certainly exists, particularly now that the study of avian aerodynamics may be entering a very active phase, given theoretical (Rayner 1979a, b; Ellington 1984b; Norberg 1995; Dickinson et al. 1999) and experimental (e.g. Chai and Dudley 1995, Dial et al. 1997, Spedding et al. 2003, Tobalske et al. 2003) advances in animal-flight research over the past few decades. Here, we describe the conflict in terminology and suggest a solution, in hopes of avoiding misunderstandings in future studies of aerodynamics by ornithologists. We also discuss how ornithologists might best take some measurements of interest in aerodynamics studies.

In aerodynamics, the definition of wing length *R* is distance from base of the wing to tip. For birds, that distance should be measured on a wing extended in a natural position, as during flight (see Fig. 1). Wing chord *c* is defined in aerodynamics as any straight-line distance between leading and trailing edges of the wing, taken perpendicular to the long axis of the wing (i.e. wing length)—and that definition appears in standard non-ornithological sources like the Oxford Unabridged Dictionary. Animal wings typically vary in chord length from base to tip (most wings become narrower distally), and mean chord of the wing is defined as $S/2R$, where S is the area of both wings (Ellington 1984a).

The definition of wing length in ornithology has been more ambiguous. Because classical ornithology developed around use of bird specimens, the traditional measurement of wing length was the one taken most conveniently on study skins (and most mounts): distance from bend of wing (i.e. wrist joint) to tip of the longest primary feather, measured over the folded wing (Fig. 1). That is the only measurement of wing length given in most ornithology textbooks (e.g. Pettingill 1985, Proctor and Lynch 1993); in many classical works (e.g. Ridgway 1901), the measure is called simply "wing," though in one standard reference (Baldwin et al. 1931) a more accurate term, "length of closed wing," is

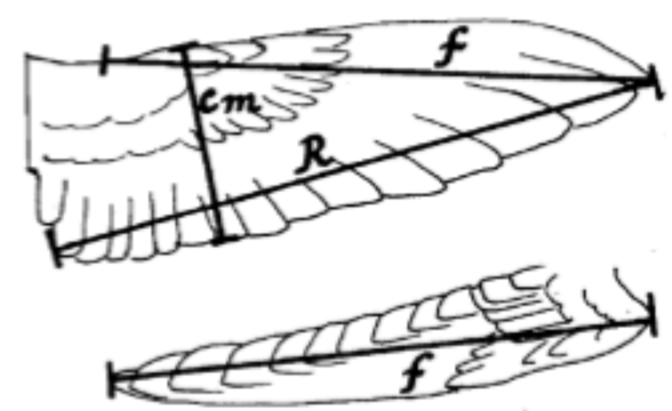


FIG. 1. Measurements of a wing of a hummingbird (male *Heliodoxa aurescens*). Top: spread wing, opened to approximate the natural extended position in flight. Bottom: the same wing in closed (folded) position, as in a perched bird (or a study skin). Abbreviations: f = length of closed (folded) wing; R = length of wing; c_m = length of (maximum) chord or "width" of wing. Note that position of wrist joint, or bend of wing, is not obvious on the planform of the spread wing. See text for details.

[4]E-mail: fgstilesh@unal.edu.co

Page No. 2 of [redacted] *Fill this out when done

White-winged Dove Parts Collection Morphology Data Sheet

Name: Brian L. Pierce

Date: 1 September 2011

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County: Hays

Check Station Name/Description: TPWD Office San Marcos

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Step 9 – Tarsus Length (mm)
Tail Length (mm)
Wing Length (mm)

