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DO BAND-TAILED PIGEONS SEEK A CALCIUM SUPPLEMENT AT MINERAL SITES?[1]

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Abstract. We tested the hypotheses that mineral sites in western Oregon are used by Band-tailed Pigeons (*Columba fasciata*) to supplement dietary calcium and sodium. We compared mineral composition of sites used by Band-tailed Pigeons, adjacent unused sites, and three major food items during the nesting season. Sixty-five percent of used mineral sites were low in calcium (<200 ppm), whereas mean concentrations in food items were high (1,960–2,290 ppm). All but one used mineral site were high in sodium (≥678 ppm), whereas mean concentrations in food items were low (20–254 ppm). Food items were high in mean concentrations of potassium (12,470–26,980 ppm) and potassium:sodium ratios (138–656). Used and adjacent, unused, estuary mineral sites were similar in calcium and sodium concentrations. We hypothesize that because of insufficient sodium intake and inefficient sodium retention, Band-tailed Pigeons seek a sodium source to supplement their diet during the nesting season. Use of mineral sites probably depends upon sodium concentration, but also vegetation structure, development, human activity, and congregation use by Band-tailed Pigeons. Used mineral sites appear to be scarce in western Oregon, and are seemingly essential resources for this species. Eighty-six percent of known currently-used mineral sites are privately owned and subject to possible alteration from land-use practices. Mineral sites used by Band-tailed Pigeons should be included in the overall management scheme for maintaining stable breeding populations of this species.

Key words: Band-tailed Pigeon, calcium, Columba fasciata, *mineral site, nutrient composition, sodium, potassium.*

INTRODUCTION

Band-tailed Pigeons (*Columba fasciata*) use and congregate at mineral sites throughout their range (Neff 1947, Smith 1968, Jarvis and Passmore 1992). This behavior is most frequent and consistent in that portion of the breeding range of the Pacific Coast population (*C. f. monilis*) in western British Columbia, Washington, Oregon, and northern California.

The behavior of Band-tailed Pigeons at mineral sites indicates these resources are critical. Band-tailed Pigeons home to mineral sites using one or several adjacent sites within a year and in subsequent years (Jarvis and Passmore 1992). They remain at mineral sites 1–2 hr, a substantial portion of their non-nest diurnal activities (Jarvis and Passmore 1992). Hawks are commonly observed at mineral sites; however, Band-tailed Pigeons seem concerned only when near the ground or when closely approached (less than 10 m) by a hawk (Jarvis and Passmore 1992). Band-tailed Pigeons use mineral sites about once per week during the nesting season (Passmore 1977). They repeatedly attempt to approach and land near the mineral source despite shooting during hunting season (Morse 1950).

Use of mineral sites by Band-tailed Pigeons is well documented. Counts at mineral sites are used as an index of population abundance in Oregon (Jarvis and Passmore 1992) and Washington (Western Migratory Upland Game Bird Technical Committee 1994). Jarvis and Passmore (1992) reported 1,332 Band-tailed Pigeons were counted arriving at one mineral site between daylight and noon; the average of eight sites was 317. Mineral sites also are popular with sportsmen: most Band-tailed Pigeons harvested in the Pacific Northwest are shot at mineral sites (Morse 1950, 1957, Einarsen 1953).

Early investigators thought mineral sites were used by Band-tailed Pigeons only during fall migration (Einarsen 1953, Morse 1957, Smith 1968). More recently, an association between use of mineral sites and nesting activity was demonstrated (March and Sadleir 1975, Jarvis and Passmore 1992). March and Sadleir (1975) found high levels of serum calcium during ovulation and production of crop milk. Both male

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and female adults regurgitate crop milk, a curd-like substance, to feed their young for about one week after hatching and then in decreasing amounts until fledging (March and Sadleir 1975, Griminger 1983). Crop milk contained 0.5 mg calcium g^{-1} and March and Sadleir (1975) estimated that Band-tailed Pigeons needed 10 mg day^{-1} of calcium to maintain calcium equilibrium while feeding young. They suggested mineral sites were used to supplement a calcium-deficient diet. Furthermore, mineral sites examined by Smith (1968) and March and Sadleir (1972) contained high concentrations of calcium ions.

