ROOSTING BEHAVIOR OF THE PIÑON JAY IN AUTUMN AND WINTER

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ABSTRACT.—This study describes the overt roosting and arousal behavior, associated environmental and biological variables, and possible selective factors experienced by a flock of about 80 color-marked Piñon Jays in northern Arizona. Birds roosted in the same 70-ha pine forest on 22 occasions between October and March. Birds arrived on the roosting grounds 1–2 h before going to roost and roosted primarily on the southern sides of the trees facing south and west. Roost sites were possibly selected for thermal economy and predator protection. The dispersion of roosting jays was similar to that of the nests and specific roost sites were similar to sites where nests were built. Birds roosted either with the bill pointed forward or tucked under the scapulars. In a cage where birds most often roosted facing a slightly illuminated wall, the female always settled into the roosting posture before the male. Postroosting arousal was typified by vigorous calling and short rapid circling flights. The former may act to reassemble the flock and the latter to increase the birds' metabolic rate and body temperature.—*Department of Biological Sciences* and (T.R.B.) *Department of Mathematics, Northern Arizona University, Flagstaff, Arizona 86011.* Accepted 5 December 1975.

Studies that concentrate on behavioral-ecological phenomena can be interpreted most profitably if a detailed description of the overt behavior being performed is given and viewed in terms of the physiological, ecological, and ethological selective pressures operating on the organism (Hinde 1952). Because activities concerned with survival are not performed in an ecological or behavioral vacuum, accurate descriptional data may provide clues important to understanding the overall biological significance of the event. A behavioral event is often performed in a particular fashion because of a constellation of selective pressures, but often the most important factors are easily identified.

In this report, we describe the pre- and postroosting behavior of Piñon Jays (*Gymnorhinus cyanocephalus*) and attempt to describe the selective pressures and their resolution as shown by their behavior. The Piñon Jay is ideal for a study of this type because each flock is a discrete unit and occupies a relatively stable home range (Balda and Bateman 1971, 1972). Because the birds spend the majority of their time in a flock, striking behavioral and ecological patterns are immediately obvious because of the large number of birds interacting at the same point in time and space. Such a situation has proved of value in defining nest-site selection in the Piñon Jay (Balda and Bateman 1972). Extensive investigations on the daily routine and social behavior of the study flock were underway during the period of this study, allowing us to place the roosting activities in proper biological perspective.

MATERIALS AND METHODS

Observations on the roosting behavior of a single flock of Piñon Jays numbering about 80 individually color-marked birds were made between 13 October 1974 and 20 March 1975. The year-round activities of this flock have been monitored for the past 3 years. This study was conducted during the portion of the year when the jays performed three successive activities: caching piñon pine seeds (13 October–1 November), late fall and winter foraging (2 November–17 February), and courtship and nesting (18 February–20 March). The beginnings and ends of these periods were determined by the predominant activities performed by the birds during various hours of the day throughout the study period.

The geographic location of the roosting area was determined in relationship to the known home range of the flock. Preroosting activities were noted on 22 occasions and postroosting activities on 13 occasions.

Notes were kept on vocalizations, flock movements, feeding and maintenance activities, and roost site selection by as many individuals as we could see at dusk.

Temperatures were recorded with a Honeywell hygrothermograph placed 2 m above the ground in a standard weather box at a location 0.5 km from the roosting site, and from two Taylor maximum-minimum thermometers placed in shelters 1.5 and 3.4 m above ground. Black vials containing 50 cc of water were placed around a tree ½ km from the nesting grounds at eight evenly spaced intervals. The vials were placed at a height of 5 m and just inside the green foliage. In each vial a thermistor was sealed in place through the cap. Readings were taken at 5-min intervals with a YSI telethermometer between 1630 and 1845 on 11 evenings during the course of the study.

Measurements of tree and bird heights were made with an Abney level until the observers became proficient at estimating heights accurately (± 1.5 m). All directions were determined with a Brunton compass. Measurements of roosting and nesting locations were made in a similar manner.

One adult male and one adult female were caged in order to determine possible differences in roosting postures and time of roosting. Under laboratory conditions, the birds were placed together in a cage so they could roost either facing a solid cage wall or a wire wall. On 12 successive nights the birds were watched when they initiated roosting and again between 2300 and 2330 to determine roosting posture and orientation. The cage was rotated 90° each evening so that the opened and closed walls were in each of the four positions three times during the experiment.

