DEVELOPMENT OF HUNTING AND SELF-SUFFICIENCY IN JUVENILE RED-TAILED HAWKS (*Buteo jamaicensis*)

SARA JANE JOHNSON

ABSTRACT - Forty-eight juvenile Red-tailed Hawks (*Buteo jamaicensis*) were observed for 2 mo following fledging. Their flight activity and capture rate of vertebrate prey were quantified as a means of describing development of self-sufficiency. As juveniles aged, increasing amounts of time were spent in hunting versus nonhunting activities, and versatility of hunting methods increased. Capture of vertebrate prey began 42 d after fledging, but parents continued to provide food at least to 53 d past fledging. Development of self-sufficiency was indicated to be a gradual process whereby juveniles progressively capture more and more of their own food while parental food provision declines.

During 2 yrs of field study on post-fledging behavior of the Red-tailed Hawk (*Buteo jamaicensis*) (Johnson 1973), I rarely saw juveniles capture vertebrate prey. This limited hunting ability of juveniles during the early post-fledging period was consistent with both Amadon's (1964) and Ashmole and Tovar's (1968) assumptions that the long post-fledging period in many species of birds is an adaptation to enhance survival of juveniles while they acquire specialized feeding techniques. Juvenile foraging behavior in a variety of bird species has been quantified to indicate progressive improvements in foraging efficiency through increases in hunting versus nonhunting activities (Buckley and Buckley 1974; Davis 1975), as well as progressive development of increasingly complex capture techniques (Dunn 1972; Smith 1973; Buckley and Buckley 1974; Feare 1975; Davies 1976; Davies and Green 1976). For raptors, development of juvenile hunting skills in the field has been defined in descriptive rather than quantitative terms, and only for several species such as the Swainson's Hawk (*Buteo swainsoni*) (Fitzner 1979) and Peregrine Falcon (*Falco peregrinus*) (Sherrod 1983). The objective of this study was to describe the development of self-sufficiency of the juvenile Red-tailed Hawk in the early post-fledging period by quantifying flight types when juveniles remained localized in the vicinity of the parental territory.

METHODS

I conducted my study during the 1971-1973 breeding seasons in the Gallatin Valley, Gallatin Co., Montana. For details of the site see Johnson (1973). The Gallatin Valley is comprised of a mixture of pasture and dryland farming. Deciduous trees generally occur only along rivers and creeks.

A total of 48 juveniles were observed, 21 from 8 nests in 1971, 20 from 8 nests in 1972, and 7 from 2 nests in 1973. All juveniles were color-marked on ventral wing surfaces with nontoxic enamel spray paint. No abnormal wear and tear was observed on marked feathers. Radio transmitters were placed on 10 and 6 juveniles in 1972 and 1973, respectively. Transmitters weighed up to 41 g, including the harness, frequency range 150-151 mhz, and transmitted approximately 0.3 km at ground level to 25-31 km from the air. Transmitters were monitored with a 12-channel AVM portable receiver and four-element Yagi antenna. A double-layered polyethylene harness held the transmitter on the bird's back between the wings with the antenna extending parallel to the tail. A dissolvable gut suture attachment gradually deteriorated and allowed the harness to eventually fall off the bird. The earliest any harness fell off was 33 d following placement on the bird. The influence of the transmitter on the hawk's flight behavior was unknown; some influence may have been possible.

Frequency, but not duration, of 7 flight types was measured during hour-long observation periods throughout each day between 0900 H and 1900 H. Measurements were initiated on an opportunistic basis when located birds became active. Due to difficulty in locating untagged birds, most flight measurements were recorded on radio-tagged individuals. The 7 flight types quantified included 1) perch/perch-direct flights between 2 elevated perches, 2) perch/quarter-indirect flights between elevated perches during which birds engaged in random quartering flights within 3-15 m of the ground, 3) perch/ground-direct flights from an elevated perch to the ground, 4) quarter/ground-indirect flights to the ground during quartering flights, 5) ground/ground-flights which were initiated and terminated on the ground, 6) perch/adult-approaches to the parent birds and 7) perch/soar-initiation of soaring flights.

I considered 3 of the above flights as hunting activity: perch/quarter, quarter/ground and perch/ground. Quartering flight is a common prey-search method for buteos (Wakeley 1974), and Red-tailed Hawk flights to the ground generally occur during prey-capture attempts. In some instances, the 3 flight types I have identified as hunting activity may not have actually involved hunting activity. However, there is no means of separating these out, and I do not believe they contribute any significant problem to data collection.