The demonstrated increase in calcium need during reproduction does not, however, necessarily reflect a calcium deficiency. Jarvis and Passmore (1992) hypothesized that in the Pacific Northwest, the diet of Band-tailed Pigeons during the breeding season, principally berries of red elder (*Sambucus racemosa* var. *arborescens*) and cascara (*Rhamnus purshiana*), is deficient in calcium, and that these birds seek mineral sites to supplement dietary calcium. Braun (1994) reported, based on available literature, that calcium intake by adults is extremely important during the nesting cycle, especially when feeding nestlings. The calcium deficiency hypothesis, however, has not been tested.

We tested the hypotheses that Band-tailed Pigeons visit mineral sites to supplement dietary calcium and sodium. We compared mineral composition of mineral sites and major foods used by Band-tailed Pigeons and unused mineral sites during the nesting season. We also documented the location and origin of all known mineral sites used by Band-tailed Pigeons in western Oregon. We reasoned that if Band-tailed Pigeons visit mineral sites to supplement dietary calcium, then used mineral sites would contain high concentrations of calcium, and diets would be deficient in calcium. Alternatively, we suspected that Band-tailed Pigeons seek sodium at mineral sites rather than calcium upon observing them pecking at livestock-salting areas and drinking saltwater along bays and estuaries.

METHODS

STUDY AREA

The study area encompassed western Oregon from the Pacific Coast to the western Cascade Range (42°00′–46°15′N, 122°00′–124°35′W). Western Oregon includes four major physiographic regions: Coast Range, Willamette Valley, western Cascades, and Klamath Mountains (Franklin and Dyrness 1973, Loy et al. 1976).

The climate is marine west coast, characterized by wet, mild winters (October–June), and cool, dry summers (July–September). Rain falls abundantly on the Coast Range and western slopes of the Cascade Range, especially at high elevations due to orographic lifting. Annual precipitation ranges from 100 to 300 cm, 75–85% of which occurs between 1 October and 31 March in the form of rain, with some snow at higher elevations. Temperatures are generally mild averaging 2–8°C and 14–20°C during January and July, respectively. Average annual temperature varies from 9 to 12°C along the Coast Range, 12 to 15°C in the Willamette Valley, and 15 to 18°C along the western Cascades. The number of days with dense fog decreases from 40 to 20 days moving inland from the coast. The minimum temperature in January averages −2.5 to +2.5°C with a maximum of 20–30°C in July.

Western Oregon is characterized by dense, potentially long-lived (>500 years) coniferous forests in mountainous regions and diversified agriculture in the Willamette Valley (Franklin and Dyrness 1973, Jackson and Kimmerling 1993). Natural forested areas have an overstory dominated by western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziesii*), and red alder (*Alnus rubra*). Most areas are managed for timber production, however, and are dominated by Douglas-fir. The Willamette Valley is dominated by cities, farmlands, and other development. Vegetation mosaics in undeveloped areas include Oregon white oak (*Quercus garryana*) woodlands, coniferous forests, grasslands, and riparian forests. Agricultural production includes orchard crops, vegetables, grains, hay, berries, grapes, livestock, poultry, and nursery stock. In coastal valleys, and some parts of the Willamette Valley, dairy farming is the principal agricultural activity.

Mineral sites used by Band-tailed Pigeons in western Oregon are often mineralized deposits or, more typically, water. These sites are often naturally occurring, but some are the result of human activity. Dry sites include mineral deposits exposed during landslides and sites where livestock salt blocks (mainly sodium chloride) dissolved into the soil. Wet sites include mineralized springs, saltwater bays and estuaries, waste water from pulp mills, and abandoned artesian salt wells. Used mineral sites are characterized by ample, adjacent perching sites.