Step 10
Primary Molt

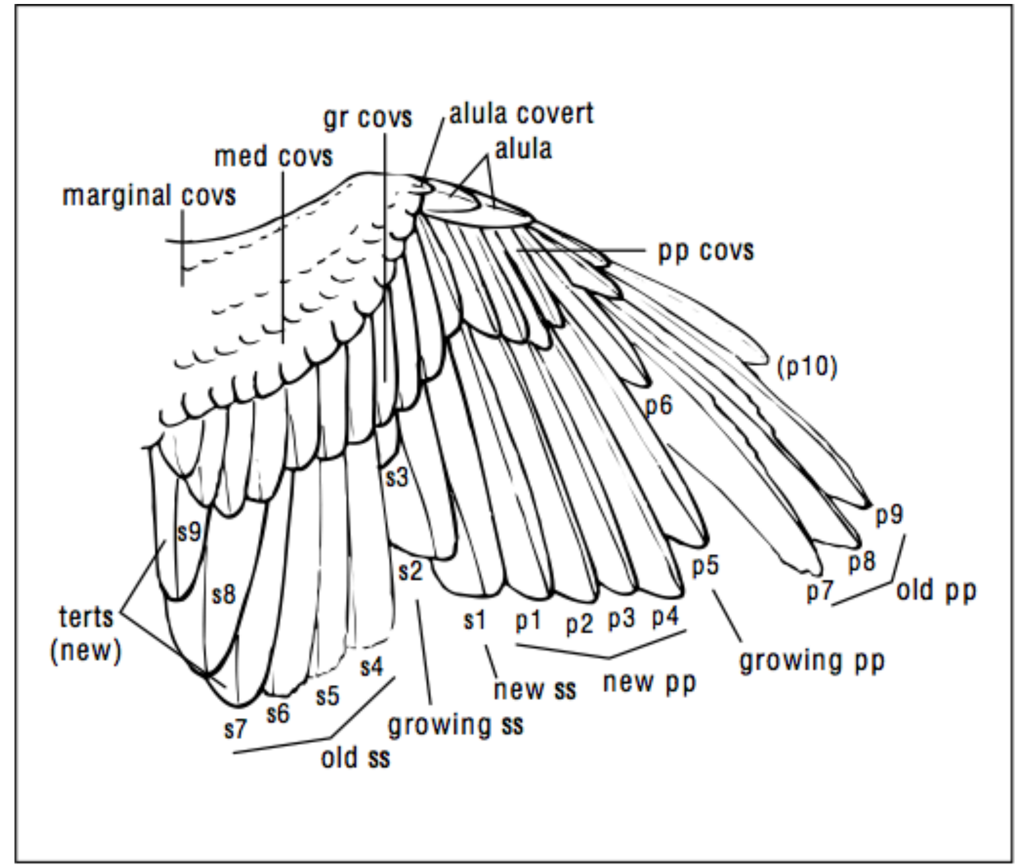
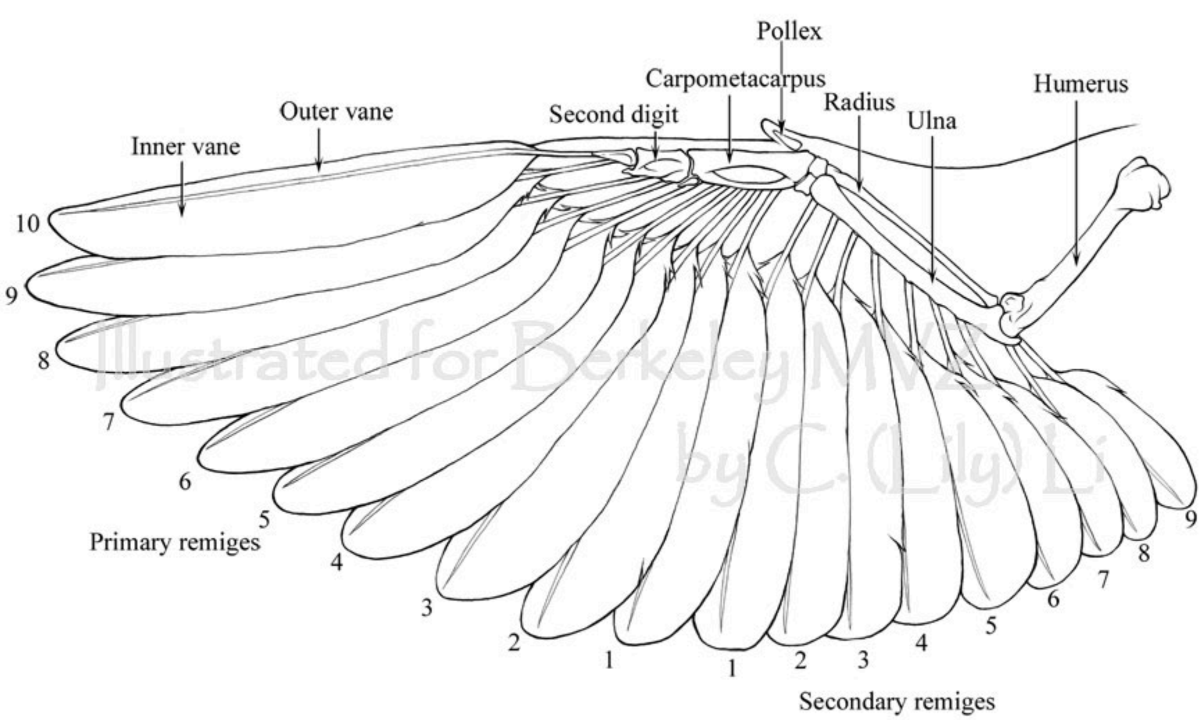
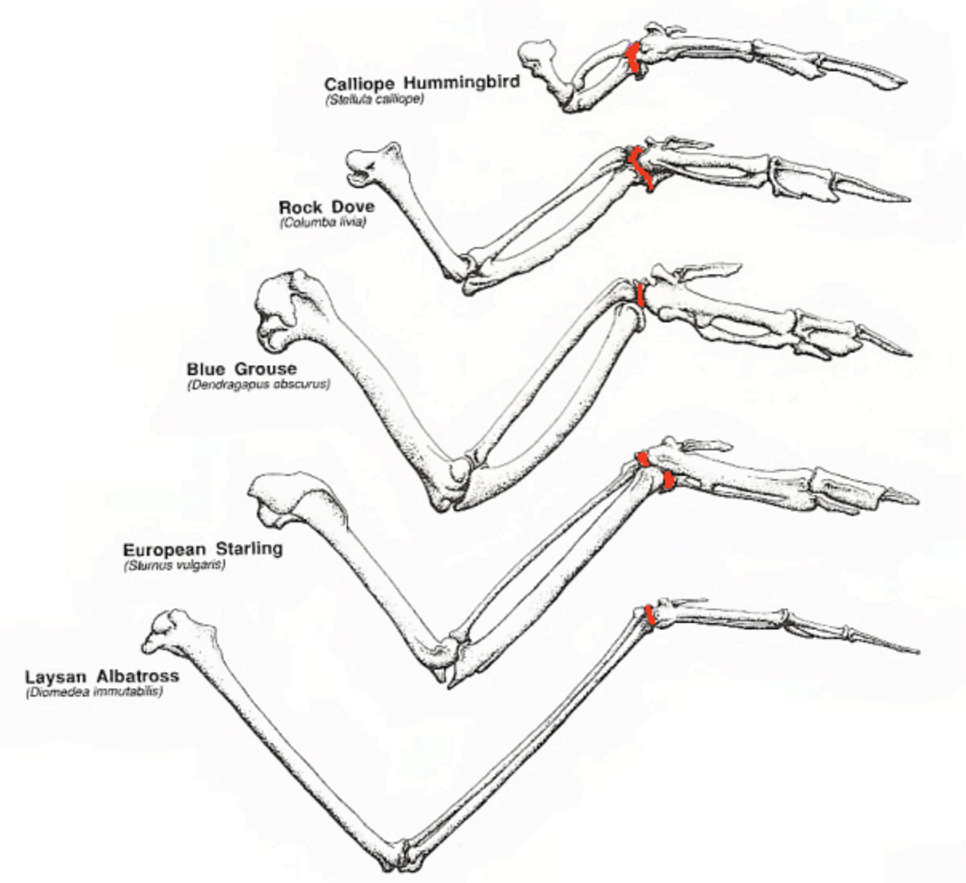