The 4 remaining flight types were defined as general movement activity (perch/perch, perch/soar), harassment of parent birds for food (perch/adult) and play and/or capture of invertebrates (ground/ground). I did not consider soaring flight a juvenile hunting activity; during the 3 field seasons, I never observed soaring juveniles attempting to capture ground-level prey. I did observe soaring juveniles grab air-borne invertebrates with their feet.

For purposes of analysis, I combined the hourly observation samples into 5 age classes. Age classes were initially designated at 10-day intervals, since notable range expansions of juveniles occurred at approximately 20 and 30 d past fledging (Johnson 1973). However, because the number of monitored individuals

Table 1. Mean (± S.D.) number of moves per hour by age class for 7 types of flights by juvenile Red-tailed Hawks. The sample is based on a total of 48 known-aged juveniles observed during 3 breeding seasons. Percentages (in parentheses) include only the non-soaring flight activities.

Age Past Fledging (Days)	Hours Observed	Perch/ Perch	Perch/ Quarter[1]	Perch/ Ground	Quarter/ Ground	Ground/ Ground	Perch/ Adult	Perch/ Soar	Total Moves
0-10	22	2.14±1.46	---	0.18±0.39	---	---	---	---	2.32±1.45
		(92.2)	---	(7.9)	---	---	---	---	---
11-20	62	3.21±2.93	0.19±0.43	0.79±1.06	0.06±0.25	0.03±0.00	---	0.10±0.35	4.38±3.26
		(75.0)	(4.4)	(18.5)	(1.4)	(0.7)	---	---	---
21-30	117	2.03±1.73	0.32±0.80	1.09±1.34	0.02±0.13	0.16±0.62	0.07±0.41	0.34±0.61	4.03±2.63
		(55.0)	(8.7)	(29.5)	(0.5)	(4.4)	(1.9)	---	---
31-43	55	2.75±2.23	0.58±1.01	1.91±1.76	0.09±0.45	0.27±0.80	0.15±0.36	0.43±0.62	6.18±3.40
		(47.8)	(10.1)	(33.2)	(1.6)	(4.7)	(2.6)	---	---
44-57	58	1.90±2.16	1.38±1.93	0.97±1.60	0.21±0.55	0.07±0.37	0.29±0.79	0.38±0.86	5.20±3.49
		(39.4)	(28.6)	(20.1)	(4.4)	(1.5)	(6.0)	---	---

[1] Quartering flights which resulted in prey-capture attempts are included in another category.

decreased as older fledglings died or dispersed, the older age classes were extended to increase sample size as follows: 1-10, 11-20, 21-31, 31-43 and 44-57 days after fledging.

During the hourly observation periods, I recorded all instances where juveniles captured vertebrate prey. I did not disturb the birds who had captured prey in order to identify the prey item. Due to the distances from which I observed the birds (≥ 300 m to avoid influencing behavior) I was unable to identify any species of vertebrates captured. I was able to distinguish between a juvenile's capture of vertebrates versus invertebrates. Vertebrate prey was visible in the bird's talons, whereas invertebrate prey was not. When no prey was visible during juvenile bill-cleaning activity (which follows feeding), I assumed the bird had been consuming invertebrates.

RESULTS

A summary of juvenile Red-tailed Hawk flights through the first 2 mo after fledging is given in Table 1. These data were analyzed using the Friedman Two-Way Analysis of Variance by Ranks (Siegel 1956). Distributions of the 7 juvenile flight types were significantly different ($P \leq 0.01$) between the 5 age classes.

First 3 Weeks After Fledging. This period includes the 0-10 and 11-20 d age classes. The young Red-tailed Hawk activity level was lowest immediately after fledging, but essentially doubled within 3 wks as juvenile flight endurance improved. During this initial post-fledging period, the most common juvenile flight type was the simple, direct flight between elevated perches, which comprised 92% of all flights during the young's first 10 d out of the nest. Hunting-related activity was limited during this period. Even in the 11-21 age class, flights to the ground and aerial searching via quartering flight comprised only 24% of all hourly flights. However, not all flights to the ground during this period involved hunting. Birds also went to the ground to retrieve food, or simply because they were unable to sustain their flight.

As this initial fledging period progressed, juveniles moved more easily between elevated perches and the ground, so that their use of the ground increased. At the same time, juveniles spent greater amounts of time away from the nesting trees in open fields where fence posts were available for perching. Direct flights to the ground from elevated perches comprised most of the hunting-related activity, and by 3 wks after fledging comprised 76% of hunting activity. The most limited hunting activity was dropping to the ground from quartering flights. Although these comprised 24% of all quartering flights, I believe many resulted from the juvenile's poor flight endurance.