SAMPLE COLLECTION

Water samples at, and adjacent to, mineral sites, and samples of the major food items (berries of red elder, blue elder [*Sambucus cerulea*], and cascara) consumed by Band-tailed Pigeons (Jarvis and Passmore 1992) were collected during the nesting season (May–early September, Leonard 1998). Band-tailed Pigeons select almost exclusively singular food items in sequence of seasonal availability (Neff 1947; C. E. Braun, unpubl. data). We collected 10 berry samples of each species during 29 July–28 August 1997 in a 60-km-wide strip from the coast to Corvallis encompassing two major highways that transverse high-quality habitat (Leonard 1998, Sanders 1999). We collected berry samples from different open-canopied forest areas where we observed Band-tailed Pigeons foraging. Each sample consisted of 3.8 l of berries picked from trees or shrubs in the area obviously used. Forage areas typically consisted of a few trees or shrubs where all succulent berries are consumed from the tops downward (pers. observ.). All berry samples were frozen within 8 hr after collection to preserve them for laboratory analysis.

We located mineral sites used by Band-tailed Pigeons by investigating sites currently or historically used. Potential sites were identified in cooperation with sportsmen and personnel from Oregon Department of Fish and Wildlife (ODFW) and U.S. Geological Survey. We and ODFW biologists confirmed the presence and use of Band-tailed Pigeons at each mineral site. The main activity of Band-tailed Pigeons while on the ground at mineralized-water sites was drinking; pecking was incidental and most mineralized-water sources had inaccessible substrates. We recorded the mineral site type (spring, estuary, dry substrate, livestock salting area, or waste water) and location using the Universal Transverse Mercator grid system (Grubb and Eakle 1988).

We collected a water sample from 19 springs, 14 estuaries, and 3 waste-water mineral sites between Roseburg and a location 20 km north of Portland during 13 August–24 September 1997. At each mineral site, we observed Band-tailed Pigeons drinking water and then collected a 250 ml water sample in a urethane bottle from that location. We obtained water samples within a 5-m radius and from the top 2 cm of the water.

At estuary sites, Band-tailed Pigeons typically used an area of shoreline <100 m long. To compare used and unused sites, we also collected a water sample from areas 300–500 m in each direction along the shoreline. We did not collect samples at all unused sites due to access constraints or severe changes in site characteristics. All water samples were frozen within 8 hr after collection to preserve them for laboratory analysis.

Band-tailed Pigeons use grit throughout the year (Neff 1947, Smith 1968), which may be obtained at roadsides and some mineral sites (March and Sadleir 1972; pers. observ.). We collected grit from the gizzards of 29 Band-tailed Pigeons shot by hunters during mid-September in western Oregon to determine whether grit was a readily available source of minerals. Seventy-six percent (22/29) of the gizzards collected contained grit. Twenty-two gizzards contained 6.0 cc of grit that weighed 15.0 g and ranged in diameter from about 1 to 8 mm (n = 628, $\bar{x} \pm$ SD = 2.1 ± 1.2 mm). Most (81%) of the grit was less than about 3 mm in diameter. The grit sample appeared to consist of quartz stones (about 50%) and other stones similar to those found along roadsides in the area. Houston (1963) similarly reported that grit selected by Band-tailed Pigeons was mainly quartz stones. Other birds thought to supplement mineral-deficient diets have been found to select calcium-rich substances (soil, wood ash, bone, snail shell, egg shell) (Maclean 1974, Graveland 1996, Perrins 1996) or sodium-rich substances (soil, livestock salt blocks, road salt) (Tozer 1994). Grit selected by Band-tailed Pigeons does not appear to provide a readily available source of calcium or sodium, and therefore was not considered further in this study.

LABORATORY ANALYSES

Each berry sample (n = 30) was stirred thoroughly and a 500-g sample was removed and placed in an aluminum pan for drying. We placed samples in a drying oven at 60°C and stirred them daily. After 96 hr, samples were removed and weighed to determine partial dry matter. Each sample was ground in a Wiley mill to fit through a 1-mm screen and then placed in

TABLE 1. Mineral composition ($\bar{x}$ ± SE ppm) of spring, estuary, and waste-water mineral sites (n = 33, 22, and 3, respectively) used by Band-tailed Pigeons in western Oregon, 1997.

