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RED-SHOULDERED HAWK NESTING ECOLOGY AND BEHAVIOR

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Wallace (1969), Brown (1971) and Henny (1972) suggest serious declines in Red-shouldered Hawk (*Buteo lineatus*) populations. Stewart (1949), and Henny et al. (1973) reported on intensive studies in Maryland, Craighead and Craighead (1956) in Michigan, and Wiley (1975) in California. None of these presented a detailed description of nesting behavior. This paper provides a detailed and quantitative description of behavior at 4 nests and presents various aspects of the ecology of a Red-shouldered Hawk population nesting in a reservoir watershed of central Massachusetts during 1973 and 1974.

STUDY AREA AND METHODS

Prescott Peninsula, averaging 3 km wide and extending, north to south, 16 km into Quabbin Reservoir of central Massachusetts, consists of about 5000 ha of hemlock (*Tsuga canadensis*)–white pine (*Pinus strobus*)–northern hardwoods forest. The hilly terrain ranges in elevation from 150 to 330 m. Eastern and western shores of the peninsula are steep, elevations normally increasing by 140 m from reservoir shoreline to 0.5 km inland. A nearly continuous series of streams and beaver impoundments characterizes the relatively flat central peninsula.

Upland vegetation consists mainly of red oak (*Quercus rubra*), black oak (*Q. velutina*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and white pine. Wet areas are mainly forested with black birch (*Betula nigra*), yellow birch (*B. lutea*), and red maple (*Acer rubrum*). Small groves of hemlock occur in both uplands and lowlands. Forest coverage is continuous, except for unwooded beaver ponds and narrow roadways. Understory is lacking in most areas because of overbrowsing by white-tailed deer (*Odocoileus virginianus*). Ground cover includes *Vaccinium* spp. and ferns.

Other raptors that we observed nesting in the area included: Great-horned Owl (*Bubo virginianus*), Barred Owl (*Strix varia*), Red-tailed Hawk (*Buteo jamaicensis*), and Broad-winged Hawk (*Buteo platypterus*). Raptors observed occasionally during the breeding season, but not observed nesting, included: Turkey Vulture (*Cathartes aura*), Goshawk (*Accipiter gentilis*), Cooper's Hawk (*A. cooperii*), Sharp-shinned Hawk (*A. striatus*), Bald Eagle (*Haliaetus leucocephalus*), and American Kestrel (*Falco sparverius*).

Human activity on Quabbin Reservation is officially restricted to logging, road maintenance, and forestry and wildlife research; thus, human intrusions are infrequent.

Methods.—We located old raptor stick nests during the 1972–73 and 1973–74 winters by searching the peninsula on foot, and returned to these nests in March to determine activity. Courtship and territorial activity of Red-shouldered Hawks in March provided clues to locations of newly-constructed active nests. We recorded locations and activities of all hawks sighted in the study area during daily field visits from March through July.

Twelve nest sites used by breeding Red-shouldered Hawks during 1973 or 1974 were

characterized, after young had fledged, by recording nest tree species, nest tree height, nest tree diameter at breast height (DBH), nest height, and slope aspect of the ground directly below the nest. We also described the forest cover type by identifying, measuring (DBH), and enumerating all trees (i.e. woody and at least 5 cm DBH) within 15 m of the nest tree.

We determined clutch-size at 9 nests by climbing nest trees during late incubation. We did not climb nest trees thereafter, but determined hatching dates by inspecting nests daily from adjacent trees. Fledging rate was ascertained at only 4 nests where blinds allowed frequent observations during the fledging period.

We collected regurgitated pellets in or under nests immediately after young had fledged, and identified prey from hair and bone remains. To watch specific feeding behaviors, we built blinds and spent 71 h observing sibling and parental interactions at 4 nests. Observations, of 3 to 14 h duration, began 10 days after eggs had hatched and continued at various times during the nestling period until young fledged. At the same time, we identified and counted prey items delivered by adults as a check on the verity of pellet analyses.

In addition, nesting behavior was recorded and timed at 4 nests in 1974, using time-lapse photorecorders. Two of these 4 nests were also monitored periodically by observers in blinds. Camera units consisted of Rollei SL-82 super 8 movie cameras (reference to commercial products does not imply endorsement by the U.S. Government) set for single frame exposure and exposed by use of a solenoid-activated mechanical trigger (Temple 1972) and an astable free-running multivibrator timing device (Fig. 1). We packaged camera and timing components in a water-proofed plywood box. A 6-volt storage battery provided power for the intervalometer circuitry and was separately housed with electrical leads routed through a hole in the housing. Each camera unit was bolted to an adjacent tree at least 8 m from, and slightly above, an active nest using a modified mobile antenna mount. Rotation of the mount in 2 planes allowed aiming the camera at a nest without repositioning the entire mount.