No juveniles were observed pursuing or capturing vertebrates during this period. The adults appeared to provide all vertebrate food for their young. The former were observed bringing food to the nesting area at least 4-5 times/d. To an unknown extent, juveniles supplemented their diet with ground-associated invertebrates captured themselves.

Soaring flight behavior began developing at the end of this period. These flights were generally of only several min duration. Ground to ground flights, which were associated with play activity, involved both single individuals or groups of siblings. Play involved pursuit of, striking at and wing-beating inanimate objects and/or invertebrates. Sticks and dirt clods were carried around in the bird's beak or talons. Occasionally, birds pursued objects which they had tossed from their beak. Grounded play activity was usually interspersed with dusting and resting activity. During this period, juveniles remained grounded continuously at times up to 18 minutes.

Four To Six Weeks After Fledging. This period includes the 21-30 and 31-43 d age classes. Juvenile Red-tailed Hawk activity levels reached their peak within 6 wks after fledging. At this time, only 48% of the flights/h involved direct perch to perch movement, while 45% involved hunting activity. The dominant hunting activity was still prey-capture attempts directly from perches. These totaled 74% of all hunting-related flights/h and 95% of all prey-capture attempts. Prey-capture attempts occurred during 13% of the quartering flights.

During this period, juveniles were observed pursuing vertebrates. At 35 d after fleging, an individual pursued but didn't contact a Striped Skunk (*Mephitis mephitis*). At 38 d after fledging, a 2nd juvenile followed a flock of English Sparrow (*Passer domesticus*). At 41 d after fledging, a 3rd bird attempted to capture a Black-billed Magpie (*Pica pica*) in a heavy clump of tree branches. And at 41 d after fledging, a 4th bird dove repeatedly at a Red Fox (*Vulpes vulpes*).

It appeared that juveniles were still obtaining most, if not all of their vertebrate food from the parents during this period. Food transfers between parent and offspring were now initiated by the juveniles. Observations of adults carrying food to their young were rare and were only noted for juveniles fledged < 35 d. Juvenile approaches to

parents increased continually through this period. Juveniles were observed approaching and taking food from parents 19 times. In 13 instances juveniles had been hunting with adults in hunting areas, and in 6 instances juveniles flew to adults from other areas of the territory. Adults readily gave up food to their young during this period.

Juveniles also obtained food from other nonsibling juveniles within a juvenile staging area located within the study area and from migrant adult Red-tailed Hawks who were moving through the area. Juveniles obtained food by taking it directly from other juveniles, and also by waiting for adults and possibly other juveniles to abandon food after feeding.

Soaring and ground play activity both increased through 6 wks after fledging. Juveniles spent continuous periods of 1 hr or more soaring. Soaring activity appeared to include exploration of the parental territory and surrounding areas, migration and social and play activity. Groups of up to 20 juveniles were observed soaring together. Play activity consisted of stoops where 2 birds made simultaneous vertical drops of 10-30 m or greater. During ground play, juveniles were observed grounded an hour or more at one time.

Seven To Eight Weeks After Fledging. This period includes the 44-57 d age class. During this last period, the number of juvenile ground-associated flights declined from previous age classes. The biggest decline occurred for general activity between perches; these fell to 40% of all hourly flights. In turn, hunting-related flights now comprised 53% of all hourly flights. Within hunting activity, there was a shift in the dominance from direct prey-capture attempts from perches to aerial searching activity via quartering flight. The latter comprised 62% of all hunting flights. The percentage of such flights which resulted in prey-capture attempts, however, remained at 13%. Thus the dominance of prey-capture attempts made directly from perches continued, although it declined to 82% of all attempts.

During this period, juveniles were observed capturing small vertebrates. In all cases, the suspected prey species were small rodents. Ages of birds involved were 44, 47, 52 and 53 days past fledging. Juveniles were still obtaining an unknown percentage of their food from the parents during this period, and offspring approaches to parents continued to increase in hourly frequency. Juveniles were observed 10x to take prey from parents. Nine incidents occurred when juveniles were hunting close to adults, while 1 incident involved a longer approach across the parental territory. I observed parents resisting food piracy by their offspring during this period. Incidents involved parents carrying food away from, as well as taking food back away from, their offspring. Additionally, I saw 1 adult strike at (loosening feathers) and drive its young away several hundred meters. This attack appeared to stem from repeated harassment by the juvenile for food.