Attribute[a]	Spring	Estuary	Waste water
Barium	2.29 ± 0.68	0.10 ± 0.02	2.99 ± 2.19
Boron	5.72 ± 1.69	1.53 ± 0.15	1.40 ± 0.95
Calcium	1,662.1 ± 426.3	106.1 ± 12.1	51.3 ± 16.9
Magnesium	10.6 ± 3.0	272.7 ± 29.5	92.0 ± 25.0
Manganese	0.78 ± 0.46	0.57 ± 0.25	0.18 ± 0.16
Nickel	0.02 ± 0.00	0.01 ± 0.00	0.15 ± 0.08
Potassium	33.7 ± 6.9	177.4 ± 27.2	118.0 ± 54.1
Silicon	5.35 ± 0.86	1.68 ± 0.20	16.16 ± 3.92
Sodium	3,480.1 ± 918.9	5,027.4 ± 688.7	2,741.0 ± 968.4
Sulfur	110.2 ± 31.2	291.7 ± 38.7	26.7 ± 5.4
Zinc	0.11 ± 0.03	0.09 ± 0.03	0.35 ± 0.24

[a] Minerals below detectable limits (ppm): aluminum (<0.03), arsenic (<0.1), cadmium (<0.01), chromium (<0.01), cobalt (<0.01), copper (<0.02), iron (<0.1), lead (<0.03), molybdenum (<0.01), phosphorus (<0.1), and selenium (<0.1).

a sealable plastic laboratory bag. Samples were frozen for future analyses.

We evaluated percent water, dry matter, and inorganic matter in duplicate subsamples of each sample (n = 60; 3 food items × 10 samples each × 2 subsamples) following methods described by the Association of Official Analytical Chemists (1998). We submitted berry and water samples to Oregon State University's Central Analytical Laboratory for analysis by induction-coupled plasma (ICP) spectrometer scan to measure cation composition (Tables 1 and 2, respectively).

DATA ANALYSES

We used one-way analysis of variance to compare calcium, sodium, and total inorganic matter among food items (n = 30; 3 food items × 10 samples) and to compare calcium and sodium among mineral sites used by Band-tailed Pigeons (n = 36; 19 spring, 14 estuary, and 3 waste-water mineral sites). We used Fischer's protected least significant difference (FPLSD) test criterion (Steel and Torrie 1980) to make pairwise comparisons among means when the ANOVA F-statistic was significant ($P \leq 0.05$).

We used a paired t-test (n = 26) to compare mineral composition of estuary mineral sites used by Band-tailed Pigeons (n = 14) versus adjacent unused sites (n = 17). In three cases, where two adjacent samples were collected (one 300–500 m in each direction along the shoreline from the used site), we treated each comparison with the used site as independent. Samples from

TABLE 2. Mineral composition ($\bar{x}$ ± SE ppm) of estuary mineral sites used by Band-tailed Pigeons (n = 14), adjacent unused sites (n = 17), and paired difference between used and adjacent unused sites (n = 26) along the Oregon coastline, 1997.

				Test statistics[a]	
Attribute[b]	Used	Unused	Paired difference	t	P
Barium	0.10 ± 0.02	0.06 ± 0.01	0.03 ± 0.01	2.5	0.02
Boron	1.53 ± 0.15	1.50 ± 0.20	−0.01 ± 0.12	0.1	0.96
Calcium	106.1 ± 12.1	98.7 ± 14.2	7.8 ± 7.9	1.0	0.33
Magnesium	272.7 ± 29.5	263.2 ± 33.0	9.1 ± 18.9	0.5	0.63
Manganese	0.57 ± 0.25	0.08 ± 0.02	0.54 ± 0.19	2.9	0.01
Nickel	0.01 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	2.7	0.01
Potassium	177.4 ± 27.2	178.1 ± 28.9	−2.2 ± 15.0	0.2	0.88
Silicon	1.68 ± 0.20	2.47 ± 0.33	−0.87 ± 0.27	3.2	<0.01
Sodium	5,027.4 ± 688.7	4,916.5 ± 732.5	121.3 ± 389.4	0.3	0.76
Sulfur	291.7 ± 38.7	285.1 ± 39.9	4.3 ± 21.1	0.2	0.84
Zinc	0.09 ± 0.03	0.03 ± 0.01	0.06 ± 0.02	2.6	0.02

