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ROOST CHARACTERISTICS AND BEHAVIORAL THERMOREGULATION IN THE SPOTTED OWL

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Previous studies on the Spotted Owl *(Strix occidentalis)* have established important parameters in habitat preference of this species. Old growth, multi-layered forests; water availability; and the presence of suitable nest sites are consistent characteristics of the habitats occupied (Gould 1974, 1977; Forsman 1976). These authors postulated heat intolerance as a possible factor in habitat selection. To further examine this hypothesis, we analyzed aspects of Spotted Owl habitat in preferred use areas, particularly at major roost sites, and related this information to behavioral adaptations of the owls.

This preliminary investigation was aimed specifically at understanding features of the forest environment which determine roost site selection. Relating to these features, possible limitations imposed on the Spotted Owl by physiological tolerances to environmental extremes were also considered.

STUDY AREA AND METHODS

The bulk of this study was conducted on The Nature Conservancy's 20,000 ha Northern California Coast Range Preserve (NCCRP) in Mendocino County; three locations in Marin County were also examined. The study spanned the period from 20 June to 31 August 1977. NCCRP encompasses a variety of vegetational communities of which the Mixed Evergreen Forest (Sawyer, Thornburgh, Griffen 1977) is a major component. The South Fork of the Eel River runs north through the Preserve. The watersheds of several tributaries to the Eel are included within the boundaries of NCCRP. Two of these tributaries, Fox Creek and Skunk Creek, were centers of Spotted Owl activity during the study period.

The habitat analysis phase of this study dealt with ten major roost sites. Seven of these were located at NCCRP; sites 2 and 6 were within the territory of pair 1, at Skunk Creek, and sites 1, 3, 4, 5, and 7 were in the territory of pair 2, at Fox Creek. Pair 1 fledged two young this season; pair 2 did not produce offspring. The last three sites were located in Marin County, representing two pairs of owls. Sites 8 and 9 were in a steep sided creek drainage near Palomarin. This pair of Spotted Owls fledged two young this year. Site 10 was at San Geronimo, where one immature owl was observed roosting.

Daytime roosts were located by walking through the areas where Spotted Owls had been seen or heard. Owl roosts are distinguished by a large accumulation of white fecal matter and pellets. Major roosts were identified on the basis of the presence of Spotted Owl pellets ranging in age from a week to several months old, indicating a long period of use. Secondary or minor roosts were noted as having only insignificant fecal accumulations with few or no pellets.

A 50 m transect was marked in four compass directions (N, S, E, W) from major roosts to establish a 10,000 m^2 plot. Vegetation along the transect was evaluated by a count of the number and age class (adult/sapling) of each species encountered in a 5 m wide swath. We measured relative humidity, using a sling psychrometer, and ambient temperature at ground level, using a centigrade thermometer, hourly at major roost sites both when observing the owls and when the owls were absent. Temperature was also recorded in open canopy situations adjacent (within 50 m) to the major roosts. Humidity values were recorded as percentage of 100% saturation and were then converted to ambient vapor pressure, in torr (Weast 1972-73).

We observed heat stressed owls on seven separate occasions for a total of 25 hours. Direct observation of the owls was made at distances ranging from 2 to 5 m. Signs of disturbance due to our presence (such as watchfulness or evasive behavior), which could add to their stress, were never noted in the owls during observations.

RESULTS

Roost Selection

The canopy at major roosts was typically of two heights, with Douglas-fir *(Pseudotsuga menziesii)* forming an irregular upper stratum as tall as 65 m. Tanoak *(Lithocarpus densiflora)* formed a major component of a more continuous lower stratified canopy of heights to 35 m. Douglas-fir was not the sole component of the primary canopy. Coast Redwood *(Sequoia sempervirens)* was a frequent, though less abundant, coniferous companion to the Douglas-fir. At the more hydric sites 8 and 9 at Palomarin there was a shift in the hardwood understory from Tanoak,

Table 1. Percent occurrence of coniferous and hardwood trees in 10,000 m^2 plots surrounding each major roost site. Standard deviation from the mean of both vegetation types was 10.3.