Although our time interval between exposures ($\bar{x} = 1.48$ min) probably missed some brief nest visits by adults, those behavioral sequences discussed herein were adequately sampled. Visits by food-carrying adults during late nestling stages were probably too short to be consistently recorded, but were evidenced by subsequent periods of nestling self-feeding, observable on the photorecord.

We installed cameras when oldest nestlings were 3, 10, 13, and 21 days old, at the 4 monitored nests respectively, and continued filming until nestlings fledged (i.e. left the nest during the day). Ages of nestlings during filming, number of frames exposed, and total duration of photorecording is tabulated for each nest (Table 1). Film and camera-advance batteries had to be changed every 6 days. All gaps in coverage were caused by the failure of a mechanical trigger to activate single-frame film advance in the cameras.

We analyzed time-lapse exposures by passing the processed film through an adapter in a 5 × 5 cm slide projector and viewing the enlarged image on a screen. The behavior depicted in each frame was categorized and behavior sequences were timed from the known exposure interval. Behavior categories included: adult brooding, adult feeding young, adult present (neither feeding nor brooding young), young feeding themselves, young standing (at least 2 of 3 nestlings standing in the nest), and young reclined. We later calculated the mean percentage (data from 4 nests combined) of time spent in each activity for each day of the nestling period, for determinations of behavioral trends.

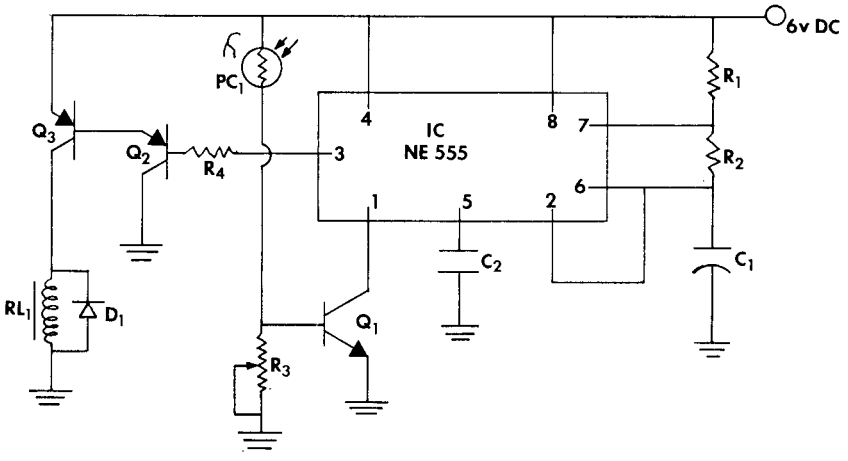

FIG. 1. Light controlled intervalometer circuitry for time-lapse photorecorders used to record activity at Red-shouldered Hawk nests. Components: R_1 = 15K–750K (timing resistor), R_2 = 10K, R_3 = 10K Pot, R_4 = 800 ohm, C_1 = 75uf–300uf (timing capacitor), C_2 = .01uf, Q_1 = 2N1308 or equiv, Q_2 = 2N3250 or equiv (select for HFE 40 min, R_4 = 800 ohm, I_{B2} = 7.5mA will give I_BQ_3 300mA), Q_3 = 2N4387 or equiv, PC_1 = CL904 or equiv, RL_1 = relay 6V3A, D_1 = 1A 30V PIV, IC_1 = 555 timer.

RESULTS AND DISCUSSION

Nesting chronology and survival.—Red-shouldered Hawks first appeared in the study area during the first week of March. Most adults were paired, territorial, and vociferous at this time. Courtship flights continued from 7 to 25 March and most commonly occurred between 11:00 and 13:00 on clear days. During the last week of March and first week of April, adults repaired and decorated old nests by the addition of dead twigs and fresh evergreen (usually hemlock) sprigs. Egg-laying was usually completed by mid-April; we noted incomplete clutches from 4 to 18 April 1974. Clutch-size ranged from 2 to 4 and averaged 3.33 eggs per nest (N = 9). Hatching occurred from 8 to 24 May 1974; at 3 nests where hatching rate was determined, 8 of 11 eggs hatched. Most fledglings left the nest between 25 June and 5 July. Ten of 14 hatchlings in 5 monitored nests successfully fledged; mortality at these nests was caused by Great-horned Owl predation (the entire 28-day-old brood at 1 nest) and by wind and possible hail (one 20-day-old nestling found dead under its nest after a thunderstorm).