[a] t-test of differences between paired estuary mineral sites used by Band-tailed Pigeons and adjacent unused sites (n = 26).
[b] Minerals below detectable limits (ppm): aluminum (<0.03), arsenic (<0.1), cadmium (<0.01), chromium (<0.01), cobalt (<0.01), copper (<0.02), iron (<0.1), lead (<0.03), molybdenum (<0.01), phosphorus (<0.1), and selenium (<0.1).

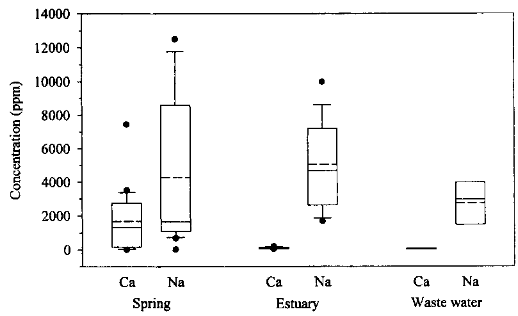

FIGURE 1. Distribution of calcium and sodium concentrations in spring, estuary, and waste-water mineral sites used by Band-tailed Pigeons in western Oregon, 1997. Boxes represent the 25th and 75th percentiles, solid horizontal lines mark the values of the 50th percentiles, broken horizontal lines indicate means, capped bars signify the 10th and 90th percentiles, and solid circles mark all data points outside the 10th and 90th percentiles.

13 used mineral sites were paired with samples from adjacent unused sites. Nine of 17 unused estuary sites were between used mineral sites and, therefore, were used in two comparisons. Values are reported as mean ± SE.

RESULTS

We located 83 mineral sites used by Band-tailed Pigeons; 65 currently used and 18 previously used. Of the currently used mineral sites, 33 were springs, 22 were estuaries, 5 were dry, 3 were waste water, and 2 were livestock salting areas. Known mineral sites currently used by Band-tailed Pigeons were scarce in western Oregon (1/3,846 km^2). Nine (13.8%) of these sites were publicly owned and 56 (86.2%) were privately owned.

The mineral sites currently used by Band-tailed Pigeons varied in mineral composition (Table 1). Mean calcium concentrations differed among mineral site types ($F_{2,33} = 5.8$, $P = 0.01$). Calcium was similar in estuary and waste-water sites (FPLSD $P = 0.95$), but was higher in spring sites than in estuary and waste-water sites (FPLSD $Ps < 0.07$). Spring sites had 17.2 times more calcium than estuary and waste-water sites combined (1,662.1 ± 426.3 ppm vs. 96.4 ± 11.5 ppm). Several mineral sites contained little calcium (Fig. 1). All estuary and waste-water sites had ≤192 ppm. Calcium was variable among spring sites, and 6 of 19 springs (31.6%) had <200 ppm. Calcium was <200 ppm at 64% (23/36) of all mineral sites.

Mean sodium concentrations were higher than those of all other minerals and did not differ among mineral site types ($F_{2,33} = 1.1$, $P = 0.36$). Sodium was variable among mineral sites, but 88.9% (32/36) of the sites had ≥969 ppm (Fig. 1). Sodium was <678 ppm at only one site. Overall, mineral sites provided a consistently rich source of sodium but did not provide a consistently rich source of calcium. Of all minerals present in both berry and water samples, only sodium occurred in greater concentrations in water samples than in berry samples.