Results

Location of roosting site.—The study flock roosted in the same 70-ha ponderosa pine (*Pinus ponderosa*) forest on all 22 evenings. On a given evening the flock was dispersed over an area of about 40 ha. The roosting site was near the northeast edge of the flock's home range at an elevation of 2148 m. The 8 sq km home range was inhabited throughout the period of study except for temporary departures to harvest piñon pine seeds that the birds brought back to and cached on the home range through 1 November. After that time, the birds spent their entire time (or vast majority of it) on the home range. In addition to the 22 days we directly observed the birds on the roost site, we watched birds flying towards this site in late afternoon on numerous other occasions. Some of these flights were up to 6 km in distance and in a straight line towards the roosting grounds. We believe the flock roosted in this specific place on most nights during the study period.

Piñon Jays were often accompanied to the roosting grounds by groups of 20 to 80 Starlings (*Sturnus vulgaris*) that usually arrived on the site independently and earlier than Piñon Jays. The Starlings appeared to go to roost in the same vicinity and at about the same time the jays started roosting.

The flock started nesting at this site in late February 1975. During the nesting period, males and yearlings continued to roost in this specific area. No reasons are known to us why this site was selected for roosting and nesting as it was not used in this manner in other years. In other years and in other flocks (Balda MS), nesting and roosting sites were usually separated. This roosting site was adjacent to a new housing development where construction and the usual suburban noises were common. Many parts of the home range were undeveloped and seemingly offered the birds a more peaceful atmosphere.

Preroosting behavior.—The birds usually arrived on the roosting grounds in one or two loose flocks with a few birds straggling behind, usually between 1 and 2 hours before actually going to roost. They flew at an elevation of about 20 m, giving moderately loud "kraws" at a frequency and pitch usually heard during normal daily movements.

Upon arriving, the birds slowly settled into the lower branches and limbs of the pines. After 2 to 3 min some birds descended to the ground and started foraging.

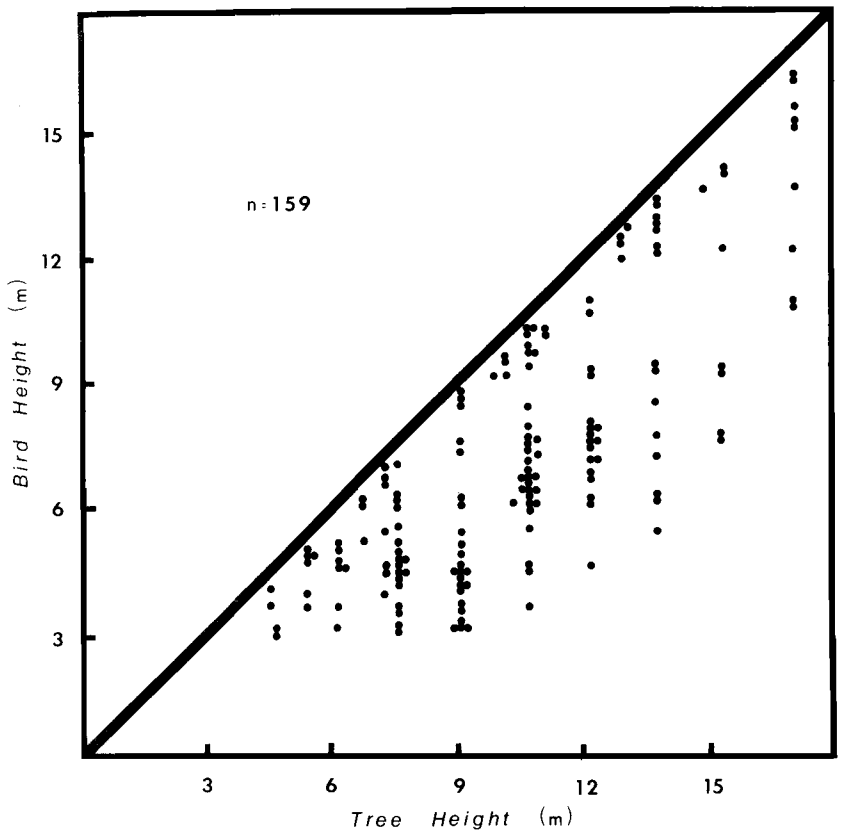

Fig. 1. Bird height vs. tree height for 159 roosting Piñon Jays. Black line indicates maximum possible bird height for trees of a given size.