Nesting habitat.—All of approximately 110 separate Red-shouldered Hawk sightings during 1974 occurred within the central strip of riparian habitat

TABLE 1

PHOTORECORDER FILM COVERAGE AT 4 RED-SHOULDERED HAWK NESTS IN MASSACHUSETTS, 1974

Nest no.	Extent of nestling period (days)	Time interval(s) (min)	Inclusive ages of nestlings during filming[a]	No. of days covered	No. of frames exposed	Total film-hours
1	28[b]	1.5	3–5	3	1,488	37.2
2	40	1.4	10–13, 16–26, 29–40	27	12,061	281.4
3	32	1.2	13–18, 25–32	14	6,846	136.9
4	39	2.1	21–26	6	2,016	70.5
		1.2[c]	29–31, 33–39	10	4,113	82.3
	TOTAL				26,524	608.3

[a] Nestling age is based on age of the oldest chick in each nest. Gaps in film coverage were due to camera failures.
[b] Brood killed by Great-horned Owl on day 28.
[c] Time interval was changed at day 29 post-hatch.

on Prescott Peninsula. Twenty-five percent of these sightings represented hawk hunting excursions which we watched from lookouts above the canopy. Six courtship flights in March 1974 likewise took place over wetlands and proximate slopes. This attraction for wet lowland habitat has been well documented (Kennard 1894, Henny et al. 1973, Wiley 1975).

All 12 nest sites found during our 2-year study were located in wet deciduous woods, as evidenced by the dominance of wetland tree species in sample plots around the nest tree: 32% black and yellow birches, 25% red maple, 16% sugar maple, 12% red and black oaks, 7% white ash, 6% white pine, and 2% assorted uncommon species. Tree density and mean DBH were fairly constant at the 12 nest-sites (Table 2) and indicated a mature forest stand. Nest tree DBH and height also varied little as nests were commonly placed in the largest deciduous tree available within a breeding pair's nesting habitat.

Black and yellow birches, comprising only 32% of all mature trees within sample plots, were chosen as nest sites 67% of the time. Stewart (1949) and Henny et al. (1973) also found most Red-shouldered Hawks' nests in black birch in Maryland. This preference for birch was probably related to its physical structure. Mature black and yellow birch trees supported few branches below 10 to 14 m; at this height many large branches extended laterally to form a platform, whereon nest construction and maintenance probably required less energy. Also, consistent nest height (Table 2) was probably related to this uniform branch divergence at 10 to 14 m.

TABLE 2

TOPOGRAPHICAL AND VEGETATIVE FEATURES OF RED-SHOULDERED HAWK NEST-SITES IN CENTRAL MASSACHUSETTS

		Nest site vegetation[a]					
				Nest tree			
Nest no.	Slope aspect	Forest density (trees/ha)	Mean tree DBH (cm)	Species	DBH (cm)	Height (m)	Nest height (m)
1	N,NE	778.1	18.0	*Betula nigra*	57.6	19.0	12.4
2	E,NE	622.5	22.6	*Betula nigra*	37.6	19.4	14.0
3	E	551.7	19.2	*Betula nigra*	51.4	26.0	13.4
4	E	636.6	22.7	*Betula nigra*	43.6	28.0	14.6
5	E	550.4	23.9	*Betula nigra*	57.9	18.2	11.5
6	NE	580.0	25.1	*Betula nigra*	61.8	20.6	12.9
7	E	565.9	16.1	*Quercus velutina*	53.5	28.0	9.8
8	E	693.2	21.0	*B. papyrifera*[b]	39.5	23.6	12.8
9	NE	707.3	21.8	*Acer rubrum*	30.2	29.6	10.6
10	NE	382.0	23.4	*B. lutea*	50.9	38.4	10.6
11	E	677.4	18.3	*B. lutea*	55.7	25.2	9.0
12	NE	551.7	21.8	*Acer saccharum*	41.1	24.8	11.8
$\bar{x}$		608.1	21.2		48.8	25.1	12.0
SD		102.1	2.3		7.3	5.5	1.7

[a] Trees of at least 5 cm DBH within 15 m of nest tree.
[b] American white birch.

Distances between adjacent active nests found on Prescott Peninsula in 1974 ranged from 0.9 to 3.0 km and averaged 1.7 km (N = 7), with nests arranged almost linearly along the central strip of streams and beaver flowages.

