WAITE, T. A. 1986. Experimental studies of foraging and anti-predator behavior in some captive birds of a winter bark-foraging guild of temperate deciduous woodland. M.S. thesis, The Ohio State University, Columbus, Ohio.

——— AND T. C. GRUBB, JR. Diurnal caching rhythm in captive White-breasted Nuthatches (*Sitta carolinensis*). Ornis Scand. In press.

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Age-class differences in the use of food sources by European Starlings.—The foraging patterns of adult birds often differ from those of juvenile conspecifics. Such age-class differences may be related to the juveniles' lack of skill at a difficult foraging technique (e.g., plunge-diving; Dunn 1972), adult-juvenile competition (Burger and Gochfeld 1983), or because juveniles forage in areas that contain little food (Magrath and Lill 1985).

Age-specific diet differences occur in European Starlings (*Sturnus vulgaris*). While adults continue to feed on soil invertebrates through the summer (Tinbergen 1981), the diet of fully independent juveniles consists largely of plant matter (Feare 1984). Juveniles are less able than adults to locate soil invertebrates (Stevens 1985). The segregation of age classes into different foraging habitats appears to occur only in summer (Feare 1984).

Here I (1) compare the foraging substrates used by adult and recently fledged juvenile starlings during two breeding seasons, (2) present evidence that the food sources used by juveniles often are of poor quality, and (3) speculate that the latter may contribute to the high juvenile mortality during this time of year (Coulson 1960).

Study areas.—I established two circular 300-km^2 study areas in central New Jersey. Owing to the starling's broad diet (Lindsey 1939), I selected two study areas with different land-use characteristics. The Franklin area, near New Brunswick in Middlesex County, was mostly urban-suburban, with abundant grassland but little agriculture. The Adelphia area, 40 km SSE of Franklin in Monmouth County, was largely rural-agricultural, with less grassland than Franklin.

Methods.—I estimated starling populations during weekly roadside censuses along 50 km of established routes in each study area during the breeding seasons of 1983 and 1984. Censuses were begun within 30 min after sunrise and lasted about 3 h. I drove at an average speed of 30 km/h, and stopped often to observe birds. Foraging birds were recorded as adult or juvenile, and each was assigned a foraging substrate, including grassland (managed lawns; unmanaged pastures and meadows); crop fields (mainly soybean, corn, and small grain) in various stages (plowed, planted, mature, harvested, fallow), and human-assisted sources (e.g., bird feeders, garbage pails). I did not assign an age class to flying or resting birds. Censuses began in early June, after first-brood juveniles were observed in the area, and were discontinued in early August after I could no longer use plumage to separate juvenile from adult birds with sufficient reliability. Each two consecutive weekly censuses were combined into biweekly periods to facilitate comparisons with food availability, which was measured every two weeks.

I measured invertebrate density in grassland and growing soybean fields, and grain density in harvested wheat fields. In each study area I sampled three grass fields and three fields of both crop types every two weeks. Grasses were sampled using a grid technique (Ng et al. 1983). The surface, thatch, and soil were searched to a depth of 4 cm, which I judged to be