Usually not more than half the flock was on the ground at one time and some birds were always sitting in the tips of pines on the periphery of the foraging flock. The flock usually moved very slowly in a set direction and was relatively silent. Only an occasional loud "kraw" was heard and most calls given were relatively soft and low pitched. The birds in the trees flew or glided between branches to maintain position within the flock. Ground and bark probing, needle gleaning, picking in pine cones, bill wiping, and grooming were all performed in what appeared to be a leisurely pace until about ½ hour before going to roost. As the roosting time approached, fewer birds continued to forage on the ground and most birds gradually ascended into the trees. From the trees the birds emitted occasional loud calls and hopped between branches, often going to the upper reaches of the trees and then gliding down to a low branch in nearby trees and proceeding upward again.

About 5 min before going to roost, calling almost completely ceased although the birds continued to move between trees. Individuals remained still on apparent roost sites for 10 to 20 sec but then moved to different sites. After about 5 min, most birds had selected their roost sites and became motionless and silent. They remained in this state until the next morning unless disturbed by a predator or a loud sharp noise. In these cases the birds gave loud rhythmic danger calls that increased in loudness and frequency, and then most, if not all, birds flew off. Domestic cats were a common

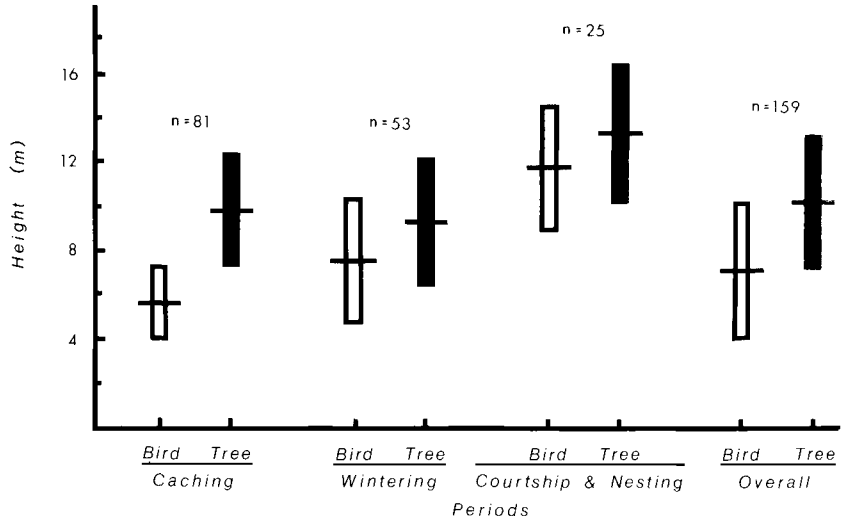

Fig. 2. Bird and tree heights for the three biological periods, showing mean and two standard deviations.

disturbance that caused the flock to shift location. On one occasion an unknown cause precipitated this antipredator behavior at 2140.

The caged female invariably settled into the motionless roosting posture a short time before the male ($\bar{x}$ = 10 min, range 7–15 min). These kinds of data could not be recorded in the field because of the poor light conditions at roosting time. All birds in the flock appeared to settle into roosting positions within a time span not exceeding 5 min.

Location of roost sites.—All birds seen roosting did so in ponderosa pine, the only species of tree present that contained foliage at this time of year. The jays roosted at heights ranging from 3 m to 16 m above the ground with a mean height of 7.4 m (Fig. 1). Birds moved up higher in the trees as the year progressed. Between October and February, the mean height of the roosting jays more than doubled (Fig. 2). The differences in these means were highly significant ($P < 0.01$, t-test) for each period.

The mean height of the trees used by the birds for the entire study was 10.4 m and ranged from 4 to 17 m. During the caching and winter foraging period the mean height of roost trees was about 10 m. During the courtship and nesting period the mean was 13.4 m (Fig. 2). This latter mean differed significantly ($P < 0.01$, t-test) from the mean tree heights for the earlier two periods.