The mineral source at estuary mineral sites was relatively non-discrete in nature and provided an opportunity to compare mineral concentrations between sites used by Band-tailed Pigeons and adjacent, unused sites. Five of the 11 minerals in detectable amounts differed between used and unused sites ($t_{25} \geq 2.5$, $Ps \leq 0.02$; Table 2). These five minerals occurred in mean concentrations of ≤2.47 ppm and differed by < 0.9 ppm. Sodium and calcium did not differ between used and unused estuary sites ($t_{25} \leq 1.0$, $Ps \geq 0.33$) and averaged 4,966.6 ± 499.8 ppm and 102.0 ± 9.4 ppm, respectively.

Food items varied in mineral composition (Table 3). Mean inorganic content differed among food items ($F_{2,27} = 43.7$, $P = 0.01$; FPLSD $Ps < 0.03$). Red elder had the highest mineral content and was 1.7 times higher than cascara and 1.1 times higher than blue elder. Mean calcium concentration did not differ among food items ($F_{2,27} = 1.4$, $P = 0.28$) and averaged 2,157 ± 87 ppm. Food items contained 1.3 times higher calcium than spring mineral sites and 22.5 times higher calcium than estuary and waste-water mineral sites. Mean sodium concentration differed among food items ($F_{2,27} = 41.9$, $P = 0.01$; FPLSD $Ps < 0.06$). Sodium was low in red elder, but was 13.0 times higher than in cascara, and 3.5 times higher than in blue elder. Mean potassium concentrations were high in food items. Consequently, potassium:sodium ratios also were high. The potassium:sodium ratios were 137.6 ± 33.2 for red elder, 656.3 ± 41.5 for cascara, and 311.8 ± 50.3 for blue elder.

DISCUSSION

MINERAL SITES

Many avian species depend on mineral intake from natural or anthropogenic sources to sup-

TABLE 3. Mineral composition ($\bar{x}$ ± SE ppm; moisture-free) of red elder, cascara, and blue elder berries (n = 10 each) sampled in the central Coast Range of Oregon, 1997.

Attribute[a]	Red elder	Cascara	Blue elder
Water (%)	76.0 ± 1.1	71.5 ± 0.8	82.7 ± 0.5
Dry matter (%)	24.0 ± 1.1	28.5 ± 0.8	17.3 ± 0.5
Organic (%)	94.6 ± 0.1	96.8 ± 0.1	95.2 ± 0.2
Inorganic (%)	5.4 ± 0.1	3.2 ± 0.1	4.8 ± 0.2
Boron	15.4 ± 0.9	15.7 ± 1.5	15.6 ± 0.8
Calcium	1,960 ± 164	2,290 ± 148	2,220 ± 136
Copper	4.9 ± 0.7	3.3 ± 0.2	4.5 ± 0.3
Iron	39.7 ± 5.3	18.6 ± 1.8	100.5 ± 16.6
Magnesium	1,630 ± 97	910 ± 50	1,240 ± 43
Manganese	36.4 ± 3.6	49.2 ± 5.1	9.2 ± 0.9
Nickel	0.6 ± 0.1	0.1 ± 0.1	1.0 ± 0.1
Phosphorus	3,330 ± 133	2,290 ± 148	2,260 ± 138
Potassium	26,980 ± 1,086	12,470 ± 410	19,690 ± 1,716
Sodium	253.8 ± 31.8	19.5 ± 1.0	72.6 ± 8.3
Sulfur	458.1 ± 37.5	295.4 ± 15.2	441.5 ± 36.0
Zinc	11.6 ± 0.8	7.5 ± 0.3	14.1 ± 0.9

[a] Minerals below detectable limits (ppm): arsenic (<4), cadmium (<0.4), chromium (<0.4), lead (<0.8), molybdenum (<0.4), and selenium (<4).

plement mineral-deficient diets (MacLean 1974, Graveland 1996, Perrins 1996). However, congregations of birds at mineral sites, sometimes called mineral licks, are rare, and is not a universal characteristic among any Family of birds. Among birds, mineral use is most notable among a few species of pigeons and doves (Jarvis and Passmore 1992), parrots and macaws (Emmons and Stark 1979, Gilardi and Munn 1998), and finches (Fraser 1985). The most plausible hypotheses proposed to explain the use of mineral sites are to: (1) provide grit for grinding food in the stomach, (2) serve as a mineral supplement, (3) buffer acidic or alkaline foods in the gizzard (Bechtold 1996), (4) detoxify secondary plant compounds such as alkaloids and tannins (Diamond 1998), and (5) replace electrolytes lost during daily diuresis (Adam and des Lauriers 1998).