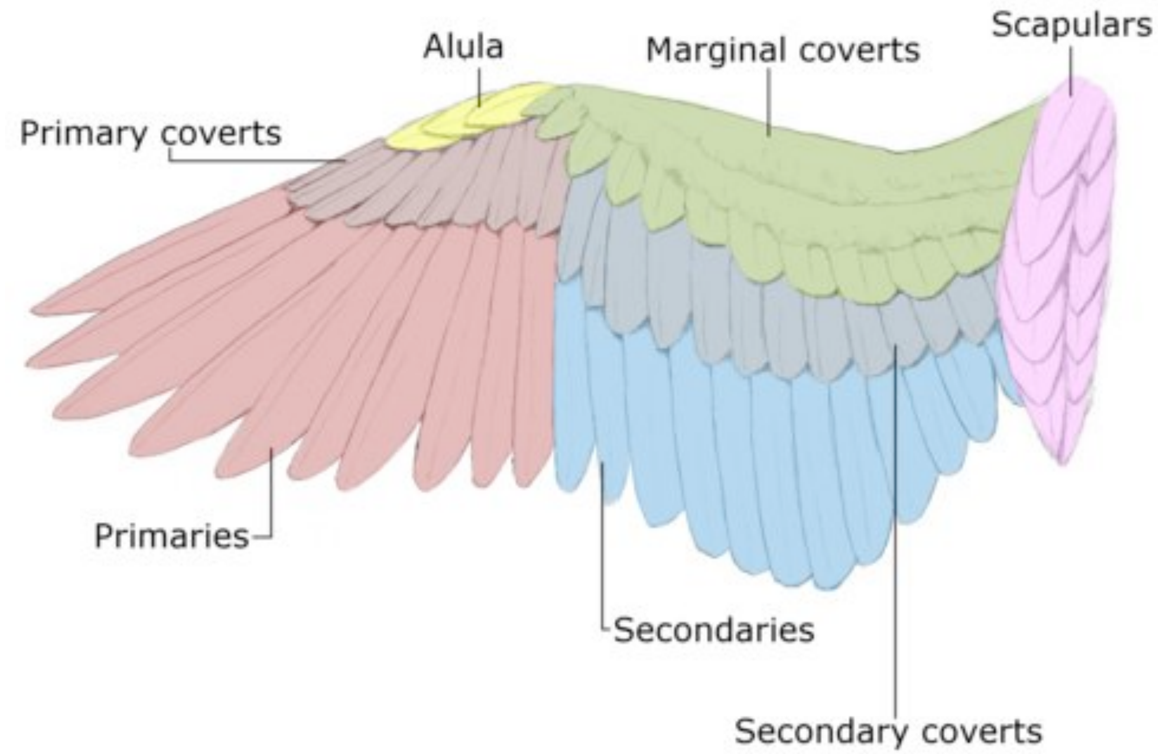
Figure 1. A wing during complete molt in typical sequence, including wing feather terminology.