The adaptive value of nesting on strictly east or northeast slopes (Table 2) is difficult to explain. (Although we did not sample topography and vegetation on other slopes, it appeared that similar nest sites [i.e. mature black birch] and nesting habitat [i.e. wet woodland] were available on south and west slopes.) We could find no mention in the literature of slope aspect preferences by other nesting raptors. Perhaps the habit is practically neutral in adaptive value and has become traditional within this specific population, being learned by nestlings who as adults were attracted to nest sites most like their natal nest.

Nestling food.—Errington (1932) listed various problems encountered in accurately enumerating the prey individuals represented in nestling buteo pellets. Additionally, we observed that most mammalian prey were already decapitated when delivered to nestlings; therefore, jaw fragments and teeth, which might otherwise have survived gastric digestion, were usually excluded

from nestling diets. Besides making prey identification more difficult, the absence of these remains in pellets made actual counting of individual food items impossible. We therefore recorded the occurrence of all prey species in each discrete pellet and calculated percent frequency for each species based upon the 212 pellet total (Table 3).

As reported elsewhere (New York, Ernst 1945; Maryland, Stewart 1949; Michigan, Craighead and Craighead 1956; and California, Wiley 1975), Massachusetts red-shoulders preyed most often upon small mammals, specifically eastern chipmunks (*Tamias striatus*). The frequency of hawk predation on chipmunks was apparently related to this sciurid's abundance in the springs of 1973 and 1974. Also, reproduction in Massachusetts hawks coincided with the availability of their principal prey—hatching coincided with emergence from burrows of young-of-the-year chipmunks (D. Snyder, pers. comm.).

During our observations from blinds, we observed the delivery of 46 prey items to nestlings; species representation paralleled the results of pellet analyses (Table 3) except for a much higher incidence of frogs (*Rana* spp.), which were probably completely digested and excluded from pellets. Similarly, Snyder and Wiley (1976) observed (from blinds) that 50 reptiles and amphibians were delivered to a Florida Red-shouldered Hawk nest during the same period that only 8 reptile and amphibian prey were counted in pellets.

Sex roles.—Sexual dimorphism in adult red-shoulders was not apparent; we were therefore unable to treat male and female adult behaviors separately. Only 1 adult was visible at the nest on all but 3 of over 26,000 photorecorder exposures, suggesting to us a distinct separation of sex roles in rearing the brood. If both adults shared nest duties, we believe the photorecord would have shown many more interactions involving both adults at the nest, especially during early nestling stages when adult attentiveness was most intense (see below).

Often while observing nests from blinds, we saw the departure of an attentive adult immediately after we had heard the nearby call of (presumably) its mate. Within 30 sec to about 5 min after such an interchange, an adult returned to the young carrying food. On 5 occasions at 2 different nests, the adult that originally left the nest was so marked, by a peculiar bloodstain on the cere, that it could be distinguished from its mate; on these occasions the same adult that departed the nest also returned with food and remained the only attentive adult throughout the day of observation. These few observations invite the hypothesis that 1 member of the pair (tentatively the hunting male) delivers prey to the nest vicinity and transfers the food to his mate (the female) who attends and feeds the nestlings.

TABLE 3

RED-SHOULDERED HAWK NESTLING DIET DETERMINED BY PELLET ANALYSES AND BY VISUAL OBSERVATIONS FROM BLINDS, CENTRAL MASSACHUSETTS, 1974

Species represented	Pellet analyses		Visual observations	
	No. of pellets containing remains	Percent[a]	No. of occurrences	Percent[b]
Mammalia	211	99.5	33	71.7
Tamias striatus	138	65.1	20	43.5
Peromyscus leucopus[c]	20	9.4	2	4.3
Parascalops breweri[d]	19	9.0	2	4.3
Blarina brevicauda[e]	16	7.5	4	8.7
Sorex cinereus[f]	6	2.8	0	0
Microtus pennsylvanicus[g]	5	2.3	0	0
Clethrionomys gapperi[h]	5	2.3	0	0
Tamiasciurus hudsonicus[i]	2	1.0	0	0
Unidentified	0	0	5	10.9
Aves	7	3.3	2	4.3
Unidentified	4	1.9	0	0
Cyanocitta cristata[j]	3	1.4	2	4.3
Reptilia	49	23.1	2	4.4
Colubridae[k]	48	22.6	0	0
Thamnophis sirtalis[l]	1	.5	1	2.2
Opheodrys vernalis[m]	0	0	1	2.2
Amphibia	1	.5	9	19.6
Rana spp.[n]	1	.5	9	19.6
Insecta	2	1.0	0	0
Coleoptera[o]	2	1.0	0	0