DISCUSSION

Development of self-sufficiency in juvenile Red-tailed Hawks is a gradual process. Flight activity and capture rate of vertebrate prey changed progressively through the first 2 mo after fledging. The shift with age in the juvenile's use of flight types resulted in a progressive increase in hunting versus non-hunting activity. At the same time, juvenile versatility of hunting methods increased. Initial hunting activity was comprised mostly of searching and prey-capture attempts from perches. Gradually their use of aerial searching via quartering flights increased, as did prey-capture attempts initiated from quartering flights. A similar increased use of quartering flights for searching out prey with increasing juvenile age has been reported for Swainson's Hawks (Fitzner 1979), and progressions in complexity of capture techniques have been noted in a variety of nonraptorial bird species (Dunn 1972; Smith 1973; Buckley and Buckley 1974; Feare 1975; Davies 1976; Davies and Green 1976).

Juveniles were first observed capturing vertebrate prey during week 7 after fledging. This likely reflects the average age that juveniles begin capturing vertebrates, since it is unlikely all young develop at the same rate. Development of hunting ability among young Peregrine Falcons has been found to vary considerably (Sherrod 1983).

Gradual development of hunting in young Red-tailed Hawks is similar to that described for young Peregrine Falcons (Sherrod 1983). Both cumulative experience and increasing versatility of capture techniques are likely involved with improved ability to capture vertebrates at young age. Experience, particularly in the form of encounters with live prey, has been shown to be important in the development of self-sufficiency of young rap-

tors; through such encounters, juveniles can learn to select capture opportunities which have a reasonable probability for success (Sparrowe 1972), as well as to select appropriate prey size (Mueller and Berger 1970). Lack of experience was likely involved in the juvenile Red-tailed Hawk's approach to inappropriate prey species such as the Red Fox and Striped Skunk, and initiation of such futile capture attempts as pursuing aerial flocks of passerines and Black-billed Magpies through heavy cover. Similar approaches of inappropriate prey by young Peregrine Falcons has also been observed (Sherrod 1983). The importance of experience seems to be born out by the very low capture rate of vertebrate prey I observed for juvenile Red-tailed Hawks (5 captures during 313 h of observation). Similarly, Sherrod (1983) observed that young Peregrine Falcons make hundreds of pursuits on prey before they begin making kills.

Increasing versatility of capture techniques, where young Red-tailed Hawks used more and more aerial searching for prey, may improve prey capture opportunities. Aerial versus stationery searching has been found to result in more successful hunting for the Ferruginous Hawk (*Buteo regalis*) (Wakeley 1974) and Black-shouldered Kite (*Elanus caeruleus*) (Tarboton 1978).

It was not possible from the study to determine at exactly what age juvenile Red-tailed Hawks become self-sufficient. However, it appears that even at 7 wks past fledging, when young begin to capture vertebrate prey, they remain dependent upon adults for a part of their diet for a continued period of time. Young Red-tailed Hawks were observed obtaining food from parents up to 53 d after fledging and possibly did so for a longer period. Juveniles were observed associating with parents as long as 70 d after fledging (Johnson 1973). Juvenile approaches to parents also continued to increase through 8 wks after fledging. As has been indicated for young Peregrine Falcons (Sherrod 1983), juvenile Red-tailed Hawks may not be initially able to capture vertebrate prey on a consistent basis, and thus remain dependent upon parental support through this transition period to independent feeding. This would allow them to continue to build up fat reserves for their first fall of independence. Both Peregrine Falcons (Sherrod 1983) and Swainson's Hawks (Fitzner 1979) continue to feed their young for some time after the latter begin capturing vertebrates.

The social behavior of both juvenile and adult Red-tailed Hawks seems well suited for the progressive post-fledging development of independence in juveniles. Juveniles were attracted to suitable hunting areas within the parental territory through associations with parents and to hunting areas outside the parental territory through associations with non-sibling juveniles. A similar example of local enhancement, or use of conspecifics to key in on profitable hunting areas, has been noted in other raptor species such as harriers during migration when birds are unfamiliar with local distributions of prey (Ward and Zahavi 1973), by vultures in the Serengeti where carcasses are widely distributed at times (Sinclair and Norton-Griffiths 1979), and by Bald Eagles (*Haliaeetus leucocephalus*) when they are concentrated in wintering areas (Knight and Knight 1983). Juvenile Red-tailed Hawks may also benefit from social behavior in staging areas by obtaining food from other more highly skilled juveniles. Outside of staging areas, social behavior will benefit juveniles by decreasing the effectiveness of adult Red-tailed Hawk territorial defense. The latter have difficulty driving off large numbers of intruders.

