Survival of raccoon litters and its relationship to den site characteristics

by

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My introduction to the raccoon project and early years in

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GENERAL INTRODUCTION

Current changes in landscapes as a result of agriculture and urban expansion have made knowledge concerning life histories and critical habitats of species important. Decisions concerning which habitats to save or how habitats or species are to be managed, for the greatest good of the resource, may depend on our breadth of knowledge.

A logical starting point begins with understanding how early life stages influence population dynamics. Survival of young, in addition to pregnancy rates and litter sizes, may play an important role in the population structure of most species. Errington (1963) postulated an intercompensatory response to harvest. Hasbrouck (1991) suggested there may be compensatory survival of >1yr old raccoons (_Procyon_ _lotor_) during the harvest season in years of high exploitation. The life stages which are impacted and to the degree compensatory responses occur may be of particular interest to the ecologist, as well as the manager.

Sievert and Keith (1985) found that survival of snowshoe hares (_Lepus_ _americanus_) was related the condition of their habitat. A similar relationship may be applied to survival of young raccoons.

The objectives of this study were to: 1) determine survival rates and causes of mortality of young raccoons

between 1 and 5 months old; 2) quantify habitat and den characteristics associated with litter den sites; 3) investigate the differences in den characteristics and macrohabitat of den sites selected by yearling and adult female raccoons with litters; 4) investigate relationships of female age and den characteristics to survival rate of young raccoons; 5) make recommendations which will aid in management of habitat important to raccoon litters.

Explanation of thesis format

This thesis has been organized and written under the guidelines specified for the alternate thesis format (Iowa State University Graduate College Thesis Manual) and consists of two sections. Section 1 discusses day-time denning habitat of raccoon litters and the differences in usage between yearling and adult age classes. Section 2 focuses on survival of young raccoons born to yearling and adult females and the relationship of survival to characteristics of their day-time denning habitats. Each section was written for publication by myself and edited by Dr. W. R. Clark.

SECTION 1. DEN-SITE CHARACTERISTICS OF RACCOON LITTERS

ABSTRACT

I measured habitat characteristics of day-time den sites used by radio-instrumented raccoon (Procyon lotor) litters born to yearlings and adults in southwest Iowa in 1988 and 1989. In relation to macrohabitat characteristics, yearling females used significantly different den sites than adult females. However there were no differences detected at the microhabitat level. Of three habitat types in which day-time den sites were located, upland and lowland habitats were used with higher frequency than farmsteads. Adult females used upland ($P = 0.05$) and farmstead ($P = 0.01$) habitats more than yearlings. Yearling females used lowland habitat with greater frequency than adults ($P = 0.002$). Tree cavities and den locations on the ground were used more than all other den types. Adult females used buildings ($P = 0.003$) and dens in the ground ($P = 0.001$) more than yearlings, while yearlings used dens on the ground ($P = 0.032$) more than adults. There were also significant differences ($P < 0.05$) between age classes in the mean distance of their day-time dens to the nearest occupied building, road, water, edge habitat, crop field, and their last den location. On the microhabitat level, there were no differences ($P > 0.05$) between age classes, regarding use of tree species, tree diameter, tree height, den height, depth of den cavity, length or width of

the den cavity opening, or basal area of the adjacent trees.

INTRODUCTION

The raccoon (<u>Procyon</u> <u>lotor</u>) has historically been an important furbearer for its economic and/or recreational value. In Iowa the average price per raccoon pelt peaked during the 1978-79 season at $31.18 with a harvest in excess of 250,000 (Andrews and Judson 1988). Although average pelt prices declined to $4.74 in Iowa during the 1989-90 season, approximately 120,000 raccoons were harvested (R. D. Andrews, Iowa Dept. Natural Resources, pers. commun.), indicating a strong interest in sport hunting and trapping.

Although raccoons have proven to be very adaptable to habitat change (Sanderson and Hubert 1981), there is still a need for understanding habitat use, particularly if large or small population levels are desired. Like many species, early life stages of raccoons may require specific conditions to insure survival. Many researchers (Stuewer 1943a and 1943b, Gysel 1961, Berner and Gysel 1967, Schnell 1969-70, Shirer and Fitch 1970, Schneider et al. 1971, and Hardy 1979) have described den usage or den locations of raccoons, but few looked specifically at usage by litters or made an attempt to quantify this information.

Schneider et al. (1971) reported a shift in den usage by raccoon litters near 60 days of age. This shift from the natal den site to a ground location may reflect specific

requirements of the young near the time of weaning (Montgomery et al. 1970).

Selection of den sites may be critical to survival of the litter. Kaufmann (1982) suggested that habitat selection by different age classes may promote success or failure of the litter, and thus also affect population growth. Road kills are an important mortality factor in some adult raccoon populations (Fritzell and Greenwood 1984, Clark et al. 1989, Hasbrouck 1991) and roads may be a serious hazard to young as well. Association of dens to other macrohabitat characteristics may also be important. Glueck et al. (1988) related the importance of woody habitat and buildings to raccoons in Iowa. The reduction of mature timber and loss of old buildings, in many rural areas, may be related to reduced population levels. Differences in birth and survival between age classes may potentially affect population growth. In Iowa, Glueck (1985) found that under a normal harvest rate of 17-24% of the fall population, 62% of yearling and 91% of adult females bore young and had average litter sizes of 3.1 and 3.8, respectively. Differential age class survival, due to exploitation (Hasbrouck 1991), may further affect population productivity.

The objectives of this study were to: 1) quantify habitat and den characteristics associated with raccoon litter den sites; 2) investigate the differences in den

characteristics and macrohabitat of den sites selected by
yearling and adult female raccoons with litters, and; 3) mak
recommendations which will aid in management of habitat
important to raccoon litters. This study extends that of
Clark et al. (1989) and Hasbrouck (1991). Hasbrouck
investigated the effect of an experimentally-induced high
harvest on rates and patterns of survival in raccoons >5
months old. My study was conducted concurrently during the
period of increased harvest.