[a] Based on analyses of 212 discrete pellets collected at 7 nests.
[b] Based on 46 food items delivered to 4 nests.
Common names not included in text: [c] white-footed mouse, [d] hairytail mole, [e] shorttail shrew, [f] masked shrew, [g] meadow vole, [h] boreal red-backed vole, [i] red squirrel, [j] Blue Jay, [k] unidentified colubrid snakes, [l] eastern garter snake, [m] smooth green snake, [n] unidentified frogs, [o] unidentified beetles.

Matray's (1974) study of sex roles in the Broad-winged Hawk, a congener of the red-shouldered, lends credence to this hypothesis.

Obviously, the role of the sexes in Red-shouldered Hawk nesting needs to be studied further, ideally by individually marking each member of a pair, and especially if the sex of marked adults can be determined in the field.

Feeding interactions—visual observations.—The approach of an adult hawk to the nest was always heralded by a chirping call emitted by nestlings. This call was continued after the adult's arrival whether or not food was

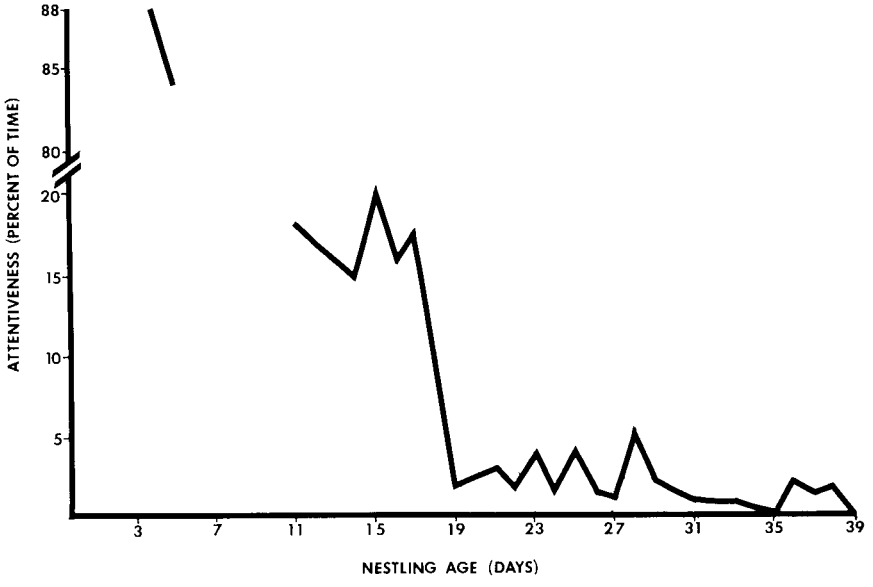

FIG. 2. Changes in adult Red-shouldered Hawk nest attentiveness with advancing nestling age.

delivered. Nestlings, even when large and fully feathered, never attempted to snatch or feed upon prey held by a parent but chirped intermittently until the adult either began feeding them or departed.

When being fed, nestlings gathered side by side before a parent bird. Meanwhile, the adult stood upon the carcass and with its beak tore away strips of flesh. When each piece of meat was presented before the nestlings the closest or most aggressive bird moved toward the proffered food. The adult immediately responded, slowly and deliberately placing the food in the nestling's open beak. Although adults initiated each feeding episode, it was apparently the movement of nestlings towards presented food that triggered the response of relinquishment in adults.

Young became capable of some self-feeding by day 18; however, throughout the nestling period an adult that arrived at the nest and encountered nestlings ineffectually pulling at prey always seized the carcass, tore off pieces of flesh, and offered these to the young. This adult reaction to incompetent nestling feeding appeared similar to the adults' response to movement toward food by downy young.