Primarys are attached to the manus (the "hand"), which starts at the ulnare & radiale.





Step 11
Buffy Coverts



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Steps 10 – 11

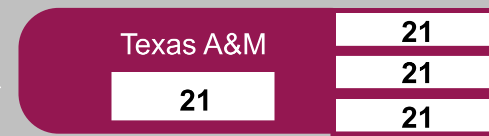
Primary Molt Postion (P1 - P10)
Buffy Coverts (Y/N)

If this is a hunter donated whole bird:

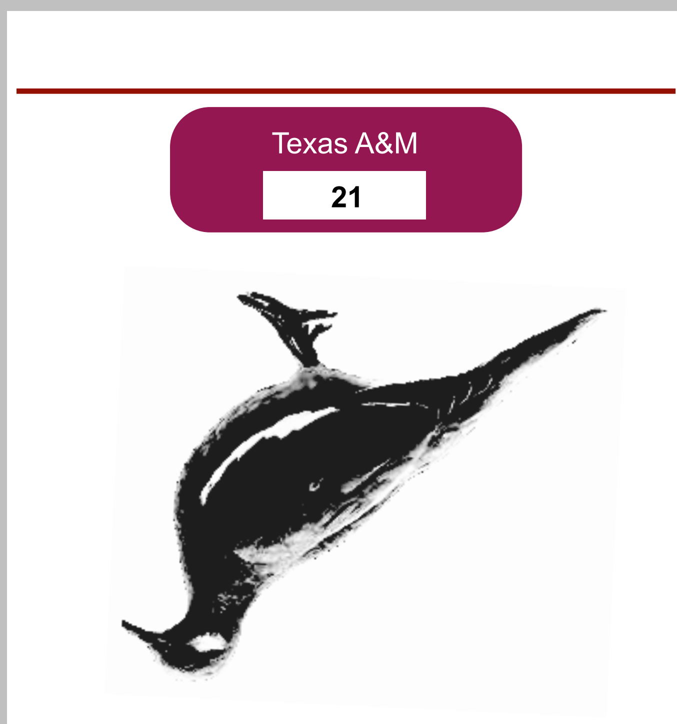
- Affix small label to data sheet
- Bag the whole bird (large ziplok)
- Check “WB” under “Parts Bagged”
- Move to the next bird