METHODS

Study Area

The study area is a 42 km^2 tract located in Guthrie
County in southwest Iowa (T79N,R31W). The area is bisected
from northwest to southeast by the South Raccoon River. Land
use consists primarily of corn and soybeans fields, grazed
pastures, and livestock forage crops. Timber comprises
approximately 10% of the area and is generally confined to
drainage systems, shelterbelts, and steep hills. Cottonwood
(Populus deltoides), silver maple (Acer saccharinum), box
elder (A. negundo), basswood (Tilia americana), and willow
(Salix spp.) dominate lowland timbered areas. Upland areas
contain oak (Quercus spp.), hickory (Carya spp.), and elm
(Ulmus spp.). Shelterbelts consist primarily of silver maple
and American elm (Glueck 1985). Grass and forb herbaceous
cover with mulberry (Morus spp.) and patches of American plum
(Prunus americana) is common in edge habitat and along field
borders. Riparian borders also contain herbaceous cover but
the woody patches are primarily willow or silver maple.

Field Sampling

I live-trapped or removed from dens female raccoons,
prior to parturition of young, from mid-March through April in
1988 and 1989. All raccoons were immobilized with an
intramuscular injection of ketamine hydrochloride (Bigler and
Hoff 1974) to facilitate handling. Females' abdomens were
palpated to determine breeding condition. All females were
weighed and measured, age was estimated from tooth wear (Grau
et al. 1970), and an incisor removed to determine exact age.
These females were instrumented with radio transmitter collars
(Advanced Telemetry System Inc., Bethel, MN). I located some
females in dens after parturition, which I also instrumented.

Breeding-age animals were assigned an age, in years,
based on cementum annuli counts (Grau et al. 1970) from teeth
removed at capture. Clark et al. (1989) found that
reproductive rates of yearling female raccoons were
significantly different from those 2 or more years old. Based
on their results, I grouped females into: 1) yearlings (1 yr
old) and; 2) adults ($\geq$2yrs old). Individuals born during the
spring of each year will be referred to as young-of-the-year,
or simply young.

I located dens of female raccoons using radio telemetry.
Females have an affinity to the birthing den for several days
prior to giving birth (Kaufmann 1982). Thus, when an

individual did not change her denning location for 3 successive days I assumed that she had given birth. The location of all dens after that time were recorded.

By 4-5 weeks age, most young raccoons had attained a sufficient body weight (approx. 700 g), which I judged to be adequate to carry the 35-g radio-collars. Approximately 5 weeks after parturition, these breeding females were relocated. Those females with young 5+ weeks old were removed from the den. I first immobilized females with ketamine hydrochloride, and the female and young were then noosed from the den. Weights and measurements of the young were taken and they were aged by tooth eruption and replacement (Montgomery 1964).

In 1988 I collared 1 young from each litter with a small expandable radio collar (Advanced Telemetry Systems, Inc., Bethel, MN), (Judson 1990). In 1989 sample size was increased to 2 per litter when possible.

Denning Habitat

I monitored den sites of females with litters for 5 months after birth of the young. I randomly selected 2 instrumented litters each day and located them with radio telemetry. Multiple den sites were recorded for each litter throughout each field season. Because individuals were

randomly selected, dens were assumed to be independent of one another.

I measured micro- and macro-habitat variables at each den site. Macro-habitat characteristics included distance of the den to inhabited buildings, roads, water, edge habitat, and crop fields, and were measured to the nearest 10 m. I used a meter tape when objects were in line-of-sight. When they were not, distances were measured from an aerial photograph with comparable accuracy. Other macro-habitat variables were den type (building, ground hole, brushpile, machinery, row crop, surface vegetation, tree cavity, or open tree limbs) and habitat type (upland, lowland, edge, fencerow, or farmstead, Glueck 1985). Micro-habitat characteristics included den height, den structure height (nearest 1 m), den cavity depth (nearest 10 cm), den opening dimensions, and for trees, diameter at breast height (DBH, nearest 1 cm), and species. I used an optical clinometer to measure den height and den structure height. For tree dens in wooded areas, I measured the basal area of adjacent trees with a 10 factor optical prism and grouped measurements into 3 categories; the number of trees <10 cm, 10-30 cm, and >30 cm. To avoid disturbance I measured cavity depth and den opening dimensions after the family had moved.

Statistical Analysis

Mean values and standard errors were calculated for each habitat parameter. I used analysis of variance or χ^2 tests to test for differences between den sites selected by yearling and adult females, when measurements were continuous or discrete, respectively. Pearson correlation coefficients (SAS Inst. 1985:355-357) were calculated to investigate the inter-relationship of all habitat variables.

RESULTS

Habitat

Of 310 day-time den locations, 7 yearling females with litter used 36.45% (113) and 14 adult female litters used 63.55% (197) of those dens. Less than 2% of all den sites were located in edge and fencerow habitat types, and were subsequently dropped from the analysis. Raccoon families used upland and lowland habitat with similar frequency and used both habitats more frequently than farmsteads (Fig. 1). A 2 x 3 contingency table was used to test for differences among upland, lowland, and farmstead habitats between yearling and adult females. The test revealed significant differences in habitat usage by the 2 age classes (χ^2 = 19.53, df = 2, P < 0.001).

Adult females used upland (χ^2 = 3.67, df = 1, P = 0.05) and farmstead (χ^2 = 6.65, df = 1, P = 0.01) habitats more frequently than yearlings. Yearling females utilized lowland habitats more and adults used them less than would be expected by chance alone (χ^2 = 9.22, df = 1, P = 0.002) (Fig. 1).