Thus birds roosted higher during the winter foraging period than they did during the caching period, but they did so in similarly sized trees. Jays roosted higher during the courtship and nesting period than during the winter foraging period and to do so selected taller trees than they did during the two earlier periods.

Most Piñon Jays roosted between 40 and 80% of the distance out on the branch from the trunk, the mean being 57% of the distance (Fig. 3). The mean length of the limbs used for roosting was 4.6 m and the mean distance out from the trunk was 2.6 m, approximately where the live foliage begins on the branch. Few individuals roosted close to the trunk and those that did were usually high in trees where branches were short. Jays seldom roosted in the dense needles of the thin branch tips.

Roosting Piñon Jays showed a definite directional preference for the southern

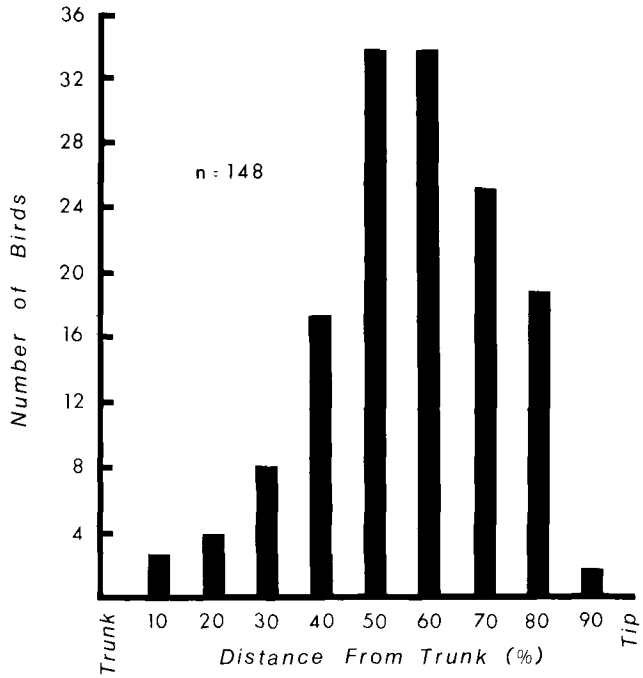

Fig. 3. Histogram of distance out on limb of roosting Piñon Jays where trunk is 0%.

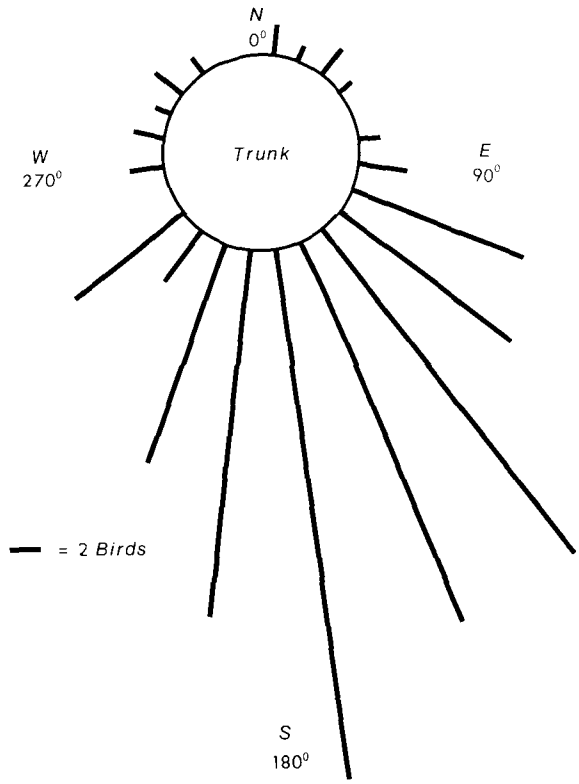

Fig. 4. Directional distribution of 185 roosting Piñon Jays.