Vegetation Type	Roost Site No.									
	1	2	3	4	5	6	7	8	9	10
Coniferous (Mean: 19.1)	42.1	25.1	21.6	8.5	20.2	17.2	5.5	8.9	14.6	27.3
Hardwood (Mean: 80.9)	57.9	74.9	78.4	91.5	79.8	82.8	94.5	91.1	85.4	72.7

typical at NCCRP, to a combined secondary canopy of California Bay *(Umbellularia californica)*, Buckeye *(Aesculus californica)* and Coast Live Oak *(Quercus agrifolia)*. At San Geronimo, Coast Redwood was the sole component of the primary canopy. Tanoak formed a secondary canopy with minor representation by California Bay. The basic floral components of each of these areas may best be represented as percentage of coniferous and hardwood trees (Table 1). The more continuous hardwood understory is particularly important to the owls; out of the 156 major and minor roost sites sampled, 151 were in hardwood trees. All major roosts were located in hardwoods.

The physical characteristics of each major roost (Table 2) were strikingly similar, particularly in view of the diverse habitat types available to the owls. In contrast to the habitat described above, the study area at NCCRP also encompassed more xeric stands of pure Madrone *(Arbutus menziesii)* or Interior Live Oak *(Quercus wislizenii)*, along with mature stands of Douglas-fir with no hardwood understory. No owl roosts were found in these additional areas. A deviation from the similarity in roosts was noted at sites 8 and 9 where the structure of the broadleaf understory trees provided comparable canopy cover, despite the lower tree density. Additionally, we could find no surface water within several kilometers of site 10.

Temperature data gathered at preferred roost sites suggest that these owls seek cool areas in the forest. There was a consistent tendency for the summer temperature to be 3° or 4° C cooler in these deeply shaded forest roosts than in open canopy situations (Figure 1). Immature owls of pair 1 selected waterside roost sites on "hot" days (open canopy temperatures of 28.4° to 35.2° C) on four of six occasions. In these areas, temperatures were as much as 7° or 8° C cooler than temperatures in the open canopy areas where direct sunlight reached the forest floor.

Table 2. Habitat analysis data for 10 major Spotted Owl roost sites at NCCRP (sites 1-7), Palomarin (sites 8, 9), and San Geronimo (site 10).

Roost Site No.	Height of Roost Above Ground (meters)	Distance from Year-Round Surface Water (meters)	Distance from Creek Drainage (meters)[1]	Slope Aspect	Surrounding Tree Density (trees/ 25 m^2 plot)[2]
1	7.5	150-200	0	NE	4.9
2	4.5	200-250	0	NNW	4.8
3	7.6	200-250	0	N	4.1
4	5.6	200-250	0	NNW	4.9
5	6.4	250-300	0	NNE	5.1
6	1.8	100-150	10	NNW	4.8
7	5.2	150-200	0	NE	4.4
8	5.0	20-30	–	ENE	2.2
9	4.0	20-30	–	WSW	3.2
10	5.0	–	0	NNW	4.2

1. A "0" denotes that the roost was located within the creek drainage; a dash denotes that no creek drainage was present near the roost (within 500 m). All creek drainages were seasonal with January to June flow.

2. This figure includes all age classes. The canopy cover at all roost siges varied between 80 and 90%, based on visual estimation.

At NCCRP, midday temperatures during the summer (June-August) average around 30.0° C. Summer temperature data for a ten year period (1966-1976) show that temperatures greater than 32.0°C and as high as 41.6° C were recorded on an average of 38 days per year from 6 May to 2 October. These temperatures were recorded in a large meadow within the boundaries of NCCRP. High temperatures during this study period ranged from 32.0° C to 37.8° C in this same open meadow. Long term temperature data for open canopy situations at Palomarin and San Geronimo were not available.

Postural Adjustments

As an initial response to increasing ambient temperatures (approaching 27.0° C), Spotted Owls displayed an unusual postural adjustment. While perching, the owls were balanced with the talons open rather than clenched on the limb of the tree (Figure 2). In this posture, the soft pads of the feet were exposed to the air; the bright pink color of these pads suggest that these areas are highly vascularized, and therefore effective surfaces for heat dissipation. This posture was observed in all stages of heat stress. The physiological mechanism for this pathway of heat loss has been previously described in pigeons (Bernstein 1974).