Our data do not support the hypothesis that Band-tailed Pigeons visit mineral sites to supplement dietary calcium as suggested by March and Sadleir (1972, 1975) and Jarvis and Passmore (1992). Mineral sites used by Band-tailed Pigeons provide an inconsistent source of calcium. Our data provide evidence that Band-tailed Pigeons are associated with mineral sites with high sodium concentration. The one sample with a low sodium concentration (<678 ppm) was collected along a creek where a potential mineral source was not obvious. Fraser et al. (1980) reported that bias in measurements of mineral concentration might occur unless the spring source was located with a conductivity meter, a procedure we did not use.

March and Sadleir (1972) suggested that calcium was the primary ion sought by Band-tailed Pigeons at mineral sites after associating timing of the breeding season, increased calcium demand, and use of mineral sites with high concentrations of calcium. March and Sadleir (1970) did not, however, determine whether Band-tailed Pigeons were dietarily calcium deficient. The results obtained from water samples analyzed by March and Sadleir (1972) representing 11 mineral sites in Oregon, Washington, and British Columbia were consistent with our data. March and Sadleir (1972) reported calcium at 2 of 11 mineral sites was ≤275 ppm and 3 had ≤383 ppm. Sodium at 10 of 11 mineral sites were ≥650 ppm (March and Sadleir 1972). The one site of lower sodium concentration contained 145 ppm. The mineral content reported by Smith (1968) of two mineralized springs used by Band-tailed Pigeons also was consistent with our data: calcium was 1,140 and 57, and sodium was 3,505 and 936 mg l^{-1}.

Estuary mineral sites are consistently rich sources of sodium. Our data provide evidence that such resources are not limited to those specific estuary sites used by Band-tailed Pigeons. Yet, this species typically uses specific tidal areas of <100 m in length (March and Sadleir 1972) and some of these sites have been used for >43 years according to recorded ODFW Band-tailed Pigeon counts. Most (85%) of the bays along the Oregon coast are associated with at least one mineral site used by Band-tailed Pigeons. Estuary and other mineral sites used by Band-tailed Pigeons appear to have specific characteristics. We judge that, in addition to specific mineral resources, the availability of perch sites, development, human activity, and tradition of congregation use are important to this species. March and Sadleir (1972) and Morse (1957) also suggested that characteristics of the area surrounding estuary mineral sites are critical to Band-tailed Pigeons. The importance of traditional use is supported by the observation of Morse (1957), who observed the creation of a small artesian flow of salt water near Portland, Oregon. Over the years, Band-tailed Pigeons found the area and numbers gradually built up until it was a heavily used spring.

NUTRITION

Berries of red elder, blue elder, and cascara provide a rich source of energy and nutrients for reproduction in western Oregon (Sanders 1999). The availability of an abundant and nutritious food supply has specifically been associated with the initiation and timing of Band-tailed Pigeon reproductive activity (March and Sadleir 1970, 1972, Gutiérrez et al. 1975, Jarvis and Passmore 1992). A diet of elder and cascara berries, however, provides little sodium. Jarvis and Passmore (1992) reported that Band-tailed Pigeons fed on red elder berries almost exclusively from late June to mid-August and then almost exclusively on cascara berries from late August into early September. Our data indicate that cascara berries contained 12.7 times less sodium than red elder berries (254 ppm vs. 20 ppm). Blue elder (72.6 ppm sodium) becomes available in late August and September. Although in our comparisons red elder contained the greatest concentration of sodium, it was especially low when compared to other berry species (Johnson et al. 1985). Jarvis and Passmore (1992) reported that use of mineral sites increased from 15 Band-tailed Pigeons per day in mid-June to a peak of 60 per day in mid-August. This increased use of mineral sites corresponds with the pattern of decreasing dietary sodium and suggests that Band-tailed Pigeons seek a sodium supplement at mineral sites.