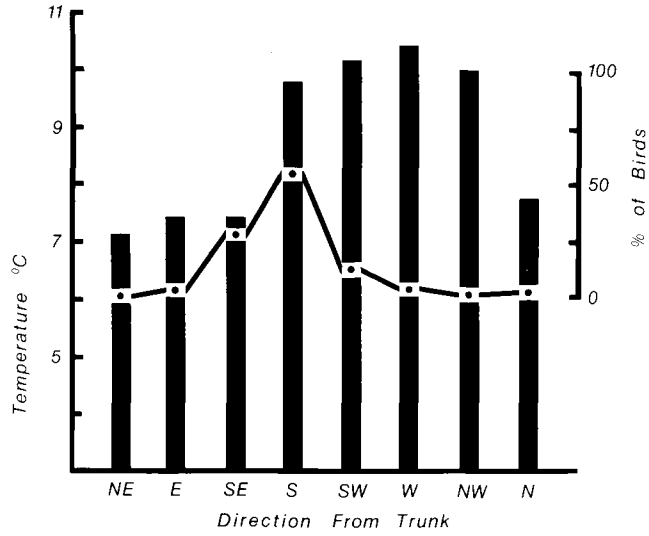

Fig. 5. Ambient air temperature (black bars) around pine tree at roosting time and directional preference (dots) of roosting Piñon Jays.

portions of the foliage within the trees. For 185 roost sites the mean direction from the trunk of the tree was 168° where 180° was used as south (Table 1) (Fig. 4). Of all birds measured, 92% roosted on the southern half of the tree and 74% were clustered in an arc of 74° centered on south. The distribution of the roost sites was determined to be unimodal and showed a preferred direction, that of the mean. The probability that the roost sites were uniformly distributed was $P < 0.001$, using the Rayleigh Z Test as described by Batschelet (1965). A portion of this directional preference may be related to the heating pattern around a ponderosa pine tree as at 1730 temperatures were warmer on the south and west sides of the tree (Fig. 5).

When roosting, the Piñon Jays also showed a definite facing direction to the south and west. The mean facing direction was 220° (Table 1) as 110 of the 148 roosting birds measured faced south, southwest or west (Fig. 6). The probability that the facing directions were uniformly distributed was $P < 0.01$ (Rayleigh Z Test). Thus, the birds were facing into the setting sun and not facing towards the trunks, dense branches, twigs, and foliage. Birds normally roosted perpendicular to the branch and used both the central and side branches. Options were thus available for selecting a variety of facing directions.

In the cage, where birds had a choice of facing either the wire mesh wall or a solid wood wall when roosting, they showed a preference for facing the wire wall. On 12 nights the birds faced the wire wall 20 times and the solid wall only 4 times. This difference is highly significant ($P < 0.01$, χ^2 test).

TABLE 1

DIRECTIONAL PREFERENCES SHOWN BY ROOSTING PIÑON JAYS

Event	Number	Mean direction	Concentration[1]	SD
Roosting direction from trunk	185	168°	0.74	41°
Direction birds faced during roosting	147	220°	0.52	56°

[1] A value of 1 indicates all birds exhibit the same directional tendency; a value of 0 indicates a uniform distribution (Batschelet 1965).

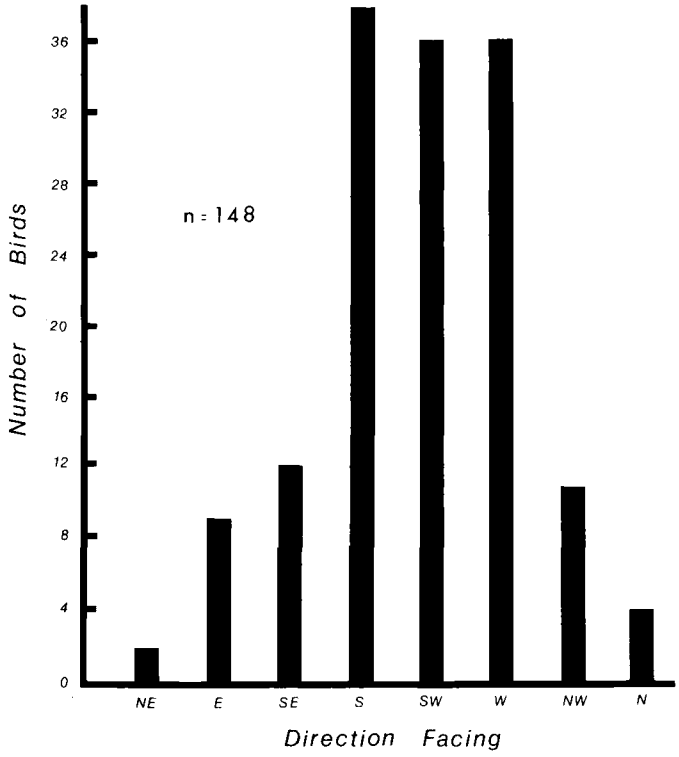

Fig. 6. Histogram of facing directions of jays at roost.

