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PROVISIONING RATES AND TIME BUDGETS OF ADULT AND NESTLING BALD EAGLES AT INLAND WISCONSIN NESTS

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ABSTRACT.—We used a remote video recording system and direct observation to quantify provisioning rate and adult and nestling behavior at Bald Eagle (*Haliaeetus leucocephalus*) nests in north-central Wisconsin in 1992 ($N = 5$) and 1993 ($N = 8$). Eagles nesting in this region have a high reproductive rate (≥1.3 young/occupied territory), and the number of occupied territories has expanded nearly threefold since 1980. The season-long provisioning rate averaged 5.2 prey deliveries/nest/d and 3.0 prey deliveries/nestling/d, and did not vary by year or with nestling number or age. Fish (Osteichthyes) made up 97% of identified prey deliveries followed by reptiles (Reptilia) (1.5%), birds (Aves) (1.2%), and mammals (Mammalia) (0.6%). Nearly 85% of prey items were >15 cm and <45 cm and 13% were <15 cm in length. Adult attendance (time ≥1 adult was at the nest) at nestling age 2–4 wk was >90% of the day and was negatively correlated with nestling age. Time adults spent feeding nestlings was negatively correlated with nestling age. Nestlings stood or sat in the nest >30% of the day, began to feed themselves, and exhibited increased mobility in the nest at 6–8 wk. We identified three stages of the nestling period and several benchmarks that may be useful when scheduling data collection for comparison of Bald Eagle nesting behavior. Our results support the hypothesis that food was not limiting this breeding population of Bald Eagles.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *Wisconsin*; *time budgets*; *provisioning*; *behavior.*

Tasas de aprovisionamiento y presupuestos de tiempo de adultos y polluelos de Aguilas Calvas en nidos del interior de Wisconsin

RESUMEN.—Usamos un sistema remoto de video grabación y observaciones directas para cuantificar las tasas de aprovisionamiento, y el comportamiento de adultos y polluelos en nidos del Águila calva (*Haliaeetus leucocephalus*) en el norte-centro de Wisconsin en 1992 ($N = 5$) y 1993 ($N = 8$). Las águilas que

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anidan en esta región tienen una alta tasa reproductiva (≥1.3 juveniles/territorio ocupado), y el numero de territorios ocupados se ha expandido a cerca de tres veces desde 1980. La tasa de la estación de gran aprovisionamiento promedió 5.2 presas entregadas/nido/d y 3.0 presas entregadas/nido/d, y no vario por año o con el número de polluelos ni la edad. Los peces (Osteoictios) represento el 97% de las presas entregadas identificadas seguido por reptiles (Reptilia) (1.5%), aves (Aves) (1.2%), y mamíferos (Mammalia) (0.6%). Cerca del 85% de los ítems presa tuvieron >15 cm. y <45 cm. y 13% tuvieron <15 cm. de longitud. La asistencia de los adultos (tiempo en que ≥1 adulto esta en el nido) a una edad de los polluelos de 2–4 semanas fue >90% del día y estuvo correlacionado negativamente con la edad del polluelo. El tiempo que los adultos pasaron alimentando a los polluelos estuvo correlacionado negativamente con la edad del polluelo. Los polluelos permanecieron parados o sentados en el nido >30% del día, comenzando a alimentarse por si mismos, y exhibiendo un incremento en la movilidad en el nido a las 6–8 semanas. Identificamos tres estados del periodo de anidación y algunos puntos de referencia que pueden ser útiles durante la programación de colección de datos para la comparación del comportamiento de anidación de las águilas calvas.

[Traducción de César Márquez]

Previous investigations (Weekes 1975, Gerrard et al. 1979, Fraser 1981, Bortolotti 1984a, Cain 1985, Jenkins 1989) have described Bald Eagle (*Haliaeetus leucocephalus*) nesting season behavior using direct observation and time-lapse still photography. These studies reported behavior and time budgets of nestlings and adults, and chronology and development of certain physical and behavioral characteristics of nestling eagles. Previously, small sample size has limited quantitative comparison of Bald Eagle behaviors. We describe Bald Eagle nestling behavioral ontogeny and parental time budgets quantitatively to facilitate comparison among specific subpopulations.