Percentage of all day-time den locations of yearling and adult raccoons with litters in three habitat types in Guthrie County, Iowa 1988-1989

Figure. % Use by Habitat Type for Yearling and Adult.

a Significantly different at P ≤ 0.05
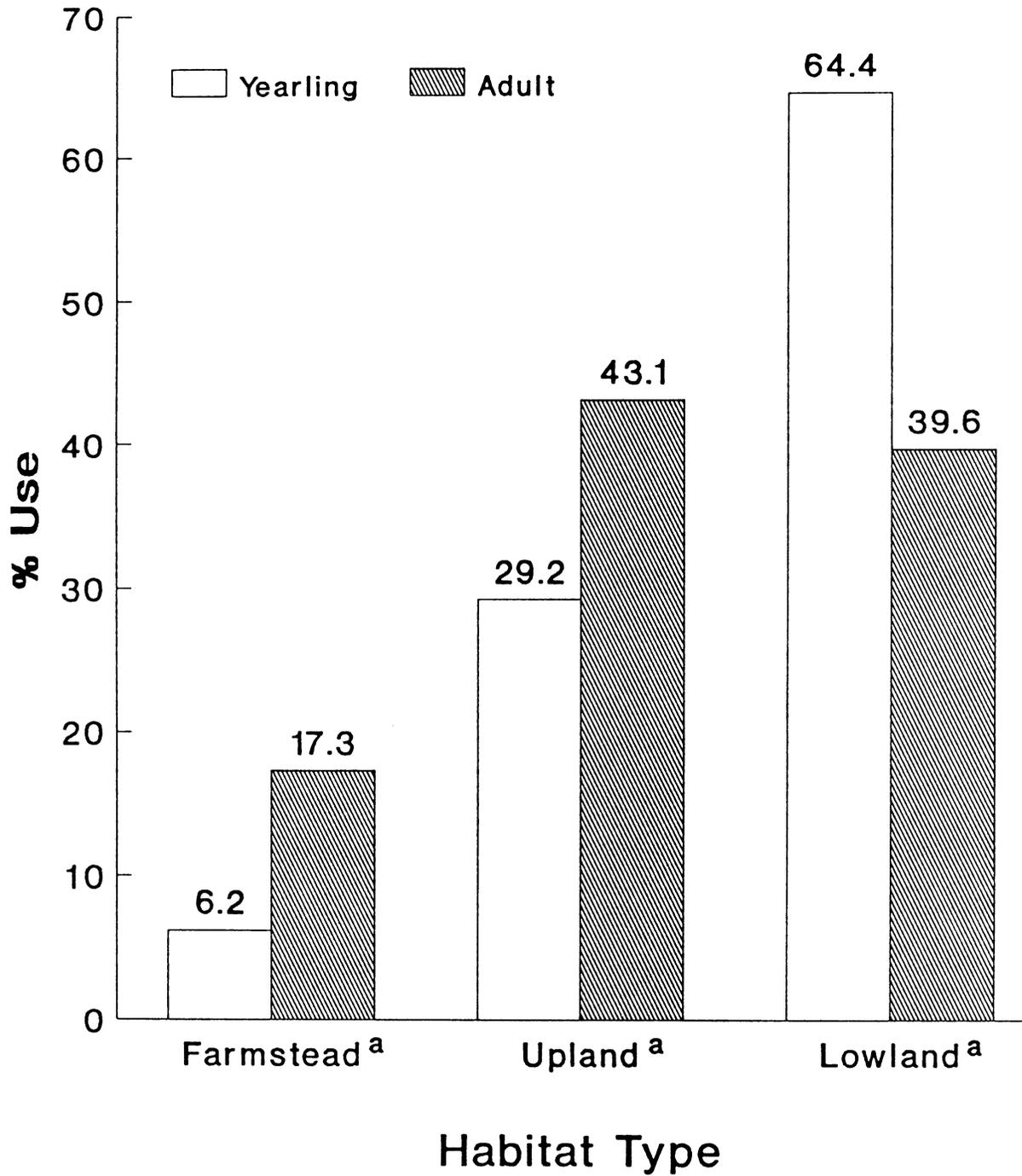
Den Type

Dens in tree cavities or on the ground in vegetation were used with higher frequency than any other den type (Fig. 2). The type of den used by yearling and adult females with litters was significantly different (χ^2 = 21.53, df = 7, $\underline{P}$ = 0.003). Adult females and their litters used buildings (χ^2 = 8.63, df = 1, $\underline{P}$ = 0.003) and holes in the ground (χ^2 = 6.64, df = 1, $\underline{P}$ = 0.001) with higher frequency than yearlings and their litters. Yearling females used dens which were in vegetation and on the ground more than litters of adult females (χ^2 = 4.61, df = 1, $\underline{P}$ = 0.032). There were no significant differences between yearling and adult females usage of tree cavities, open tree limbs, row crop fields, brushpiles, and machinery ($\underline{P}$ > 0.05) (Fig. 2).

Female raccoons used a variety of tree species as den sites. Silver maple and oaks were used with highest frequency by both age classes (Fig. 3). There was no significant difference in the species of trees used as dens by yearling and adult females (χ^2 = 1.67, df = 4, $\underline{P}$ = 0.797). Chi-square tests for the individual species also suggested there were no differences in age class use of, silver maple, basswood, oak, boxelder, cottonwood, willow, elm, and others ($\underline{P}$ > 0.05). Since there were no differences in the species of trees used by the 2 age classes, the data were pooled. "Other" species

FIGURE 2.   Percentage of day-time dens used by yearling and adult raccoons with litters in Guthrie County, Iowa 1988-1989