Whole Birds

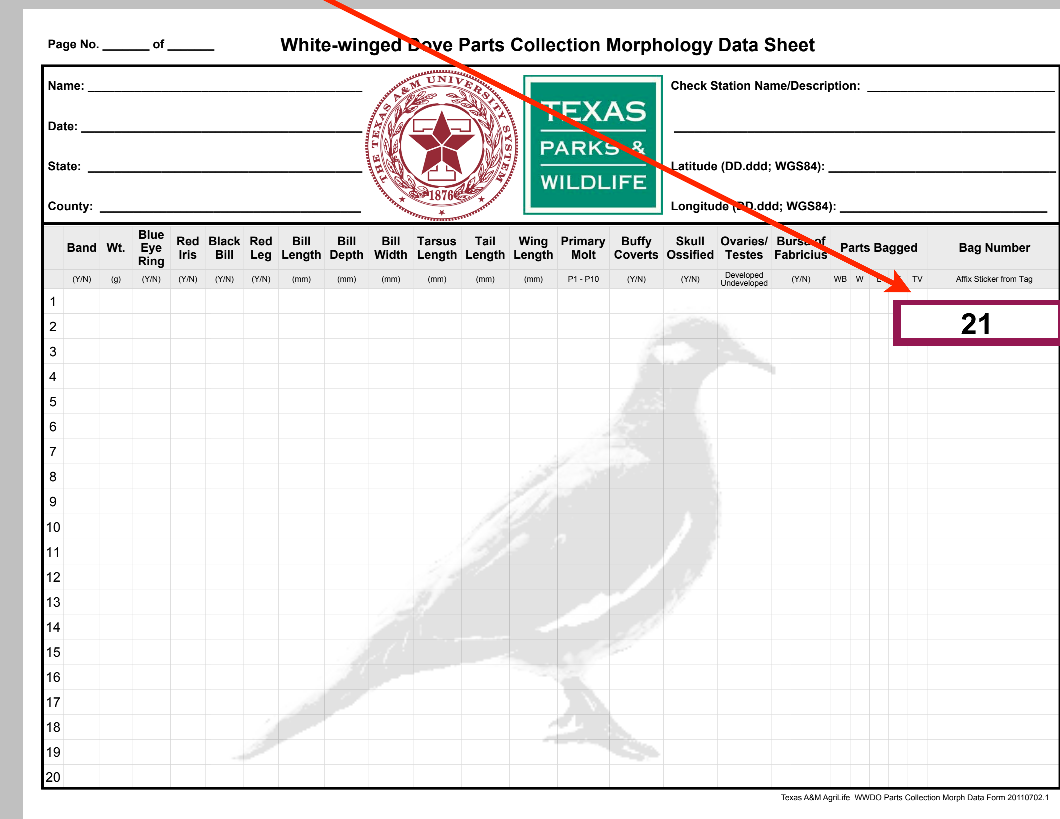
Large Label affixed inside Large Ziplok



Find the Small Label inside the large ziplok. Affix this matching label to the Data Sheet



Small Label affixed inside Small Ziplok bags


Page No. ______ of ______ White-winged Dove Parts Collection Morphology Data Sheet