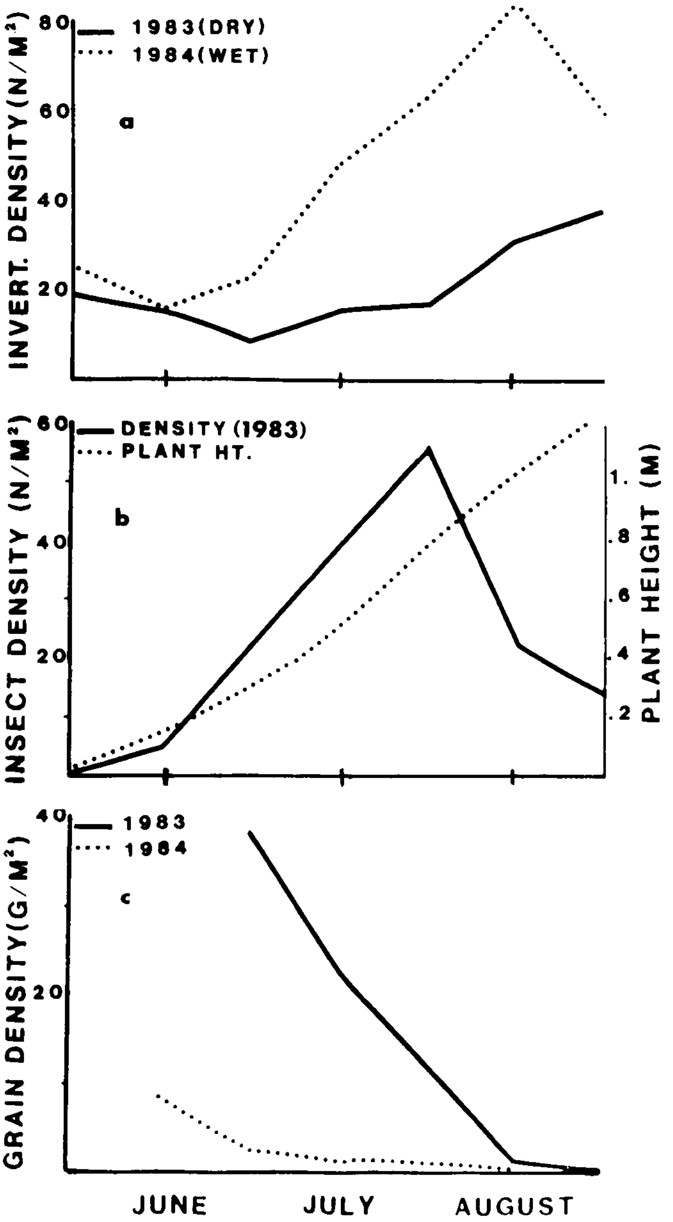

FIG. 1. (A) Total invertebrate density in grasses in 1983 and 1984. (B) Insect density in growing soybean fields in 1983. (Density was estimated to be about half as great in 1984 because of wet soil.) (C) Grain density in harvested wheat fields in 1983 and 1984. (Figures based on 6 grass fields and 6 fields of both crop types sampled every 2 weeks.)

TABLE 1

TOTAL ADULT AND JUVENILE FORAGING POPULATIONS DURING SIX BIWEEKLY PERIODS IN 1983 AND 1984 (FIGURES IN PARENTHESES ARE PERCENTAGES)

	1983			1984		
Age class	Franklin	Adelphia	Total	Franklin	Adelphia	Total
Adults	4940 (83)	5766 (69)	10,706 (75)	3686 (71)	3354 (70)	7040 (71)
Juveniles	1010 (17)	2591 (31)	3601 (25)	1506 (29)	1438 (30)	2944 (29)
Total	5950 (42)	8357 (58)	14,307	5192 (52)	4792 (48)	9984

the maximum probe depth of starlings. Samples were taken early in the morning before invertebrates had moved deeper to avoid desiccation. Insect density on soybean plants was measured using a direct-observation method (Mayse et al. 1978). In addition, a 100-cm^2 area near the base of each sampled plant was inspected to a depth of 4 cm for soil dwelling invertebrates. In both grassland and soybean fields, only invertebrates >4 mm were included in density estimates. I used a modified grid technique to measure grain density in harvested wheat fields (Ng et al. 1983).

Results.—Coleoptera (44%), mainly larvae, and earthworms (39%) were the most common grassland invertebrates. Total invertebrate density (TID) was lower in 1983, a dry summer (20 ± 9 individuals/m^2 [SD]), than in 1984, a wetter summer (44 ± 25 individuals/m^2) ($t = 2.87$, df = 22, $P < 0.01$) (Fig. 1A).

Although plant insects were not common in soybean fields (maximum 0.3 insects/plant), small (<5 mm) adult soil-dwelling beetles (mainly Chrysomelidae) were abundant. In 1983, total density increased from 6 ± 3 insects/m^2 in early June to 56 ± 32 insects/m^2 by mid-August (Fig. 1B). Owing to rain-soaked fields in 1984, insect density declined by about half between years.

In 1983, grain density in harvested wheat fields fell from 39 ± 10 g/m^2 in mid-July to 12 ± 5 g/m^2 in mid-August (Fig. 1C). Heavy spring rains in 1984 resulted in a substantial loss of the wheat crop. About half of all fields were plowed under before harvest; in undamaged fields, the harvest period was shorter and began about three weeks earlier than in 1983. In 1984 grain density declined from 8 ± 6 g/m^2 in late June to <1 g/m^2 by late July.

Starling populations.—Birds could be aged by plumage during six biweekly periods each year. In 1983, both the total number of birds and the number of juveniles were higher in Adelphia than in Franklin ($\chi^2 = 60.2$, df = 1, $P < 0.001$). In 1984, neither the total number of birds nor the number of juveniles differed significantly between study areas (Table 1).

Adults and juveniles used available foraging substrates differently ($\chi^2 = 415.7$ in 1983 and 293.7 in 1984, df = 5, $P < 0.001$) (Table 2). Adults were more numerous than expected in managed grassland both years, and they were more abundant than expected at human-assisted food sources in 1984; aggression by adults often restricted juvenile access to these sources (unpubl. data). Juveniles were more numerous than expected in unmanaged grassland, and in soybean and wheat fields both years, and in agricultural fields other than soybean and wheat in 1984.

Between years, proportionate use of unmanaged grassland by adults decreased significantly, whereas the use of agricultural fields other than soybean and wheat increased significantly.