Legend:
- Yearling
- Adult
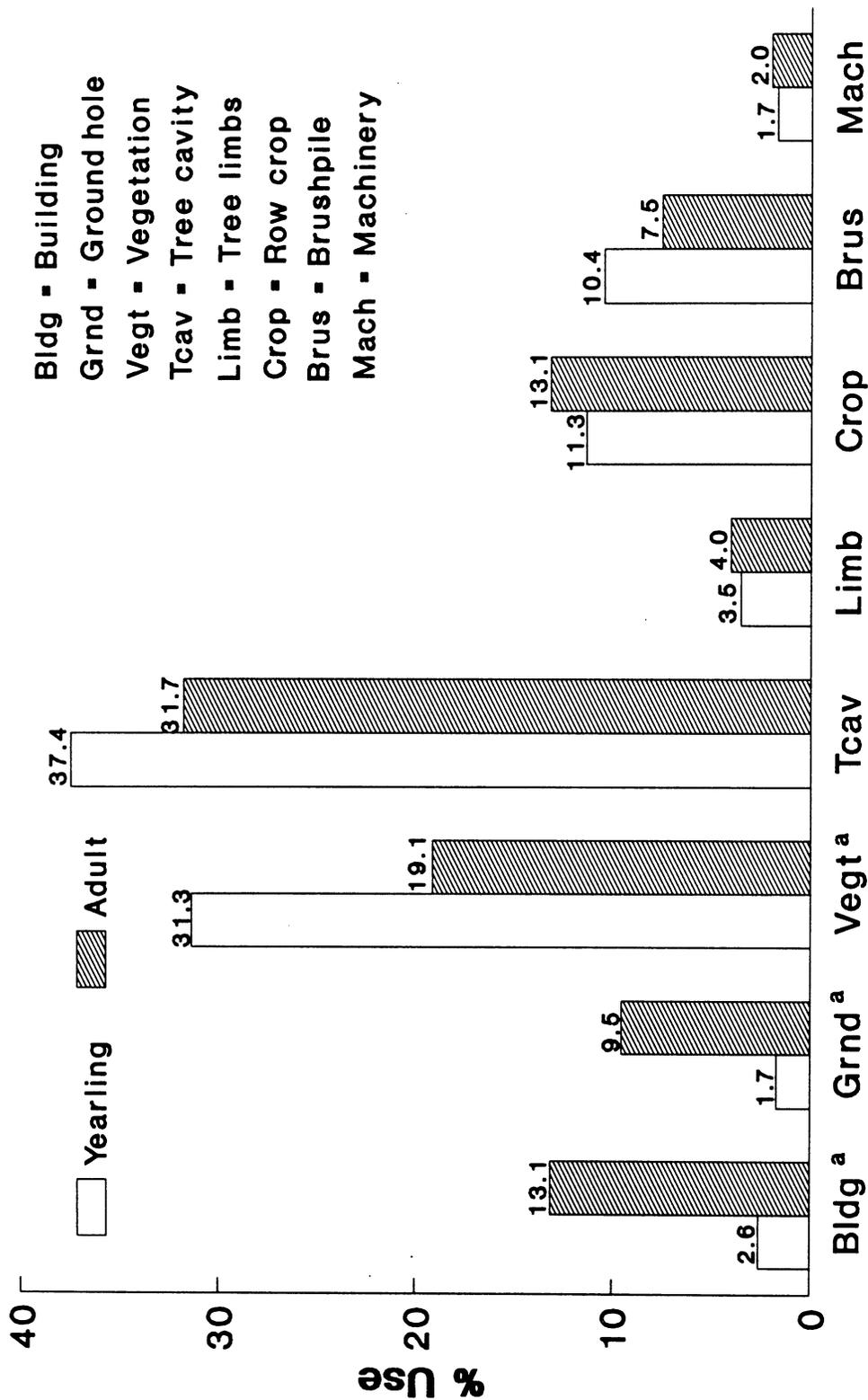
Bldg = Building
Grnd = Ground hole
Vegt = Vegetation
Tcav = Tree cavity
Limb = Tree limbs
Crop = Row crop
Brus = Brushpile
Mach = Machinery

Den Types

% Use

Bldg [a]: 2.6, 13.1
Grnd [a]: 1.7, 9.5
Vegt [a]: 31.3, 19.1
Tcav: 37.4, 31.7
Limb: 3.5, 4.0
Crop: 11.3, 13.1
Brus: 10.4, 7.5
Mach: 1.7, 2.0

[a] Significantly different at $P \leq 0.05$

FIGURE 3.   Percentage of tree species used as dens by raccoons with litters in Guthrie County, Iowa 1988-1989

Map = Silver Maple
Oak = Oak spp.
Box = Boxelder
Bas = Basswood
Cot = Cottonwood
Wil = Willow spp.
Elm = Elm spp.
Oth = Other
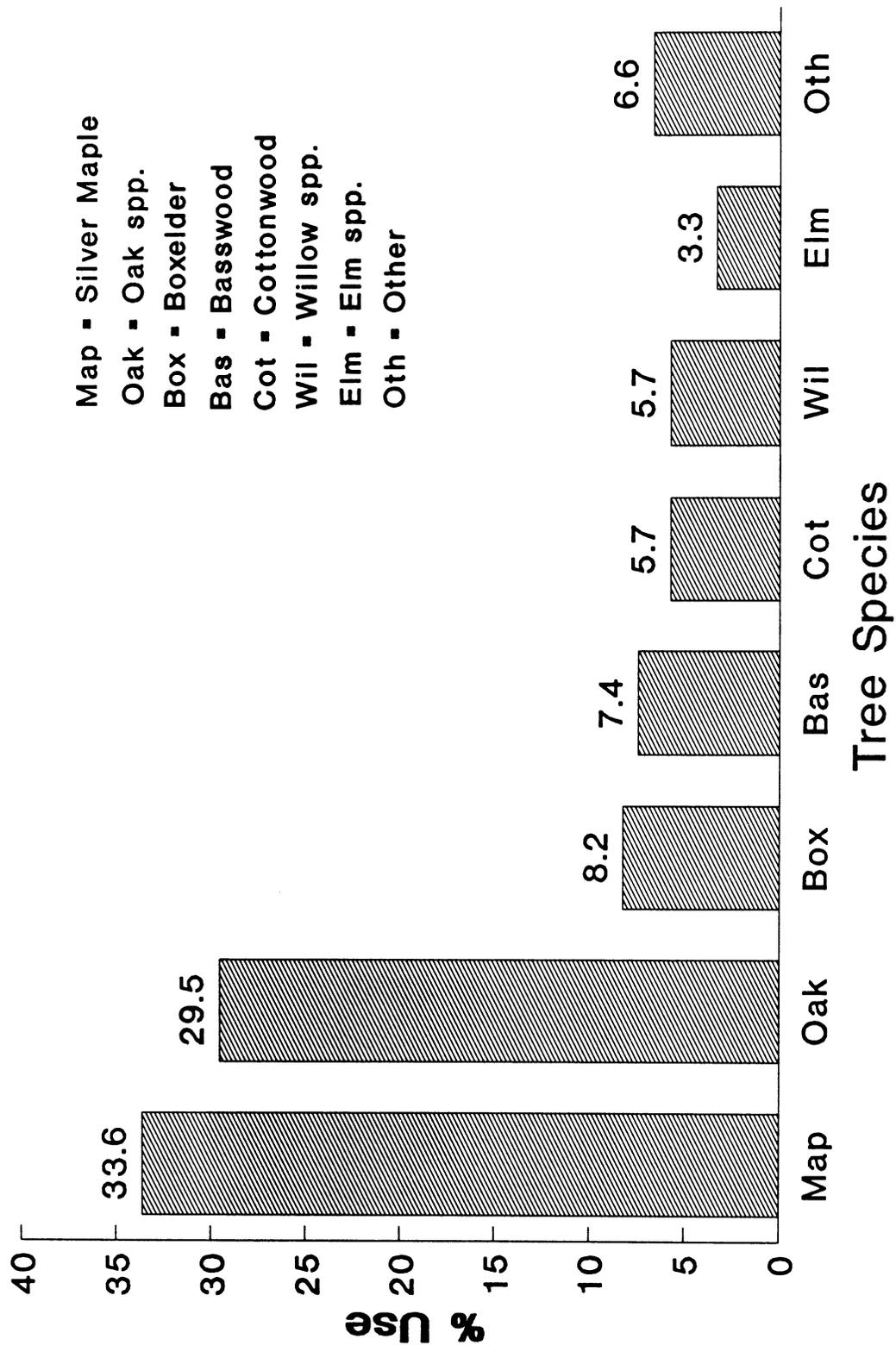
included cottonwood, elm (<u>Tilia</u> spp.), willow spp., green ash
(<u>Fraxinus</u> <u>pennsylvanica</u>), and black cherry (<u>Prunus</u> <u>serotina</u>).