Quantitative information on provisioning rates and adult and nestling time budgets is of particular interest because productivity may be related to prey availability early in the nesting season (Gerrard et al. 1979, Swenson et al. 1985, Hansen 1987, Steidl et al. 1997, Anthony 2001). Provisioning rate is usually indicative of prey availability in the environment (Newton 1979, Collopy 1984) and food supply has been indicated as a key factor in limiting Bald Eagle breeding success (Dykstra et al. 1998, Elliott et al. 1998). Adult and nestling behavior may be influenced by prey availability, in that time spent foraging is a function of prey availability, and nestling growth and development may be related to food provisioning (Dykstra 1995).

The Bald Eagles breeding in north-central Wisconsin have high nesting success and productivity (1.3 young/occupied territory, 1.7 young/successful nest [Kozie and Anderson 1991], and 1.26 young/breeding attempt [Dykstra et al. 1998]), and the number of occupied territories increased by 265% (1980–93) (F. Quamen pers. comm.). Further, this breeding population has exhibited low levels of contaminants in eggs (Dykstra et al. 1998).

Our objectives were to quantify the provisioning rate and time budgets of adult and nestling Bald Eagles in northern Wisconsin from hatching through fledging. This information may be useful for comparison to other populations in the Great Lakes region and throughout the breeding range.

STUDY AREA AND METHODS

Study Area. We monitored Bald Eagle nests in north-central Wisconsin >50 km inland from Great Lakes shorelines (ca. 46°N, 90°W). North-central Wisconsin is predominately forested with coniferous trees, including pine (*Pinus* spp.), spruce (*Picea* spp.), hemlock (*Tsuga* sp.), and fir (*Abies* sp.) (Curtis 1959). White pine (*Pinus strobus*) is the predominant nest tree species of Bald Eagles in the region (pers. observ.). Location and productivity of Wisconsin nests have been documented by Wisconsin Department of Natural Resources personnel during aerial surveys conducted twice annually since 1974 (WDNR unpubl. data). Within this study area, we selected nests where placement of video recording equipment was possible, or a good vantage for nest observation was available. These selection constraints resulted in a non-random sample of nests in the study area. However, we believe that these nests were representative of Bald Eagles breeding in northern Wisconsin, as these constraints are likely not related to behavior or prey availability.

Video Recording. In January and February 1992, six black-and-white video cameras (four Sony® model M-350, and two Sony® model M-332, Fuhrman Diversified, Inc., Seabrook, TX) were positioned to record behavior at nests. M-350 cameras were placed in an adjacent tree <15 m from the nest and M-332 cameras were placed in the nest tree 1–2 m above the nest. Cameras were concealed by affixing natural and/or artificial vegetation around them. Coaxial cable connected cameras to the video recorders which were located 200–400 m from the nest tree.

Recorders (time and date were stamped in the frame) captured ca. four consecutive days of diurnal behaviors

Table 1. Provisioning rates to inland Wisconsin Bald Eagle nests where behavioral data were collected in 1992–93

Year	Nest ID	*N* Nestlings	Observations	Mean Prey Deliveries per Day (SD)	Mean Prey Deliveries per Nestling per Day (SD)
1992	IR-33[a]	3	22	6.9 (2.8)	2.3 (0.9)
	IR-9c[a]	2→1	24	2.1 (0.6)	2.0 (0.7)
	ON-49[a]	1	14	5.6 (1.2)	5.6 (1.2)
	VI-61c[a]	3	19	7.3 (0.8)	2.4 (0.3)
	ON-79[a]	2	29	6.4 (3.7)	3.2 (1.9)
1993	VI-100[b]	2	2	3.5 (0.7)	1.8 (0.4)
	ON-16[a]	1	16	4.3 (1.4)	4.3 (1.4)
	VI-84a[b]	2	5	4.0 (1.3)	2.0 (0.6)
	ON-47a[b]	2	2	11.5 (0.7)	5.8 (0.4)
	IR-26d[b]	2	3	3.5 (0.7)	1.8(0.4)
	VI-68a[b]	2	2	2.5 (0.7)	1.3 (0.4)
	ON-25b[b]	2	2	5.5 (0.7)	2.8 (0.4)
	VI-57[c]	1	4	3.8 (1.1)	3.8 (1.1)
Mean		1.8		5.2	3.0

[a] Video cameras.
[b] Direct observations.
[c] Both.

before requiring a tape and battery change. Recorders at nests with M-350 cameras recorded one frame every second; those with M-332 cameras recorded one frame every four seconds. Video recordings were analyzed by viewing on a television monitor.