TABLE 2

NUMBER OF ADULT AND JUVENILE STARLINGS USING VARIOUS FORAGING SUBSTRATES EACH BIWEEKLY PERIOD IN 1983 AND 1984 (FIGURES IN PARENTHESES ARE PERCENTAGES)

Substrate	1983			1984		
	Adults	Jvnles	Total	Adults	Jvnles	Total
Managed grasses	929[a]	119	1048	652[a]	125	777
	(61)	(21)	(50)	(60)	(22)	(47)
Unmanaged grasses	252	124[a]	376	97	118[a]	215[b]
	(16)	(22)	(18)	(9)	(21)	(13)
Growing soybean	60	146[a]	206	62	104[a]	166
	(4)	(26)	(10)	(5)	(18)	(10)
Harvested wheat	76	98[a]	174	46	45[a]	91[b]
	(5)	(18)	(8)	(4)	(8)	(5)
All other agriculture	93	34	127	126	152[a]	278[b]
	(6)	(6)	(6)	(12)	(26)	(17)
Human-assisted	119	38	157	112[a]	25	137
	(8)	(7)	(8)	(10)	(5)	(8)
Total	1529	559	2088	1095	569	1664

[a] $P < 0.001$, indicates significant overrepresentation by an age class, determined by Chi-square analysis of foraging population.

[b] $P < 0.001$, indicates significant proportionate increase or decrease between 1983 and 1984, determined by Chi-square analysis.

For juveniles, there was a significant decrease between years in proportionate use of both soybean and wheat fields, whereas use of other agricultural fields increased significantly (Table 2).

Wheat fields, soybean fields, and grassland together accounted for 88% and 84% of all foraging birds in Franklin and Adelphia, respectively. Neither age class used harvested wheat fields in proportion to grain density. The use of growing soybean fields by juveniles was correlated significantly with insect density at these sites ($r = 0.59$, df = 18, $P < 0.01$), but there was no relationship between insect abundance and use of soybean fields by adults. Use of grassland by adults was correlated negatively with TID in 1983 ($r = -0.64$, df = 10, $P < 0.02$), but positively with TID in 1984 ($r = 0.63$, df = 10, $P < 0.02$). Juveniles foraged in grassland independent of TID both years.

Discussion.—Segregation of adult and juvenile starlings into different foraging habitats followed a similar pattern in both years, despite differences between years in food availability and distribution. Segregation by age class was extreme in grassland. Adults, which used managed grassland extensively both years (61% and 60%) despite a two-fold increase between years in prey density, presumably are able to locate scarce soil-dwelling invertebrates. Adults may use managed grassland because it provides invertebrates required by nestlings (Tinbergen 1981). Morrison and Caccamise (1985) found that even after the breeding season, individual starlings show strong fidelity to such areas. Familiarity with an area might increase an individual's foraging efficiency in that area.

In contrast, juveniles were uncommon on managed grassland. Recently fledged juveniles are probably less efficient than adults at probing for soil-dwelling invertebrates (Feare 1984).

Juveniles in the present study used grassland irrespective of invertebrate density both years, which suggests they may also be poor at assessing prey availability. Juveniles, however, were not tied to grassland as were adults, and they foraged widely in crop fields. Grain lying on the surface of wheat fields, and insects in the soft, bare soil of crop fields probably can be found with little skill. Juveniles also may reduce direct competition with adults on managed grassland by using agricultural fields and unmanaged grassland, in which adults were less common.

The foraging substrates used by juveniles often were of low quality. For example, the pastures used extensively by juveniles typically were large, unmanaged fields in which the grass was higher than that on the lawns used by adults. Starlings have lower capture success in taller grass (Brownsmith 1977), and may be less able to detect both conspecifics and potential predators when feeding in these areas. In addition, owing to rapid depletion, little grain remained in wheat fields by mid-summer, when use of these fields by juveniles peaked. Although insect abundance in soybean fields increased through August, these fields were used by juveniles only until plants reached approximately 60 cm, in July, perhaps because above this height their vision is obscured.

Recently fledged starlings may achieve poor foraging success because of low grain abundance, poor accessibility of tall-grass invertebrates, and competition with adults for human-assisted food sources and, perhaps, invertebrates in managed grassland. Juvenile mortality, which appears to be highest during summer (Coulson 1960), may, in part, be due to such competition as well as other characteristics of the food supply.

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LITERATURE CITED

BROWNSMITH, C. B. 1977. Foraging rates of starlings in two habitats. Condor 79:386–387.

BURGER, J. AND M. GOCHFELD. 1983. Feeding behavior in Laughing Gulls: compensatory site selection by young. Condor 85:467–473.

COULSON, J. C. 1960. A study of mortality of the Starling based on ringing recoveries. J. Anim. Ecol. 29:251–271.