Den Characteristics

No particular distinguishing characteristics were
detected in the microhabitats used by denning female raccoons
(Table 1). Similarly, there were no differences in tree den
usage or the specific tree species used by the 2 female age
classes. Analysis of variance revealed no differences in
other characteristics directly associated with the tree dens.
No differences were detected among den tree characteristics of
DBH, den height, tree height, depth of den cavity, length or
width of the den cavity, and basal area of the adjacent trees.
In contrast to microhabitat characteristics, macrohabitat
characteristics of den sites differed between yearling and
adult females. Analysis of variance showed significant
differences in distance to the nearest occupied building,
road, water, edge habitat, crop field, and the last occupied
den (Table 2). Adults' den sites were closer to buildings and
roads than yearlings, whereas yearlings' den sites were closer
to water, edge, crop fields, and their last den location. Of
the preceding variables, only the distance from dens to roads
and buildings was highly correlated ($\underline{r}$ = 0.61, $\underline{P}$ = 0.001).

Table 1. Dimensions of trees used by female raccoons with
          litters in Guthrie County, Iowa 1988-1989

Variables	n	Mean	SE	Range
Tree Height (m)	109	16.1	0.5	3-26
Den Height (m)	101	5.5	0.3	0-17
DBH (cm)	110	77.4	3.2	30-163
Cavity				
Depth (cm)	100	142.0	1.3	0-570
Opening Width (cm)	100	17.0	0.8	8-43
Opening Length (cm)	100	33.3	2.1	12-99
Basal Area (sq m/ha)				
Trees <10cm	105	16.4	2.5	0-99
10-30cm	105	64.5	6.2	0-297
>30cm	105	109.7	7.0	0-371
All	105	189.5	9.4	25-519

Table 2. Macrohabitat characteristics of day-time den sites used by yearling (Y) and adult (A) female raccoons in Guthrie County, Iowa 1988-1989

Distance to:	Age	n	Mean	SE	$\underline{P}>F^{a}$
Building (m)	Y	115	592.6	26.01	<0.001
	A	199	426.5	17.10	
Road (m)	Y	115	412.1	28.70	<0.001
	A	199	292.9	18.42	
Water (m)	Y	115	77.7	6.90	<0.001
	A	198	151.9	11.44	
Edge (m)	Y	115	28.0	2.32	0.025
	A	199	37.9	3.06	
Crop (m)	Y	115	82.1	6.89	0.027
	A	199	109.0	8.30	
Last Den (m)	Y	107	344.8	37.09	0.029
	A	183	460.3	33.83	

[a]Probability of yearling and adult dens being equal.

DISCUSSION

Habitat

There appears to be a distinct separation of day-time
denning habitat of yearling and adult female raccoons. This
separation was not evident at the microhabitat level, but
there appeared to be important differences in macrohabitat
usage. Although there was some overlap in habitat use between
the age classes, there was greater use of farmsteads and
upland habitat by adults. Yearlings usage of lowland habitat
and dens on the ground was also greater than that of adults.
The reason for differences in habitat use may have been due to
different requirements of the 2 age classes. Berner and Gysel
(1967) hypothesized that intraspecific competition may
influence den selection, whereas Schoener (1974) discussed the
theory of interspecific habitat separation and resource
partitioning. Similar theoretical approaches may also help
explain the intraspecific use of habitat which I observed.

At the microhabitat level, I found no difference in usage
of tree species for den sites by yearling and adult females.
The species of tree selected as a den site is probably related
more to the presence of an adequate den in the tree, than to
the actual species itself. Stuewer (1943a) also suggested
that tree species probably means little to the raccoon. I

also found no differences in the characteristics of the tree,
den cavity, and surrounding trees (measured as basal area),
selected by yearlings and adults. This may suggest
that quality den trees were not a limiting factor and no
competitive exclusion occurred at this level.