As the nestlings matured and became more adept at tearing food and thereby feeding themselves, they rarely fed upon a prey item simultaneously,

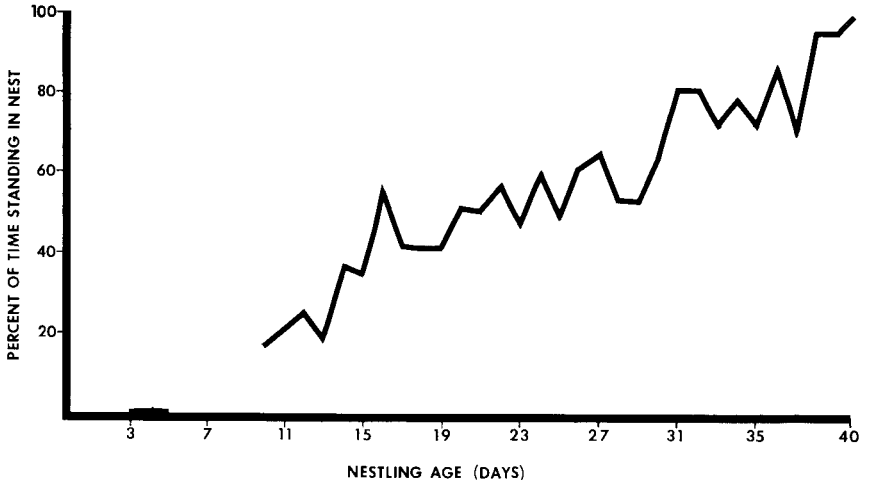

FIG. 3. Changes in nestling Red-shouldered Hawk activity with advancing age.

especially when active and hungry after a fast of several hours. Instead, a prey animal delivered to the nest by an adult would be seized by a single nestling. Other nestlings would then emit the above-mentioned chirping call with head directed and neck extended toward the feeding nestmate. This "pleading" behavior was immediately followed by a "hoarding" posture on the part of the nestling who held the food, i.e. the feeding bird stood over the carcass with lowered wings, tail, and head, and usually continued feeding. Chicks never tried to grasp food from their nestmate when the latter maintained this hoarding posture. However, when pleading failed to stimulate a hoarding response, prey was quickly snatched by a sibling who likewise displayed the hoarding behavior when a pleading nestmate approached. Hoarding was performed only by nestlings possessing food and only while nestmates pleaded. Agonistic encounters were never observed among nestmates and evidently the "pleading–hoarding" behavior pattern had adaptive value in effectively reducing violent strife.

Nestlings exhibited gular flutter when the nest was exposed to direct sunlight and ambient temperatures exceeded 26°C. Sudden gusts of wind were usually followed by vigorous wing-flapping in chicks 20 days old or older.

Nineteen times throughout the nestling period, at 3 different nests, we recorded the arrival of an adult carrying a green deciduous, hemlock, or pine (*Pinus* spp.) sprig in the beak. The adult carefully arranged this

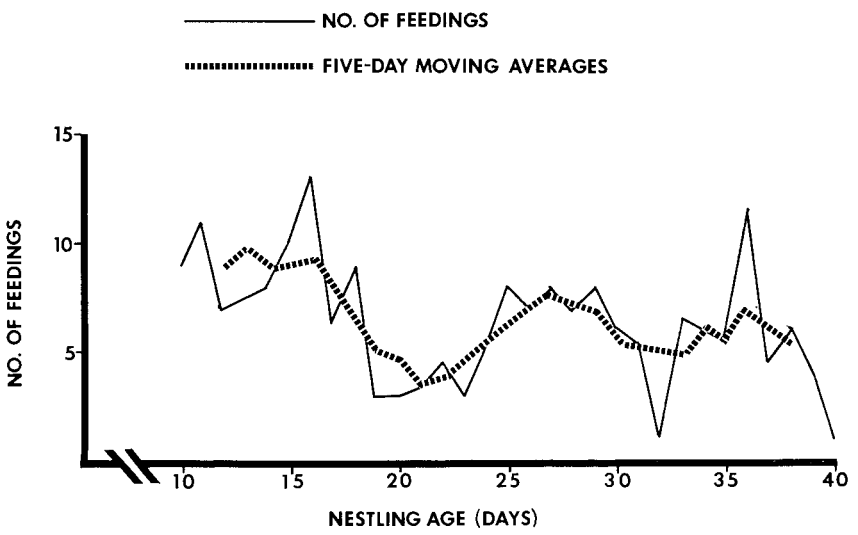

FIG. 4. Changes in mean number of daily feedings as nestling Red-shouldered Hawks grow.

material on the nest before departure. This behavior appeared to increase in frequency as nestlings grew.

Photorecord and behavior quantifications.—A total of 26,524 time-lapse exposures representing 608.3 film hours was obtained from photorecorders at 4 active nests (Table 1). All 4 nests contained 3 nestlings during filming so that energy demands, and therefore feeding rates, were comparable and data were combined in graphing behavioral trends.