Nest Observations. Direct observations began 5 May 1993 and continued through 27 July 1993 when all nestlings had fledged. We attempted to conduct one observation session each week at each study nest from blinds 200–400 m from nest trees. Locations of blinds were chosen to minimize potential for observer influence on eagle behavior while still providing researchers with a vantage adequate for collection of behavioral data (i.e., an unobstructed view of the nest area). Dawn to dusk surveillance was maintained on all eagles visible from the blind.

Data Organization and Analysis. Behavioral data collected by nest observers and by reviewing video were summarized to develop time budgets for each observation day. The specific behaviors quantified were: adults—present in the nest, absent, feeding, prey delivery, and brooding; and nestlings—lying, sitting, standing, feeding, being fed, and preening. At nests with more than one young, we attempted to identify individual nestlings throughout each day. Age of nestlings at each nest was determined by video recording or by back-calculating from age at banding (Bortolotti 1984b). At nests with multiple young, we used the date of hatch of the oldest nestling when assigning nestling ages for data analysis. Week one was defined as 1–7 d post-hatch.

Lying, sitting, and standing were defined as in Jenkins (1989). We combined sitting and standing for analysis (calling it upright). Brooding behavior was defined as an adult covering >50% of at least one nestling. Feeding ended when there was a break of >1 min between bites of food. We assumed that when behaviors of young nestlings (<4 wk) could not be determined, they were lying in the nest. Following Ellis (1979), we assumed that nestlings being brooded were lying. Branching was defined as nestlings exiting the nest and standing on adjacent branches.

Each hour was divided into twelve 5-min time intervals At the conclusion of each 5-min interval, the behavior of each bird visible during the period was summarized, and location and primary behavior of each bird were recorded. The primary behavior was defined as the behavior recorded for the most cumulative time in the preceding 5-min. The daily time budget was the proportion of all 5-min time intervals each behavior was recorded as the primary behavior. Daily time budgets were averaged at individual nests each week of age, then pooled for all nests to produce weekly time budgets across the study area

We summarized the provisioning rate at each nest each week (prey deliveries/nest/d) and pooled rates by nestling age for a study-area-wide weekly-prey-delivery rate. We calculated a season long average provisioning rate at each nest. All provisioning rates were also standardized by the number of nestlings (prey deliveries/nestling/d). All statistical tests were considered significant at the $\alpha = 0.05$ level.

Results

We monitored five nests in 1992 and eight nests in 1993. All nests where eggs were laid fledged at least one young and 1.8 young fledged/successful nesting attempt (Table 1). At one territory, where

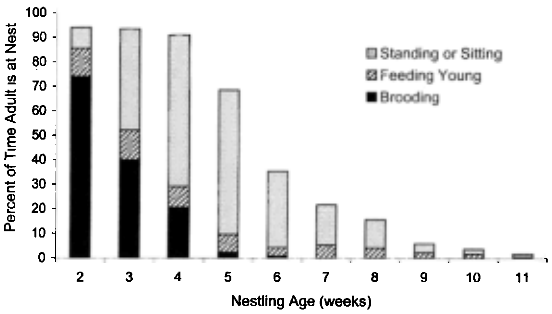

Figure 1. Weekly time budget (nestling age 2–11 wk) of nestlings related to the presence of one adult Bald Eagle at inland Wisconsin nests (1992–93). Total adult attendance is the sum of behaviors shown.

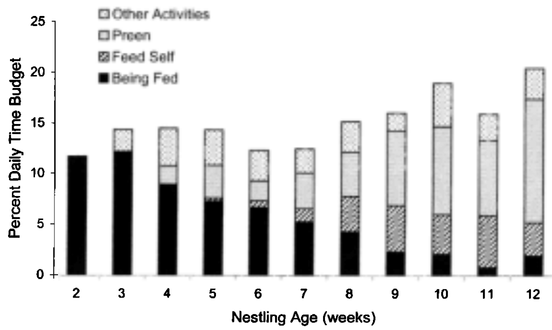

Figure 2. Weekly time budget of nestling Bald Eagle activities (age 2–11 wk) at inland Wisconsin nests (1992–93).

a camera was placed at one nest, the eagles used an alternate nest.

Provisioning. There was no difference between years in the season-long provisioning rate (1992 = 5.6 prey deliveries/d; 1993 = 4.8 prey deliveries/d; $t = 0.57$, df = 11, $P = 0.59$), so data from both years were pooled. Mean provisioning rate did not differ among nests with differing numbers of nestlings ($F_{2,10} = 1.07$, $P = 0.38$). The season-long mean daily provisioning rate adjusted for number of nestlings was 3.0 prey deliveries/nestling/d (Table 1). The adjusted provisioning rate showed no correlation to nestling age ($r^2 = 0.13$, slope = 0.03, SE = 0.014, $P = 0.072$).