Detailed information necessary for understanding mineral metabolism and requirements of the Band-tailed Pigeon and most other wildlife species, in relation to maintenance and production, is lacking (Robbins 1993). A diet consisting exclusively of elder or cascara berries appears to be adequate, except in calcium, sodium, and potassium, based upon nutritional requirements of poultry (National Research Council 1994). Nutritional requirements for growing domestic birds range from 0.4 to 1.2% calcium and 0.30 to 0.70% potassium, and are almost invariably 0.15% sodium in the dry diet (Scott et al. 1960, Ingram et al. 1984, National Research Council 1994). Nutritional requirements for Band-tailed Pigeons during egg production may be similar to growing domestic birds because this species almost invariably produces one egg per clutch (March and Sadleir 1970, Leonard 1998). Based on the mineral requirements for growing domestic birds and the mineral contents of red elder and cascara berries, Band-tailed Pigeons feeding exclusively on these berries may be 2–5 times deficient in calcium (depending on calcium requirement), 5–75 times deficient in sodium (depending on berry species consumed), and 2–9 times high in potassium (depending on berry species consumed and potassium requirement).

The diet of Band-tailed Pigeons feeding exclusively on elder and cascara berries may be particularly deficient in sodium, but it also contains a sodium and potassium cation electrolyte imbalance. The required potassium:sodium ratio ranges from 2.0 to 4.7 in poultry (National Research Council 1994). The potassium:sodium ratio in the diet of Band-tailed Pigeons while consuming red elder was 137.6, and increased to 656.3 when they switched to cascara. Electrolyte balance in a bird's intracellular and extracellular fluids is critical for cellular functions and for osmotic and acid–base relationships (National Research Council 1994, Klasing 1998). Absorption and retention of sodium can be lessened by excessive potassium intake (Rugangazi and Maloiy 1988). Sodium appetite in many mammalian species has been associated with potassium loading during the consumption of succulent vegetative forages during the growing season (Weeks and Kirkpatrick 1978, Staaland et al. 1980, Fraser et al. 1982). As a consequence of the sodium and potassium cation imbalance in berries of elder and cascara, Band-tailed Pigeons may seek a dietary sodium supplement to balance their cationic electrolyte imbalance, or satisfy their sodium deficiency associated with potassium loading.

The ionic content of mineral springs, particularly sodium, appears to be the principal attractant to Band-tailed Pigeons at these sites. The physiological requirement for sodium, however, has not been determined. In western Oregon, berries of red elder and cascara, the two primary forages consumed during the breeding season, provide a rich nutritional source necessary for nesting, but contain low concentrations of sodium and high concentrations of potassium. The diet of Band-tailed Pigeons feeding exclusively on these berries decreases in sodium and increases in the potassium:sodium ratio as they switch from red elder to cascara. We hypothesize that as a result of dependence on red elder and cascara berries during the breeding season, insufficient dietary sodium, and inefficient retention of sodium associated with dietary potassium loading, Band-tailed Pigeons must seek a sodium source to supplement their diet. Mineral sites with high sodium concentration provide such a supplementary source of dietary sodium.

Known mineral sites are scarce in western Oregon; however, mineral site availability was not found to be a factor limiting the Pacific Coast Band-tailed Pigeon population size (Sanders 1999). Nevertheless, mineral sites are seemingly important components in the ecology of this species. Eighty-six percent of the known mineral sites in western Oregon are privately owned and subject to alteration from various land-use practices. Mineral sites used by Band-tailed Pigeons should be included in the overall management scheme for maintaining stable breeding populations of this species.

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