DUNN, E. K. 1972. Effects of age on the fishing ability of Sandwich Terns, *Sterna sandvicensis.* Ibis 114:360–366.

FEARE, C. J. 1984. The Starling. Oxford Univ. Press, Oxford, England.

LINDSEY, A. A. 1939. Food of the Starling in central New York state. Wilson Bull. 51: 176–182.

MAGRATH, R. D. AND A. LILL. 1985. Age-related differences in behaviour and ecology of Crimson Rosellas *Platycercus elegans* during the non-breeding season. Austr. Wildl. Res. 12:299–306.

MAYSE, H. H., M. KOGAN, AND P. W. PRICE. 1978. Sampling abundances of soybean arthropods. J. Econ. Entomol. 71:135–141.

MORRISON, D. W. AND D. F. CACCAMISE. 1985. Ephemeral roosts and stable patches?: a radio-telemetry study of communally roosting starlings. Auk 102:793–804.

NG, Y.-S., J. R. TROUT, AND S. AHMAD. 1983. Spatial distribution of the larval populations of the Japanese Beetle (*Popilla japonica*) in turfgrass. J. Econ. Entomol. 76:26–30.

STEVENS, J. 1985. Foraging success of adult and juvenile Starlings *Sturnus vulgaris*: a tentative explanation for the preference of juveniles for cherries. Ibis 127:341–347.

TINBERGEN, J. M. 1981. Foraging decisions in Starlings (*Sturnus vulgaris* L.). Ardea 69: 1–67.

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Standard rate of metabolism in the Common Barn-Owl (*Tyto alba*).—A number of studies have examined metabolic rates of owl species in relation to ambient temperature (Graber 1962, Ligon 1969, Coulombe 1970, Gessaman 1972). None, however, has examined standard metabolic rates for any member of the family Tytonidae. Here I present results from a series of measurements estimating the standard metabolic rate of the Common Barn-Owl (*Tyto alba*).

Two adult Common Barn-Owls were obtained from the Center for Birds of Prey, Florida Audubon Society, Maitland, Florida, and housed in an indoor aviary at the University of Florida. Aviary temperature was approximately 25°C. Birds were fed a diet of chicks and rats for 6 days and fasted on the seventh. All experiments were run with birds in a postabsorptive state. Because I was unable to obtain permission to laparotomize the birds, I identified sex by comparing each bird against 95% confidence intervals about mean male and female Common Barn-Owl weights (data from Earhart and Johnson 1970:table 2). Although some overlap in confidence intervals existed, weights of both birds used here (488.2, 578.2 g) were outside the male confidence interval and within that calculated for females.

Prior to each experiment, birds were weighed to the nearest 0.1 g, and body temperature (T_b; °C) was measured by placing a thermister probe into the cloaca. Birds were then placed in an open-system chamber approximately 5 liters in volume, and oxygen consumption measured with an Applied Electrochemistry Oxygen Analyzer (Model S3A). Soda lime and silica gel were used to remove carbon dioxide and water, respectively, from air exiting the chamber. Environmental temperatures were controlled by submersing the chamber containing a bird in a thermoregulated water bath. Oxygen consumption ($\dot{V}_{O_2}$; $cm^3 O_2/g\text{-}h$) was calculated from a formula derived by Depocas and Hart (1957). Flow rates ranged from 0.35 to 0.75 liters/min (STPD). Multiple runs at different temperatures were made on each individual bird, and an experiment ended when oxygen consumption was steady for at least 30 min. All experiments were run during the daytime. Birds were weighed to the nearest 0.1 g and body temperature recorded immediately after each experiment. All values are presented as mean ± 1 SD unless indicated otherwise.

The thermoneutral zone (TNZ) of Common Barn-Owls extended from 22.5 to 32.5°C (Fig. 1). Mean oxygen consumption within this zone was 0.604 ± 0.051 $cm^3 O_2/g\text{-}h$. This value is significantly greater ($P < 0.001$) than that predicted by Aschoff and Pohl's (1970) relationship for inactive nonpasserine birds, but within the range of values reported for Strigidae owls (Ligon 1969:table 1) and that predicted by Zar's relationship for strigiforms (1968). Below TNZ, $\dot{V}_{O_2}$ was explained by the relationship $1.161 - 0.024(T_a)$ ($r^2 = 0.90$, $P < 0.001$) and extrapolated to zero metabolism at 47.9°C. Body temperatures averaged 37.8 ± 0.6°C across the range of chamber temperatures (Fig. 1).

Use of the slope of the regression below TNZ as a measure of conductance is valid only if the line extrapolates to the mean T_b (McNab 1980). Because the line below TNZ extrapolates to a temperature greater than the mean T_b, it suggests that Common Barn-Owls