Sixty-five percent of prey items delivered were identified to class (549 of 848 deliveries). Fish (Osteichthyes) made up 97% of all prey items identified, followed by reptiles (Reptilia) (1.5%), birds (Aves) (1.2%), and mammals (Mammalia) (0.6%). Eighty (9.4%) prey items were identified to genus. Bullhead (*Ameiurus* spp.) made up 40% of all items identified to genus, followed by northern pike (*Esox lucius*) (33.8%), and suckers (*Catostomus* spp.) (8.8%).

Observers and video reviewers estimated size of prey delivered in 70% (594) of prey deliveries. Nearly 85% of prey items were >15 cm and <45 cm. Prey items <15 cm made up 13% of prey deliveries and made up a greater portion of prey delivered to nests in 1993 than in 1992 ($\chi^2 = 103$, df = 3, $P < 0.001$).

Adult Behavior. Adult attendance was negatively correlated with nestling age ($r = -0.94$, SE = 0.02, $P < 0.001$; Fig. 1). Also, time adults spent feeding nestlings was negatively correlated with nestling age ($r = -0.94$, SE = 0.014, $P < 0.001$).

Nestling Behavior. Time lying made up nearly 100% of the nestling time budget at 2 wk and was negatively correlated with nestling age ($r = -0.84$, SE = 0.01, $P < 0.001$). Time resting in an upright position (standing or sitting) was positively correlated with nestling age ($r = 0.7$, SE = 0.02, $P = 0.05$). Eaglets actively sought sun and shade at 5 wk. Time spent active increased as nestlings aged, but was not related to nestling age ($r = 0.3$, SE = 0.01, $P = 0.07$; Fig. 2). Nestlings were not observed feeding themselves until 4 wk. Time nestlings spent at all feeding behaviors (being fed and feeding themselves) was negatively correlated with age ($r = -0.9$, SE = 0.01, $P = 0.01$).

DISCUSSION

Provisioning Rate and Habitat Quality. Bald Eagles breeding in north-central Wisconsin had high productivity compared to eagles breeding in other areas (1.8 young fledged/successful nesting attempt [this study]; Kozie and Anderson 1991, Steidl et al. 1997, Elliott et al. 1998, Anthony 2001), and the number of occupied territories increased by 265% from 1980–93 (F. Quamen pers. comm.). Three nestlings fledged from two nests in this study, an uncommon occurrence among Bald Eagles (Gerrard and Bortolotti 1988). Only one nestling in our study did not fledge (96% fledged). Gende and Willson (1997) reported that from 18 nests, only one nestling died and suggested that was evidence food was not a limiting factor. Hansen (1987) concluded that reproduction was influenced by available prey and that nest success was higher in areas with better food supplies. Elliott et al. (1998) recommended that the role of food supply be considered when studying the effects of hab-

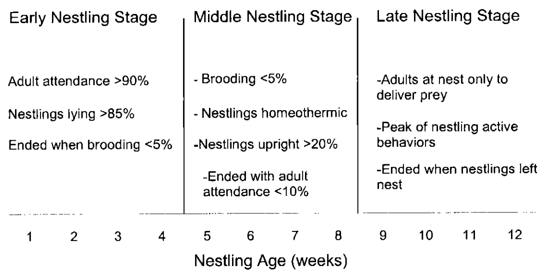

Figure 3. Early, middle, and late nestling stages defined by adult and nestling Bald Eagle behavioral changes at inland Wisconsin nests (1992–93). The captions describe characteristic behaviors during each stage.

itat quality and contaminants on Bald Eagles. Lower provisioning rates and food supply were thought to be the factors limiting productivity on the British Columbia coast (Elliott et al. 1998). Furthermore, measured nestling energy intake in north-central Wisconsin Bald Eagles was not different than predicted energy requirements (Dykstra 1995) suggesting that the provisioning rate we recorded was sufficient to support the observed productivity.

Bennetts and McClelland (1997) found support for the hypothesis that ability to obtain food increases with age. The age of the adults breeding in northern Wisconsin was unknown so we could not test that hypothesis. However, productivity was uniformly high in northern Wisconsin (away from the Great Lakes shorelines) at the same time the number of territories increased rapidly.