I found a wide range of natural variation in den tree
DBH, tree height, den height, and external cavity width and
length. This variation may have been too great to detect any
real differences in usage between the 2 age groups. There is
currently little information available concerning the use of
den trees by litters. Considerable variation in den
characteristics has been reported for raccoons of all age
classes and sexes during various seasons (Stuewer 1943a,
Cabalka 1952, and Hardy 1979).

I noted no differences in microhabitat characteristics of
dens used by the 2 age classes of raccoons, but I did observe
many differences at the macrohabitat level. Sandell (1989)
noted a spacing of female canids and related it to the
abundance and dispersion of food. Crabtree (1988) noted a
similar trend, specifically in female coyotes (Canis latrans)
during the whelping period, and felt it functioned in ensuring
protection and survival of the young. The specific separation
of individual age classes may indicate competition for and
exclusion of one group from optimal resources. Differences in
home range sizes and movements of yearling and older-aged

raccoons were noted by Stuewer (1943a), and may indicate intraspecific habitat separation.

I found that average distance to water from dens used by yearling and adult litters was significantly different. The range of values I observed for both age classes were similar to those found by Steuwer (1943a) Cabalka (1952), and Hardy (1979), although they recorded no sex, age, or seasonal differences. The reason for the age-specific difference in distance to water is unclear. The difference is not extreme and may not be ecologically significant. Hardy (1979) was in agreement, and noted that distance to water is probably not important and does not influence raccoon densities.

The statistically significant differences between yearling and adult den distances to edge and crop may again reflect requirements of, or competition between the 2 age classes for resources. Competition may be occurring for preferred food sources located along edge habitats and in crop fields. Mulberry and American plum were common along edges and field borders (S.C. Grothe and W.R. Clark, Iowa State Univ., pers. commun.) and provide ample fruit commonly utilized by raccoons (Kaufmann 1982). The age-specific differences in average distances of dens to edge habitat and crop fields were not extreme. These differences also may not be ecologically significant. They may simply reflect chance differences in the habitat used by the 2 age classes.

Dens used by adults were farther apart than those of yearlings. Steuwer (1943a) found home range size of adults to be larger than juveniles. I did not collect home range information, but larger home ranges of adult animals, as suggested by Steuwer (1943a), could account for greater distance between dens. Optimal den sites in upland and farmstead habitats may also be farther apart. Although I did not measure availability or spacing of all potential den sites, upland habitat seemed to have less protective cover than lowland habitat.

The separation of den types I noted between yearling and adult females den sites may have involved competition (Schoener 1974) for optimum den sites. Adult females may be more aggressive and exclude yearlings from those sites which were most advantageous to the litter. Or they may simply get there first because they are more experienced. Cowan (1973) stressed the importance of buildings, as protective sites, while young raccoons are being raised. These sites may therefore be preferred and competition for these sites may result in greater use by adult females.

Harvest and survival patterns may help explain the greater use of buildings as den sites by adult females. Concurrently with this study, Hasbrouck (1991) found, that with artificially increased harvest, juvenile harvest season survival (0.35) was significantly lower than adults (0.50).

Because much of the harvest pressure of raccoons occurs close to roads and buildings (Hardy 1979, Hasbrouck 1991), juvenile density may have been reduced in those areas. A larger proportion of adults home ranges which included building sites may be the result of disproportionate age class survival and harvest patterns.

Management Recommendations

Although there appeared to be no difference in den usage between the age classes at the microhabitat level, it did appear as though there were spacial differences in the location of the den sites. These differences include distance to water, crop fields, edge habitat, buildings, and roads. If these differences suggest specific requirements of the age classes, we may choose to manage for greatest impact to the resource. Fritzell et al. (1985) and Glueck (1985) found adult females had higher pregnancy rates and larger litter sizes than yearlings, indicating the importance of this age class. Thus, intensive management of habitat important to adult female raccoons (uplands and farmsteads), may have a influence on population levels.

Most importantly, raccoons use a wide variety of habitat and den types. One might presume this to indicate the species is very adaptable and has few specific requirements. I

believe this means that diversity of habitats and dens is the key to high survival and high densities.

Litter rearing habitat is an important component in the life history of the raccoon (Cowan 1973), but not the only component. Other seasonal habitat requirements, as well as harvest season regulations, can be manipulated by the manager to influence population levels.

Future Research Needs

During this study I noticed a shift from den trees to ground-type dens when young were 7-10 weeks old. Stuewer (1943b) and Schneider et al. (1971) noticed a similar trend at about 10 weeks and 7-9 weeks, respectively. This may suggest a shift in requirements of the litter at this time. Further investigation will help define why this shift occurs, and the specific requirements of the litters during these 2 periods. This information may be of specific ecological importance and may well aid managers in population regulation.

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SECTION 2. SURVIVAL OF YOUNG RACCOONS AND ITS RELATIONSHIP TO
DAY-TIME DEN-SITE CHARACTERISTICS

ABSTRACT

I used the Kaplan-Meier (K-M) product limit estimator to calculate survival estimates of 33 radio-instrumented young raccoons (Procyon lotor) born to yearling and adult females in southwest Iowa in 1988 and 1989. Cox's proportional hazards model was used to examine the effect of macrohabitat characteristics of day-time den sites on mortality of young. Of 64 earmarked young, there were 9 observed mortalities. Four mortalities were caused by dogs; the remaining mortality causes included vehicle collisions, predation, and disease. Initial K-M survival estimates for young born to yearlings and adults were significantly different ($\underline{P}$ = 0.004), because of the effect of small sample size on survival estimates at the end of the study. However there was no significant difference between the 2 final rates prior to the end of the study ($\underline{P}$ = 0.504). To eliminate the need to adjust rates, age classes were pooled. The best estimate of survival of all young raccoons from 22 May to 15 September was 0.65. Proportional hazards techniques produced a model which included 2 covariates: 1) the number of different habitat types in which day-time den sites were located; 2) the number of different day-time den types used. Both covariates had a positive influence on survival.