Exposure of the legs and feet is another possible means of heat dissipation, by convection and radiation from these structures to the air (Howell and Bartholomew 1961). This postural change was used as an early response to increasing heat load, and continued during gular flutter (see below). Spotted Owls usually perched in a squat position with the feet and legs covered by the contour feathers. When stressed by the heat, however, their posture was erect so that the legs and feet were well exposed.

As temperatures reached or exceeded 28.0° C and the need to dissipate heat was correspondingly increased, Spotted Owls erected the feathers on the breast and scapular area. In other species subjected to heat stress, elevation of the scapular feathers has been observed, notably in the Masked Booby, *Sula dactylatra* (Bartholomew 1966), and in the Brown Pelican, *Pelecanus occidentalis*, and the Double-crested Cormorant, *Pha-*

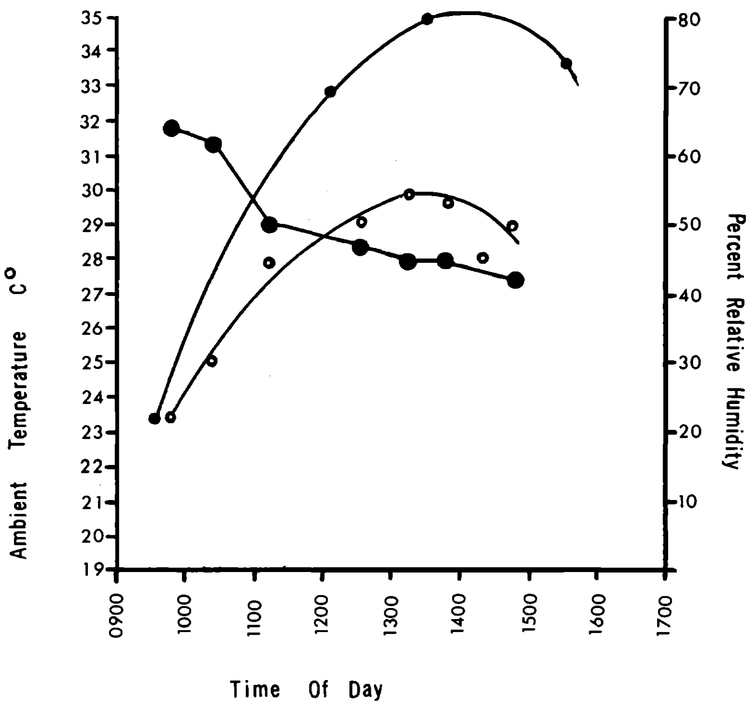

Figure 1. Temperature-humidity relationships at roost sites. Open circles represent trends in temperature at the roost sites; small dots represent temperature trends in adjacent open canopy areas; large dots represent the trend in relative humidity at the roost sites. Data points presented here are from measurements taken at site 3 but are representative of all 10 major roosts.

lacrocorax auritus (Bartholomew, Lasiewski and Crawford 1968). Feather erection permits movement of relatively cool air among the feathers, allowing heat loss by convection.

Gular Flutter

Of the climatic variables examined in the habitat analysis, temperature and humidity influence the effectiveness of gular flutter. The ability of the owls to dissipate heat through evaporation would be inhibited by high ambient temperature, when coupled with high ambient vapor pressure. In Oregon, Spotted Owls have been observed to initiate gular flutter at ambient temperatures as low as 29.0° C (Forsman 1976). At NCCRP, Spotted Owls were observed to initiate gular flutter at 28.0° C for fledgling young and 29.5° C for an adult male.

Observations of gular flutter by the owls, apparently indicative of greater degrees of heat stress, were rare. Gular flutter was observed on three occasions, once in an adult male owl and twice in the immature birds of pair 1. The owls gular fluttered intermittently; in each case the mandibles were held slightly open and the amplitude (gauged by the degree of distension of the gular region) was variable, increasing when flutter frequency was increased. The adult male was observed to initiate gular flutter at 29.5° C (humidity varied from 26%, or 9.3 torr, to 30%, or 8.6 torr) in contrast to the observed response of the owlets; they initiated gular flutter at 28.0° C (humidity varied from 43%, or 15.2 torr, to 50%, or 14.2 torr).