Roosting posture.—In the cage Piñon Jays roosted in one of two postures. Upon going to roost, the birds became still but remained in the normal perching posture except that the legs were flexed and partly covered by the belly feathers. Shortly thereafter the neck was retracted close to the body and the head held directly between, and in front of the wings. The bill was pointed straight ahead. The scapulars and anterior feathers of the spinal tract were slightly elevated as were the belly and flank feathers. The bird had a slightly ball-like appearance. From field observations in poor light conditions and from observations on caged birds, we conclude that jays initially assume this posture to roost, and may remain as such until morning.

Some birds on some nights changed from the posture described above to one in which the bill is placed on or near the skin of the dorsal apterium between the spinal and humeral feather tracts. The bill was completely covered by the scapulars and dorsal contour feathers of the anterior spinal tract. These latter feathers were noticeably fluffed. The anterior portion of the head was covered but the eyes were exposed (Fig. 7). The caged female placed her bill under her feathers on 75% of the nights whereas the male did so on only 42% of the nights.

Postroosting arousal.—On 13 occasions between 9 October 1974 and 20 March 1975 the postroosting behavior of the flock was observed. Time of arousal was determined as that time when the first overt movements were seen and/or vocalizations heard in the morning. Conceivably the birds could have been awake and alert but silent and motionless prior to this time, but we have no data to indicate this was the case.

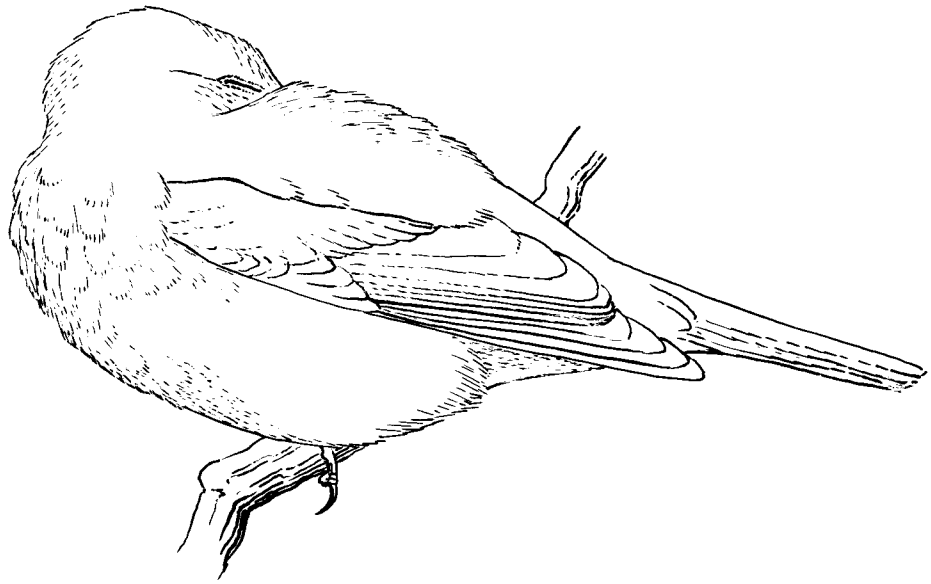

Fig. 7. Piñon Jay at roost with bill on back.

Arousal was initiated by loud calling by one or two birds but then joined by many birds. The "kraw" call was given loudly and in rapid succession continuously for approximately 10 min and then stopped. While these initial calls were being given the birds flew rapidly through the trees in a tight flock that occupied an area of no more than 100 sq m. Occasionally two groups formed next to one another. Many times the entire flock would regroup in two or three trees that were 20 to 70 m apart. During this time the birds selected the very tops of the trees and it was not uncommon for 8 to 10 birds to perch on a limb 1 m in length. Most birds perched on the south sides of the tree where the first early morning rays of the sun were evident.