Adult attentiveness, mainly brooding, was the dominant behavior at the nest during the first week following hatch (Fig. 2). Nestling activity steadily increased. From day 19 until fledging, attentiveness rarely exceeded 10 min per day and consisted almost entirely of brief feeding sequences; meanwhile nestling activity continued to increase linearly (Fig. 3).

Mean number of feedings per day has been calculated and trends clarified by computing 5-day moving averages (Fig. 4). The decrease in feedings per day from day 16 to 21 represented the reduction in adult feedings as nestlings began feeding themselves from prey remains left in the nest. From days 22 through 27, rapidly growing young required more energy; therefore, a greater number of prey items were delivered by adults, accounting for the increase in recorded feeding sequences. This increase in energy demand is also reflected in the total time spent feeding per day (Fig. 5) after day 22.

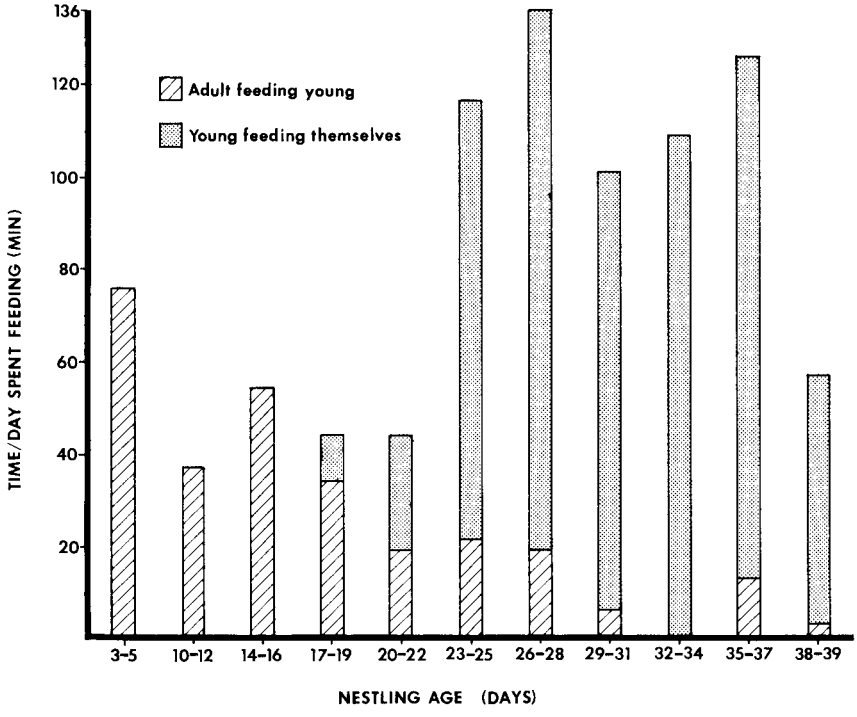

FIG. 5. Changes in the total time spent feeding per day by nestling Red-shouldered Hawks.

We computed the mean duration of adult and nestling feeding sequences for each day of photorecord from four 1974 nests (Fig. 6). Adult feedings took longest during the first few days following hatching, when prostrate nestlings required most assistance.

After the first few days of the nestling period, we observed a gradual reduction in duration of adult feedings, but no important changes in duration of self-feeding sequences by nestlings after day 18 (Fig. 6). An 8.1 min overall difference in mean feeding duration between the 2 types of feeding sequences was in part due to the difference in feeding proficiency between adults and young. Increased food intake also contributed to the time spent feeding by nestlings over 21 days old.

Feedings occurred more frequently between 08:00 and 16:00 than either between 06:00 and 08:00 or between 16:00 and 20:00 (ANOVA, $P < 0.05$). The gradual increase in the number of feedings from dawn through late