INTRODUCTION

Understanding rates and patterns of survival in young mammals is a major gap in our ecological data base. Lidicker (1978) defined three modes by which populations can be negatively influenced, as: 1) increasing mortality 2) decreasing natality and 3) increasing emigration to immigration ratios. Mortality and thus survival can be important in regulating population size. In particular, Clark (1987), Clark et al. (1989), and Hasbrouck (1991), hypothesized that changes in survival may be a mechanism by which exploited species, such as raccoons (Procyon lotor), compensate for changing harvest.

There is considerable mortality and survival information for raccoons during and after their first harvest season (Stuewer 1943, Mech et al. 1968, Cowan 1973, Fritzell and Greenwood 1984, Clark et al. 1989, and Hasbrouck 1991). Annual mortality rates of these populations typically range from 0.50 to 0.60 (Cowan 1973), though Hasbrouck (1991) reported annual mortality rates, during years of high exploitation, of 0.73 for birth-year and 0.62 for after birth-year raccoons. Few workers have investigated survival and mortality in younger individuals (Stuewer 1943, Sanderson 1950, Mech et al. 1968, Schnell 1969, Schneider et al. 1971). Of the studies which have included demographics of young

raccoons, most were simply observational or were based on very small samples.

Hasbrouck (1991) used proportional hazards techniques (Cox 1972) to investigate the effect of ecological and physiological variables, such as furharvest level, sex, age, habitat where marked, and physical condition, on the survival of harvest-age raccoons. Glueck et al. (1988) related the importance of woody habitat and buildings to raccoons, whereas Kaufmann (1982) suggested the success of litters may be related to specific characteristics of the den and the associated habitat. Information concerning the relationship between ecological factors and survival will be valuable to wildlife habitat managers interested in changing raccoon population densities.

Exploitation may alter the age composition of breeding-age populations. Hasbrouck (1991) found greater harvest mortality among juveniles than among older-aged raccoons during years of high exploitation. Manipulation of the harvest may play an important role in individual age-class survival and thus population growth. Fritzell et al. (1985) and Glueck (1985) showed that yearling raccoons have more variable and somewhat lower reproductive potential than adults. The differential survival and reproductive potential of these 2 age classes may result in population densities remaining unaffected, even during periods of high

exploitation. There is significant importance in understanding the potential of these age classes and how they contribute to the breeding biology of the species.

The objectives of my research were: 1) to determine survival rates and causes of mortality of raccoon young between 1 and 5 months old; and 2) to investigate relationships of female age and den-site selection to survival rates of young raccoons.

This study extends that of Clark et al. (1989) and Hasbrouck (1991). Hasbrouck investigated the effect of an experimentally-induced increased harvest on rates and patterns of survival of raccoons of age >5 mo. My study was conducted concurrently during the period of increased harvest.

METHODS

Study Area

The study area is a 42 km^2 tract located in Guthrie County in southwest Iowa (T79N,R31W). The area is bisected from northwest to southeast by the South Raccoon River. Land use consists primarily of corn and soybean fields, grazed pastures, and livestock forage crops. Timber comprises approximately 10% of the area and is generally confined to drainage systems, shelterbelts, and steep hills (Glueck 1985, Judson 1990).

Field Sampling

I live-trapped or removed from dens female raccoons, prior to parturition of young, from mid-March through April in 1988 and 1989. Two methods were employed for their capture: 1) live-traps; and 2) removal from den trees. Trapped raccoons were immobilized with a hand-held intramuscular injection of ketamine hydrochloride (Bigler and Hoff 1974) to facilitate handling. Those taken from dens were immobilized with ketamine hydrochloride using a jab-stick and then noosed from the den.

Females' abdomens were palpated to determine breeding

condition. Females were weighed and measured, age estimated from tooth wear (Grau et al. 1970), an incisor removed to determine exact age, and both ears tagged with plastic numbered tags. Tags were marked with a number and "Iowa DNR" (Iowa Department of Natural Resources). Pregnant females were fitted with radio transmitter collars (Advanced Telemetry System Inc., Bethel, MN).

I assigned all females to age classes, based on cementum annuli counts (Grau et al. 1970), from teeth removed at capture. Reproductive rates of yearling and >2 yr old female raccoons in this population have been shown to be significantly different (Clark et al. 1989). For this reason I grouped females into yearlings (1 yr old) and adults ($\geq$2 yrs old). Individuals born during the spring of each year will be referred to as young-of-the-year, or simply young.

I located dens of female raccoons using radio telemetry. Females have an affinity to the birthing den for several days prior to giving birth (Kaufmann 1982). Thus, when an individual did not change her denning location for 3 successive days I assumed that she had given birth. The location of all dens after that time were recorded.

By 4-5 weeks of age, most young raccoons had attained a sufficient body weight (approx. 700 g), which I judged to be adequate to carry the 35-g radio-collars. Approximately 5 weeks after parturition, these breeding females were