After arousal the flock spent 20 to 30 min on the roosting site alternating silent perching with vigorous circling flights accompanied by loud calling. These flights were 30 sec to 3 min in duration and usually covered an area of less than 300 sq m. Most all birds participated in these flights and the flock was tightly knit as most of the birds were within 0.5 m of each other. Often at the end of these flights the birds returned to perch silently in the same trees they occupied before the flight.

No birds were seen foraging during this period. Postroosting behavior terminated when the flock flew off at least 0.5 km to start their daily feeding.

Discussion

Behavior associated with roosting.—Three biological factors appear important to Piñon Jays at the time of roosting: thermal economy, flock cohesiveness, and predator protection. It was somewhat surprising that the flock consistently arrived on the roosting site well before going to roost. Nice (1943) and Odum (1942) report that the Song Sparrow (*Melospiza melodia*) and Black-capped Chickadee (*Parus atricapillus*), respectively, go directly to the roost sites and roost. During the time preceding roosting, the Piñon Jay flock may well be inspecting the roosting site for predators, as some birds appear to be sentinels as noted during daily foraging activities (Balda and Bateman 1971). The constant movement of the birds through the

foliage may indicate a careful scrutiny of the site for stationary predators. The obvious shuffling that goes on immediately before roosting could be interpreted as roost site selection behavior, but we think not because apparent roost sites are obvious and plentiful. The shuffling may involve location of the mate, as the birds are monogamous and have a permanent pair bond (Balda MS). We have no data to support or disclaim this suggestion as color bands were impossible to read in the dim light. This shuffling may also act to confuse a watching crepuscular predator as all birds performed it in unison.

We have no field data to support our findings on caged birds that females go to roost earlier than males, as all birds selected roost sites and assumed the roosting posture within a 5 min time span. Males may remain alert at the site for a longer period each evening than females. This sexual difference has also been reported for the Song Sparrow by Nice (1943), and Kluyver (1950) noted Great Tit (*Parus major*) females retired to roost on an average of 12 min before the males. Male Piñon Jays are more aggressive than females (Balda MS) and generally in a more advanced state of reproductive readiness than the females (ligon in Litt.). Thus the internal motivational state of the male may be responsible for this extended period of alertness. From 1 November 1974 to 30 April 1975 a total of 25 males and 12 females were caught and weighed. The males averaged 112 g (range 102–127 g) and the females' mean weight was 100 g (range 92–106 g). Possibly the thermal demands imposed by their smaller size made it expedient for females to go to roost earlier than males.

The roosting postures assumed by the two caged birds also substantiates the above hypothesis. If we assume it is energetically more efficient to place the bill under the feathers because of heat loss from the nostrils, then the smaller sex should assume this posture more often than the larger sex, which our data support. It is not possible to separate the effects of the higher state of alertness from energetic considerations, because even though the eyes are exposed, a bird with its bill under its feathers is probably in a more defenseless position than one with its head forward.

Postroosting behavior appeared to have two important functions. The first was to rally the flock together as a compact unit before leaving the roosting site. The loud, rapid calling no doubt served to alert or awaken flock members. The jays responded by giving the same call and gathering into a small area. The conspicuous, vigorous flights could also serve to attract flock members, but it is possible that they also served to increase the birds' metabolic rate and body temperature. Laboratory studies (Cannon 1973) show the Piñon Jay reduces its body temperature about 4°C in the dark. The vigorous postroosting exercise may play an important role in elevating the body temperature. Our sighting of the birds perched in the tips of illuminated pines supports this suggestion.

The study flock has been maintained as a socially definable unit since 1972 (Balda MS) when the birds were first color banded. During the day jays move long distances on their foraging route (Balda and Bateman 1971). The rallying behavior serves to reconstitute the flock before these extensive forays start. It is possible that both the physiological function (raising the body temperature) and the sociological function (regrouping the flock) must occur before efficient foraging and energy assimilation can occur. The fact that the birds spent up to ½ h performing these behaviors suggests they are not in a pressing energy state after long, relatively cold nights. Kluyver (1950) believed Great Tits also survived the winter nights in good energetic condition because the birds performed certain social functions each morning before feeding.