Differences in response to increasing ambient temperatures between the adult owl and the owlets may be due to physical differences between these age groups. Although not directly measured in this study,

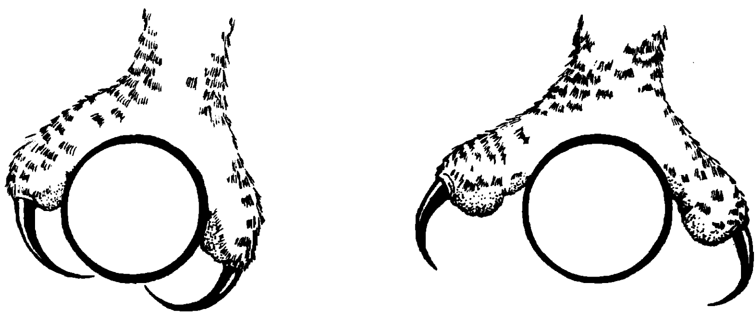

Figure 2. Spotted Owl foot postures, differing in response to varying temperature conditions. Foot on the right is characteristic of owls showing signs of heat stress, with temperatures greater than 27° C. Foot posture on left is characteristic when temperatures are less than 27° C.

differences in the insulative value of downy plumage and the feather cover of the adult may influence the efficiency of heat loss. The differences in humidity cited above could also play a role.

Spotted Owls that were actively gular fluttering, at temperatures in excess of 29.0° C, drooped the wings and held them away from the body. This behavior, documented in a number of species (Bartholomew, Lasiewski, and Crawford 1968) increases the surfaces for heat loss and exposes the more lightly feathered underwings and axillary surfaces (Calder and King 1974). Heat stressed Spotted Owls also raised the tail and fanned the rectrices out away from the body. In "typical" heat stress posture, the owl's head was tilted back to expose the throat; this movement presumably expands the surface area of the gular region for increased evaporative heat loss.

Additional Observations

Spotted Owls were observed bathing on several occasions. This behavior has been described previously for this species without reference to thermoregulation (Forsman 1976, Miller 1974). Bathing was observed by both the immature owls of pair 1 during a period of gular flutter. If, as postulated by Lasiewski and Dawson (1964), gular flutter is an efficient means of cooling, bathing should not be necessary to augment heat loss. In this instance the owlets ceased gular flutter for 2.25 hours after their baths. It could not be determined if the owls drank any water. Gular flutter was later resumed. The air temperature remained fairly constant (28.0° to 29.4° C) for the entire observation period. Possibly bathing is used as a means of feather care, and is not directly related to body cooling. Adequate interpretations of bathing behavior must, however, be reserved until more observations can be made.

DISCUSSION AND CONCLUSIONS

During the summer months Spotted Owl roosts were consistently chosen low to the ground, in understory trees which form an umbrella of leaves over the perch site. The structure of these roost sites provided a 3°-4° C depression in temperature from that of open canopy situations. Spotted Owls behaviorally facilitated heat loss at ambient temperatures above 27° C. With midday summer temperatures at NCCRP averaging near 30° C, the selection of daytime roosts could prove to be a fundamental means by which these owls avoid heat stress.

Depending on the degree of heat stress, the owls augment heat loss to the air by postural adjustments; these include exposing the pads of the feet, exposing the legs, erecting contour feathers, and drooping the wings. At temperatures ranging between 28° and 29° C Spotted Owls initiate gular flutter, a low energy means of increasing the rate of evaporative heat loss. During periods of climatic stress, the effectiveness of these behavioral mechanisms in regulating body temperatures may be intimately tied to the availability of sheltered roost sites. Our data suggest the value to the Spotted Owls of dense multi-layered forests. In regions where summer climate is unfavorable to thermoregulation, these sheltered roosts could well be essential to the owl's survival. Recognition and analysis of these problems is therefore fundamental to the interpretation of the ecology and distribution of the Spotted Owl.

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