We conclude that the mean provisioning rate recorded in this study (5.2 prey deliveries/d, 3.0 deliveries/nestling/d) reflects adequate prey availability in the environment to support high Bald Eagle reproductive success rates in the Great Lakes region. Our results support the hypothesis that food was not limiting Bald Eagle productivity in northern Wisconsin. These data may serve as a baseline for comparing provisioning rates and productivity throughout the Great Lakes region. However, the provisioning rates of Bald Eagles in northern Wisconsin may be less useful for comparison to breeding birds in other regions of the range due to potential covariates such as weather, prey type and size, and nesting chronology (Jackman et al. 1999).

Adult Behavior. Three distinct adult behavioral stages evident after nestlings hatched (Fig. 3) may be important to nestling survival and may be related to regional and local nesting conditions. When nestlings were 2 wk, adults brooded >70% of the time. Subsequently, brooding declined rapidly and ended by 5 wk. Bortollotti (1984a) predicted that Bald Eagle nestlings were able to thermoregulate at 15 d, but that they may still require adult brooding. Collopy (1984) found that brooding in Golden Eagles (*Aquila chrysaetos*) was related to age as did Fraser (1981) for Bald Eagles. Cain (1985) concluded that brooding lasted 50 d as did Ellis (1979) (Golden Eagles). Weather is likely a significant covariate when comparing brooding behavior. Our data generally agree with other studies and the loss of only one nestling in our study indicates that adults provided adequate protection to nestlings.

Adult nest attendance was high 4–5 wk after brooding decreased to <20% and adults mostly stood or sat in the nest. Jenkins (1989) and Fraser (1981) reported that adult attendance at the nest remained high after brooding ended. Adult presence was likely important to reproductive success because it may have deterred predation and/or shielded nestlings from sudden weather changes, increasing nestling survival and adult fitness (Harmata et al. 1999). Fishers (*Martes pennanti*) have been observed attempting to prey on Bald Eagle nestlings in Wisconsin (Dykstra et al. 1993, Taft et al. 1999), and Perkins et al. (1996) reported Red-tailed Hawk (*Buteo jamaicensis*) predation on an eaglet.

Decline in adult attendance at the nest 6–12 wk may be related to reduced risk of nestling predation, nestling thermal independence (Fraser 1981, Jenkins 1989), the need of energetically-stressed adults to forage more frequently, or the primary prey (fish) being less available to eagles after spawning, which resulted in increased time spent foraging to provide adequate provisioning (Bennetts and McClelland 1997).

Nestling Behavior. Nestlings 2–4 wk were inactive and dependent upon the adults for survival. Nestlings began to feed themselves, preen, and explore the nest at 4 wk. Collopy (1984) reported Golden Eagle nestlings feeding themselves at 34–37 d and Jenkins (1989) reported preening was evident in Bald Eagle nestlings at 7 wk. Nestlings appeared to be thermally independent 29 d after hatching, and possibly sooner, as brooding at 5 wk (29–35 d) was <3% of the day. These findings are consistent with previous studies (Fraser 1981, Collopy 1984, Hansen 1987). The proportion of active time spent feeding declined throughout the nesting period indicating that nestlings were able to satisfy increasing energy needs by ingesting larger boluses of food and were more skilled at picking bits of food from carcasses.

As nestlings grew older, the time spent in an upright position in the nest increased. This may have important implications in both behavioral development and survival. Competition among nest mates for food items has been documented (Collopy 1984, Jenkins 1989) and nestlings that are adept at standing and maneuvering in the nest may dominate siblings and secure more energy.

Conclusions. Quantification of Bald Eagle nesting behaviors in high-quality habitat yielded several benchmarks we feel will be useful for comparison in the Great Lakes region. First, provisioning rate averaged 5.2 prey deliveries/d (3.0 prey deliveries/nestling/d) throughout the nestling period. Second, at least one adult was at the nest for >90% of the time 1–4 wk (the early nestling stage). High adult attendance during the early nestling stage is likely critical to nestling survival because adults provide protection from weather stress and predation. Third, based on their behavior, nestlings in this study were homeothermic at 5 wk.

Division of the nestling period into three stages that are discernible based on nestling and adult behavior with each stage clearly defined by changes in adult behavior may be useful for optimally scheduling data collection with limited resources and may facilitate behavioral comparisons among regional breeding populations.

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