Name: ____ Date: ____ State: ____ County: ____

Check Station Name/Description: ____

Latitude (DD.ddd; WGS84): ____ Longitude (DD.ddd; WGS84): ____

	Band	Wt.	Blue Eye Ring	Red Iris	Black Bill	Red Leg	Bill Length	Bill Depth	Bill Width	Tarsus Length	Tail Length	Wing Length	Primary Molt	Buffy Coverts	Skull Ossified	Ovaries/ Testes	Bursa of Fabricius	Parts Bagged	Bag Number
	(Y/N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	Developed Undeveloped	(Y/N)		Affix Sticker from Tag
1																			
2																			21
3																			
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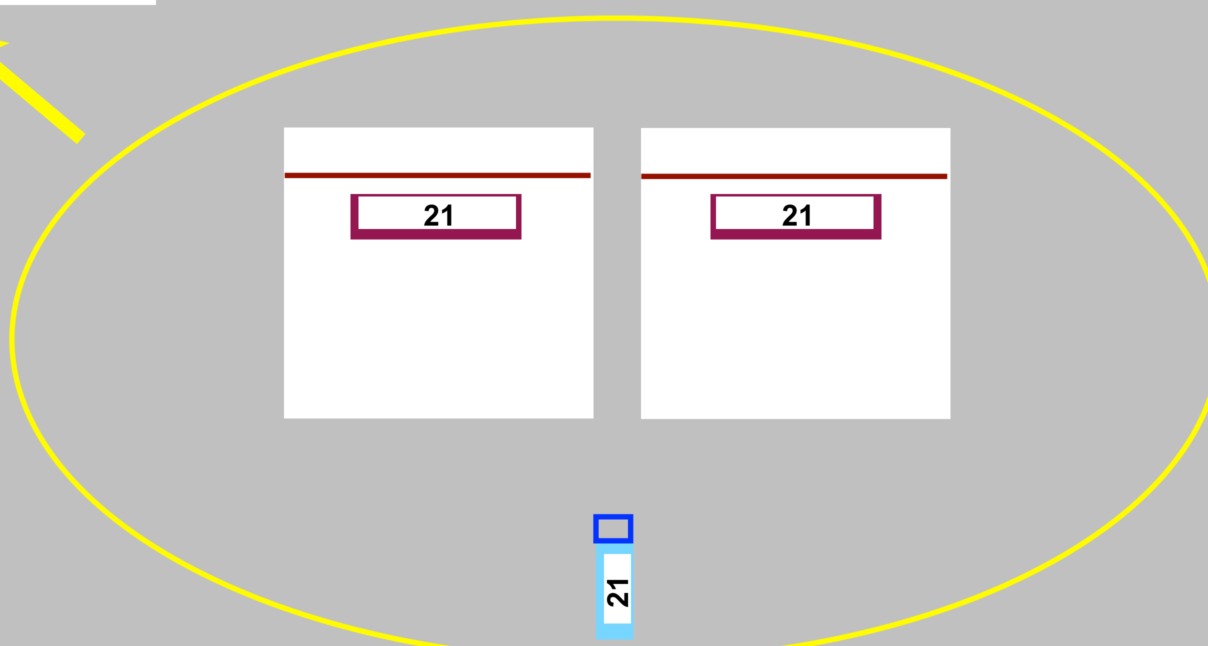
Texas A&M AgriLife WWDO Parts Collection Morph Data Form 20110702.1



Whole Bird into Large Ziplok

Place the two empty bags & vial into Large Ziplok

Page No. 2 of ____ *Fill this out when done

White-winged Dove Parts Collection Morphology Data Sheet

Name: Brian L. Pierce

Date: 1 September 2011

State: Texas

County: Hays

Check Station Name/Description: TPWD Office San Marcos

Latitude (DD.ddd; WGS84): 29.877636

Longitude (DD.ddd; WGS84): -97.935649

	Band	Wt.	Blue Eye Ring	Red Iris	Black Bill	Red Leg	Bill Length	Bill Depth	Bill Width	Tarsus Length	Tail Length	Wing Length	Primary Molt	Buffy Coverts	Skull Ossified	Ovaries Testes	Bursa of Fabricius	Parts Bagged						Bag Number
	(Band# or N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	MD, MU, FD, FU, Unknown	(Y/N)	WB	W	L	T	C	TV	Affix Sticker from Tag
1	12345678	123	Y	Y	Y	N	25	5	5	34	100	154	P9	N		–	–	X	–	–	–	–	–	21
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If this is a donated **whole bird**, then check “WB”.