The social behavior of juvenile Red-tailed Hawks, along with their ability to capture ground-associated invertebrates, may explain why many individuals disperse from the parental territory as early as a month after fledging (Johnson 1973) even though they do not begin capturing vertebrate prey until around 7 weeks after fledging on the average. Juveniles are probably able to survive by feeding on invertebrates and pirating food from other juveniles until they themselves acquire sufficient hunting skills. I have no evidence to indicate that early dispersing juveniles have either a lower or higher survival rate than later-dispersing individuals. However, since the variable dispersal age pattern of juveniles continues to be expressed in the Red-tailed Hawk population, it would seem to have some adaptive value. If so, I would suggest that this variable dispersal pattern may benefit the overall reproductive success of the population by extending the feeding opportunities of newly-fledging offspring over a larger area rather than restricting all siblings to the parental territory.

ACKNOWLEDGMENTS

I am indebted to Byron E. Harrell and Robert E. Moore for advice in developing the study, to Thomas H. Glorvigen for field assistance, to R.E. Moore and Mary M. Meagher for critical review

of the manuscript, and to David Struckman-Johnson for assistance in statistical analysis of the data. I am also appreciative to William G. Cochran for providing telemetry equipment. Support for this study was provided by the Frank M. Chapman Memorial Fund of the American Museum of Natural History, the Society of Sigma Xi, the Foundation for Environmental Education and Montana State University.

LITERATURE CITED

AMADON, D. 1964. The evolution of low reproductive rates in birds. *Evolution* 18:105-110.

ASHMOLE, N. AND H. TOVAR. 1968. Prolonged parental care in Royal Terns and other birds. *Auk* 85:90-100.

BUCKLEY, F.G. AND P.A. BUCKLEY. 1974. Comparative feeding ecology of wintering adult and juvenile Royal Terns (Aves: Laridae, Sternidae). *Ecology* 55:1053-1063.

DAVIES, N.G. 1976. Parental care and the transition to independent feeding in the young Spotted Flycatcher (*Muscicapa striata*). *Behavior* 39:280-295.

_____ AND R.E. GREEN. 1976. The development and ecological significance of feeding techniques in the Reed Warbler (*Acrocephalus scirpaceus*). *Anim. Behav.* 24:213-229.

DAVIS, J.W. 1975. Specialization in feeding location by Herring Gulls. *J. Anim. Ecology* 44:795-804.

DUNN, E.K. 1972. Effect of age on the fishing ability of Sandwich Terns (*Sterna sandvicensis*). *Ibis* 114:360-366.

FEARE, C.J. 1975. Post-fledging parental care in Crested and Sooty Terns. *Condor* 77:368-370.

FITZNER, R.L. 1979. Behavioral ecology of the Swainson's Hawk (*Buteo swainsoni*) in southwestern Washington. Prepared for the U.S. Department of Energy under Contract EY-76-C-06-1830. Pacific Northwest Laboratory, Richland, Washington. 63 pp.

JOHNSON, S.J. 1973. Post-fledging activity of the Red-tailed Hawk. *Raptor Res.* 7:43-48.

KNIGHT, S.K. AND R.L. KNIGHT. 1983. Aspects of food finding by wintering Bald Eagles. *Auk* 100:477-484.

MUELLER, H.C. AND D.D. BERGER. 1970. Prey preferences in the Sharp-shinned Hawk: the roles of sex, experience and motivation. *Auk* 87:452-457.

SHERROD, S.K. 1983. Behavior of fledgling Peregrines. The Peregrine Fund, Inc., Ithaca, NY; Fort Collins, CO; Santa Cruz, CA; 202 pp.

SIEGEL, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Company, Inc., New York, Toronto, London. 166-173 pp.

SINCLAIR, A.R.E. AND M. NORTON-GRIFFITHS. 1979. Serengeti: dynamics of an ecosystem. University of Chicago Press. 389 pp.

SMITH, S.M. 1973. A study of prey attack behaviour in young Loggerhead Shrikes, (*Lanius ludovicianus L.*). *Behaviour* 44:113-141.

SPARROWE, R.D. 1972. Prey-catching behavior in the Sparrow Hawk. *J. Wildl. Manage.* 36:297-308.

TARBOTON, W.R. 1978. Hunting and the energy budget of the Black-shouldered Kite. *Condor* 80:88-91.

WAKELEY, J.S. 1974. Activity periods, hunting methods, and efficiency of the Ferruginous Hawk. *Raptor Res.* 8:67-72.

WARD, P. AND A. ZAHAVI. 1973. The importance of certain assemblages of birds as "information-centres" for food-finding. *Ibis* 115:517-534.

Biology Department, Montana State University, Bozeman, MT 59715. Present address: P.O. Box 634, Bozeman, MT 59715

Received 22 February, 1985; Accepted 13 January 1986