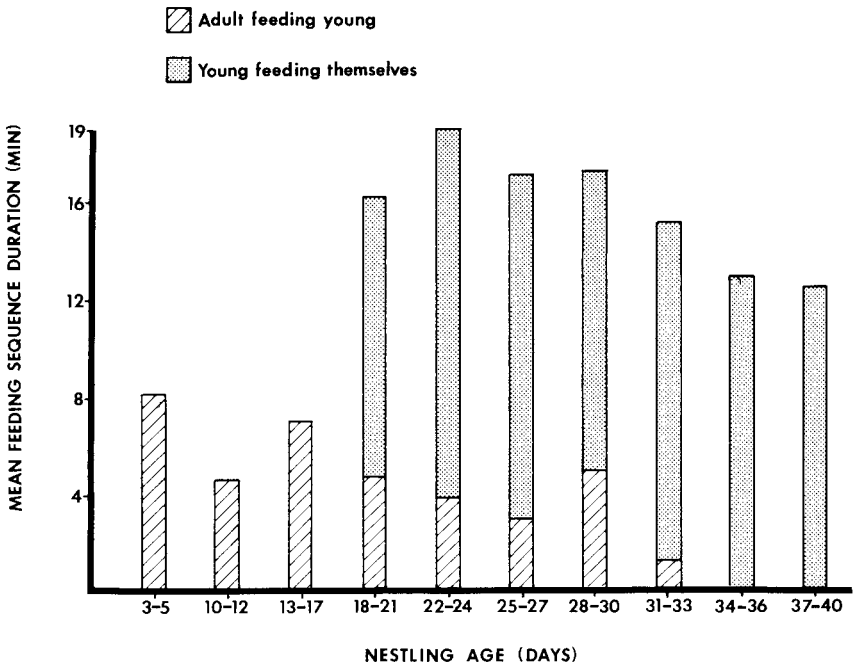

FIG. 6. Comparison of mean feeding sequence duration with respect to adult Red-shouldered Hawk feedings and nestling self-feedings throughout the nestling period.

morning reached a peak between 14:00 and 16:00, and gradually decreased from 16:00 until dark (Fig. 7). It would be interesting to compare this diurnal dispersion of feeding sequences, and presumably successful prey captures, with the activity patterns of principal prey species. Unfortunately, the activity patterns of chipmunks have not to our knowledge been documented.

SUMMARY

A study of Red-shouldered Hawk (*Buteo lineatus*) nesting ecology and behavior was conducted during 1973–74 in a 5000 ha reservoir watershed in central Massachusetts. Courtship occurred in March, egg-laying and incubation in April, hatching in mid-May, and fledging in late June and early July. Mean clutch-size was 3.33 (at 9 nests), hatching rate was 73% (at 3 nests), and 71% of hatchlings fledged (at 5 nests). Hawks hunted and nested along the central strip of riparian habitat on the peninsular study area. Inter-nest distances averaged 1.7 km (N = 7, range: 0.9–3.0 km) in 1974. All nests (N = 12) were situated in mature deciduous trees, usually black birch (*Betula nigra*), on east or northeast slopes. Eastern chipmunks (*Tamias striatus*) were the

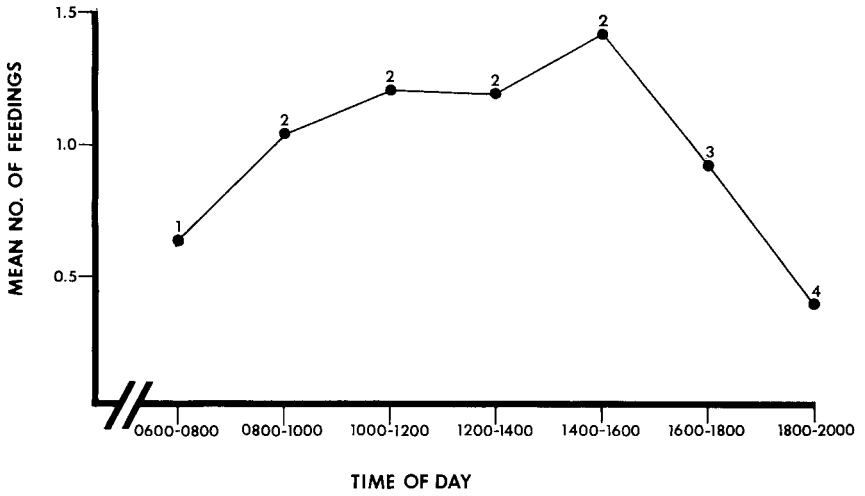

FIG. 7. Diurnal dispersion of feeding sequences (i.e. prey deliveries) at 4 Red-shouldered Hawk nests over 30 nesting days. Adjacent data points having dissimiliar superscripts are significantly different ($P < 0.05$) from each other.

principal prey fed to nestlings. Interactions of nestlings and adults during feeding are described. Behavioral trends throughout the nestling period were quantified at 4 nests using time-lapse automatic cameras. Adult attentiveness decreased rapidly from day 4 to day 19 post-hatch. Nesting activity increased linearly from day 10 to fledging. The number of feeding sequences per day decreased from day 10 to day 19, increased from day 20 to day 25, and then remained stable until the decrease just before young left the nest. Nestling self-feeding sequences averaged 8.1 min longer than adult feeding sequences. Feedings occurred more frequently between 08:00 and 16:00 than during early morning or late afternoon.

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