Leave “Skull Ossification”, “Ovaries/Testes”, and “Bursa of Fabricius” (grey boxes) blank.

Place a dash (“–”) in “W”, “L”, “T”, “C” & “TV”.

If this is NOT a hunter donated whole bird:

Step 12

- Locate sample bags, vial, & small label
- Continue specimen collection as follows

Step 13

- Remove right wing & right leg
- Bag wing & leg in pre-labeled small ziplok#1

Step 14

- Skin upper thigh, remove muscle & place in pre-labeled sample vial.

Step 15

- Remove tail fan just below vent
- Place tail fan in small ziplok#1, on top of wing & leg

Step 16

- Remove crop contents
- Place crop contents in pre-labeled small ziplok# 2

Page No. 2 of ___ *Fill this out when done

White-winged Dove Parts Collection Morphology Data Sheet

Name: Brian L. Pierce

Date: 1 September 2011

State: Texas

County: Hays

Check Station Name/Description: TPWD Office San Marcos

Latitude (DD.ddd; WGS84): 29.877636

Longitude (DD.ddd; WGS84): -97.935649

	Band	Wt.	Blue Eye Ring	Red Iris	Black Bill	Red Leg	Bill Length	Bill Depth	Bill Width	Tarsus Length	Tail Length	Wing Length	Primary Molt	Buffy Coverts	Skull Ossified	Ovaries Testes	Bursa of Fabricius	Parts Bagged						Bag Number
	(Band# or N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	MD, MU, FD, FU, Unknown	(Y/N)	WB	W	L	T	C	TV	Affix Sticker from Tag
1	12345678	123	Y	Y	Y	N	25	5	5	34	100	154	P9	N				–	X	X	X	X	X	21
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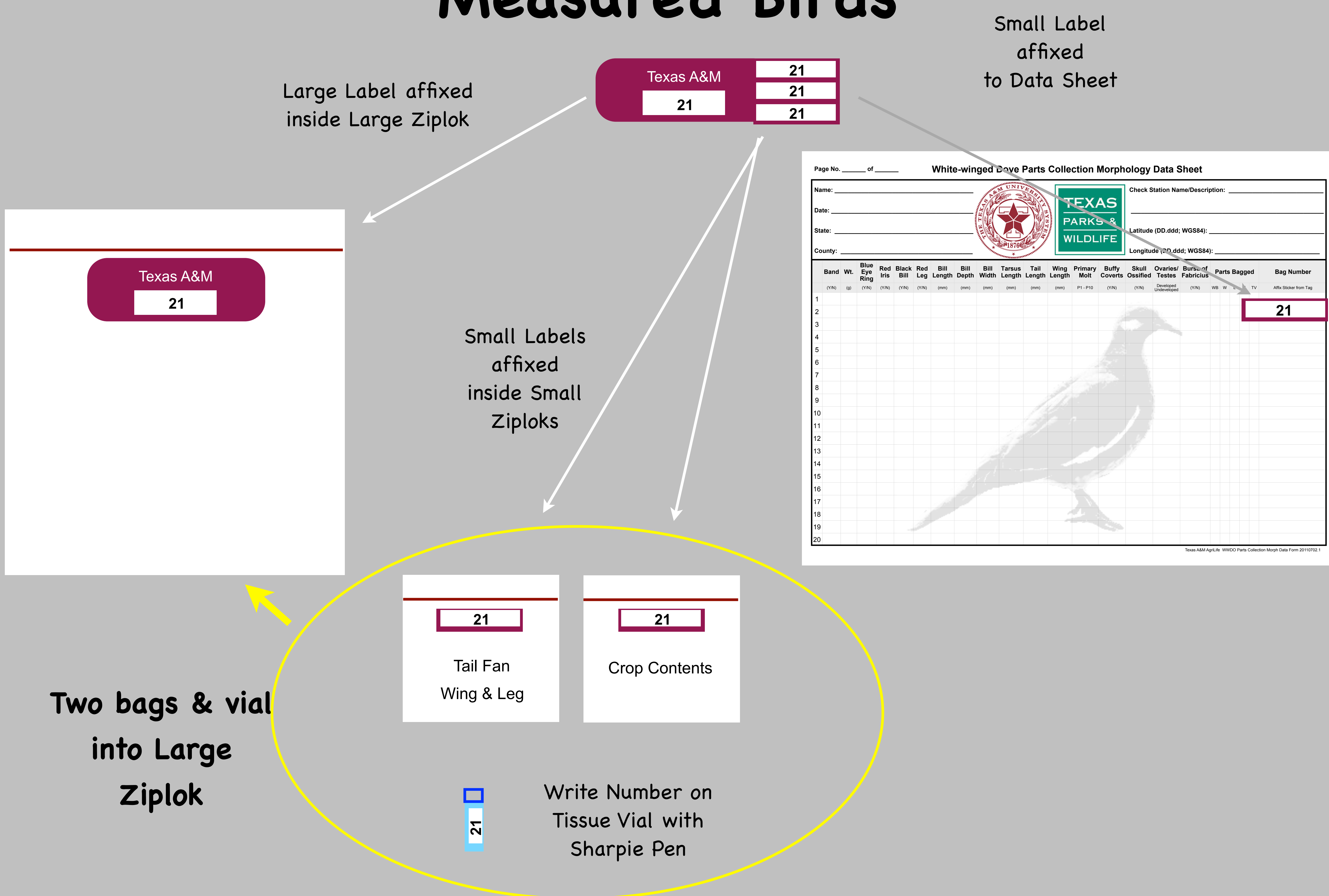
Step 12 – 16