Roosting sites.—Numerous reports indicate that species that nest in cavities or domed nests also roost there. Skutch (1940) found the wrens of Costa Rica that build domed nests also use similar structures for roosting, whereas species that nest in crannies or cavities roost in similar microhabitats. Anderson and Anderson (1957, 1960) extensively documented the use of domed structures for roosting by the Cactus Wren (*Campylorhynchus brunneicapillus*) and Verner (1965) reported similarly for the Long-billed Marsh Wren (*Telmatodytes palustris*). Some cavity nesters such as the Green Woodpecker (*Picus virescens*) (Jourdain 1936), Great Tit (Kluyver 1950), White-breasted Nuthatch (*Sitta carolinensis*), Downy Woodpecker (*Picoides pubescens*) (Kilham 1971), and occasionally the Black-capped Chickadee (Odum 1942) and Pygmy Nuthatch (*S. pygmaea*) (Knorr 1957), also roost in cavities. To our knowledge no information on the similarity of nesting and roosting sites by an open, foliage nesting species has been reported.

Piñon Jays appear to nest and roost at very similar sites. At roosting time the flock scattered over an area of about 40 ha whereas the same flock, nesting in the same forest in 1975, dispersed its nests over about 50 ha. Just as nest dispersion is possibly a compromise between placing the nests close together for common defense against predators and spacing the nests apart so they are more difficult for predators to find (Kruuk 1964), the dispersion pattern of roosting birds may serve a similar purpose. Nocturnal predators, presumably Great Horned Owls (*Bubo virginianus*), were known to enter the roosting colony on at least two nights.

Although the mean roosting direction for the three biological periods of the year was 168°, when the data are subdivided by time of year some noticeable shifts are evident. During the caching period the mean roosting direction was 162°, during winter foraging 180°, and during courtship and nesting 182°. Thus the birds appear to make a gradual shift around the southern half of the tree as the year progresses. This shift may be to take advantage of the differential heating that occurs in late afternoon and early evening at all seasons except late spring and summer (Balda and Bateman 1972), but the birds may need to take advantage of it only during the coldest time of the year. This directional preference is also shown by nesting jays. Between 1968 and 1971 the mean nesting direction was always south and varied between 163° and 191° (Balda and Bateman 1972). In 1975 the Piñon Jays also showed this preference, having a mean direction ($n = 26$) of 197°. Apparently the ambient conditions surrounding the roosting bird are very similar to those impinging on a nesting female as the locational preference seems reasonably similar in both cases.

The mean facing direction (220°) suggests that more than thermal economy may be involved in southside roosting. By facing into the declining light of sunset the birds can visually locate predators approaching in the evening sky. Looking into the darkened eastern sky or at the thick foliage, branches, and trunk of the tree prior to sleep would appear to be of no advantage to the bird. At dusk, caged birds also oriented to look in the direction of greatest illumination. We have seen Sharp-shinned Hawks (*Accipiter striatus*) and Goshawks (*Accipiter gentilis*) hunting and harassing the flock at sunset and shortly thereafter.

As the seasons progressed the jays moved higher into the trees to roost. Odum (1942) also noted this in Black-capped Chickadees but had no explanation for it. One possible reason may be that as the soil surface gradually cools in autumn reradiation of heat declines causing the temperature differential between lower and higher branches of the tree to decline. A blanket of snow will also retard reradiation of heat.

Circumstantial evidence for this comes from weather data gathered 0.5 km from the roosting area where maximum-minimum thermometers were placed 1.5 and 3.4 m above the ground. Readings from 4 October to 31 November indicate the mean daily low temperature differential between the two declined from 3.2°C to 1.1°C. At the same time the sun is setting lower on the horizon and therefore at sunset the sun's rays strike only the uppermost branches. Thus the birds may be responding to either or both of these conditions. No downward shift was seen in late winter when the angle of the sun increased, but the soil surface is slow to heat up at this time and is often snow covered.

While nesting, Piñon Jays roosted higher in the trees than they placed their nests. The mean nest height (n = 26) for 1975 was 6.7 m whereas the mean roost height (n = 25) at this time of year was 11.8 m. These means were significantly different ($P < 0.05$). The tree height in which the birds nested and roosted was not significantly different and averaged 12.8 m for nesting trees and 13.4 m for roosting trees. The tendency to nest lower in the tree may indicate a preference for the thicker, more stable branches near the bottom of the trees for nests over the more flexible thinner branches used for roosting perches. Also the pine's conical shape provides more foliage for concealment at lower levels.

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