Small Bag#1 with tail fan, leg, & wing
Small Bag#2 with crop contents
Tissue vial with thigh muscle tissue
Place small label on data sheet

Steps 17 - 19

- Check bags, tissue vial & datasheet.
- There should be matching labels on the inside/top of all three bags, vial, & the data sheet. All data boxes should be filled, except grey area.
- Place small bags & vial inside large bag, seal, and place in cooler.

Measured Birds



*Fill this out when done

Page No. 2 of ____

White-winged Dove Parts Collection Morphology Data Sheet

Name: Brian L. Pierce

Date: 1 September 2011

State: Texas

County: Hays

THE TEXAS A&M UNIVERSITY SYSTEM 1876

TEXAS PARKS & WILDLIFE

Check Station Name/Description: TPWD Office San Marcos

Latitude (DD.ddd; WGS84): 29.877636

Longitude (DD.ddd; WGS84): -97.935649

	Band	Wt.	Blue Eye Ring	Red Iris	Black Bill	Red Leg	Bill Length	Bill Depth	Bill Width	Tarsus Length	Tail Length	Wing Length	Primary Molt	Buffy Coverts	Skull Ossified	Ovaries Testes	Bursa of Fabricius	Parts Bagged						Bag Number
	(Band# or N)	(g)	(Y/N)	(Y/N)	(Y/N)	(Y/N)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	P1 - P10	(Y/N)	(Y/N)	MD, MU, FD, FU, Unknown	(Y/N)	WB	W	L	T	C	TV	Affix Sticker from Tag
1	12345678	123	Y	Y	Y	N	25	5	5	34	100	154	P9	N				–	X	X	X	X	X	21
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Steps 16 – 19

Row of data should be complete (**no empty boxes**)
Large label in large ziplok, inside near top
Small label on data sheet
Small label in wing, leg & tail fan bag, inside near top
Small label in crop contents bag, inside near top
Place 2 small bags & tissue vial into large bag & seal
Place parts bag into cooler
If table is clear, begin next bird.

You should have one dismayed hunter looking at a double-amputee WWDO
You might want to place all bird remains from one hunter into a ziplok for courtesy

References provided as *.pdf files

- WWDO Phenology SOP (this document)
- WWDO Phenology Procedure
- WWDO Phenology Data Sheet
- WWDO Phenology Check Station Sign