relocated. Those females with young 5+ weeks old were removed from the den. I first immobilized females with ketamine hydrochloride, and then the female and young were noosed from the den. Weights and measurements of the young were taken and they were aged by tooth eruption and replacement (Montgomery 1964). All young had both ears tagged with numbered tags.
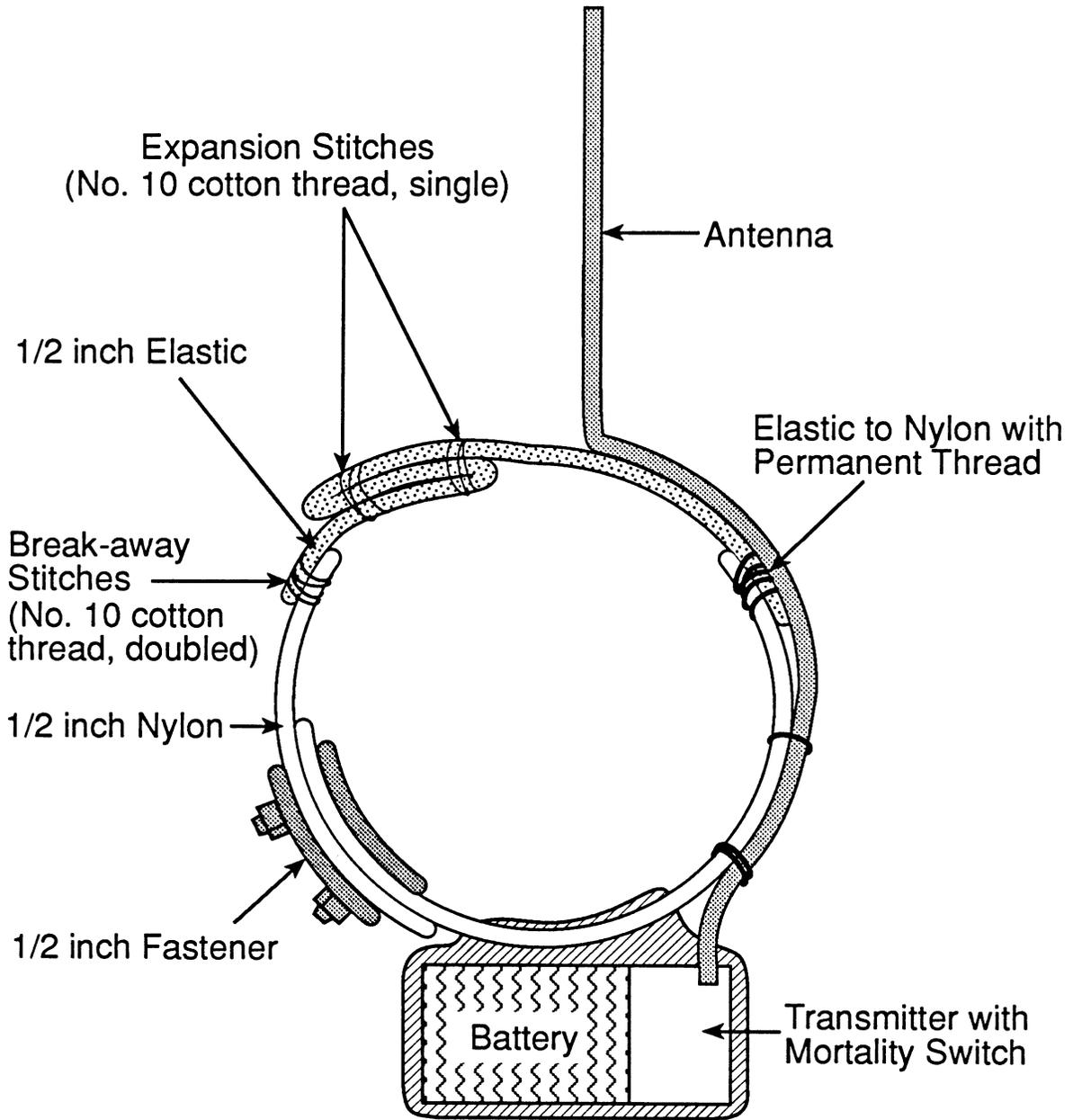
In 1988 I collared 1 young from each litter with a small expandable radio collar (Advanced Telemetry Systems, Inc., Bethel, MN) (Fig. 4). In 1989 sample size was increased to 2 young per litter when possible. If the original instrumented individual slipped its collar, I attempted to return a collar to that individual. If that individual could not be recaptured but another from the same litter could be, then a collar was placed on that other individual.

Collars were designed to expand in 2 ways. Thirty percent of the length of the collar was elastic material with the remainder made of a non-expandable nylon strap. An overlapping fold in the elastic material was sewn with 4 single stitches of number 10 cotton thread so that rotting of the thread allowed the fold to open. All expandable collars also had a break-away joint to insure the collar would fall off the animal after approximately 3 months. The 4 break-away stitches were made of the same thread as used in the expansion, but were doubled. The objective of the expansion was to insure room for growth, while the break-away

allowed the collars to be dropped near the end of the field season.

FIGURE 4. Expandable radio-collar used on young raccoons fr
1-5 months of age

Expansion Stitches
(No. 10 cotton thread, single)

Antenna

1/2 inch Elastic

Elastic to Nylon with
Permanent Thread

Break-away
Stitches
(No. 10 cotton
thread, doubled)

1/2 inch Nylon →

1/2 inch Fastener

Battery

Transmitter with
Mortality Switch

Survival

<u>Recoveries</u>   All transmitters were equipped with a
motion-sensitive switch that was activated when the
transmitter was motionless for 4 hours. This enabled
detection and examination of dead raccoons (Voight and Lotimer
1981).

All instrumented animals were relocated every 3 days from
ground vehicles to detect long movements or mortalities. If
an animal was not located after 2 such monitorings, I located
it from the air. Date, cause of death, and location were
recorded for all animals found dead. The dead animal, as well
as its surroundings, were examined to determine cause of
death. When cause of death was not apparent, the animal was
necropsied at the School of Veterinary Medicine at Iowa State
University. A reward of $10.00/eartagged and
$15.00/instrumented raccoon was also offered to encourage
return of tags and radio transmitters and to gain information
concerning the animal's fate.

Young from litters were marked beginning in mid-June
until the end of July of each year. Monitoring of young began
with instrumenting the first individual and continued until 15
September for both years. Since monitoring did not always
occur daily, I assumed the date of death or radio failure to
be the midpoint between monitorings. Only those individuals

which were collared were included in the survival estimate procedures.

Denning Habitat

I monitored den sites of females with litters from birth to age 5 months of the young. I randomly selected 2 collared females each day and located them using telemetry. Multiple den sites were recorded for each litter throughout each field season. Because females were randomly selected, their individual dens were assumed to be independent of one another.

At each den site, I measured micro- and macro-habitat variables. Macro-habitat variables included distance of the den to inhabited buildings, roads, water, edge habitat, and crop fields and were measured to the nearest 10 m. I used a meter tape to measure objects that were in line-of-sight. When they were not, distances were measured from an aerial photograph and were of comparable accuracy. Other macro-habitat variables recorded at each site were den type (building, ground hole, brushpile, machinery, row crop, surface vegetation, tree cavity, or open tree limbs) and habitat type (upland, lowland, edge, fencerow, or farmstead, Glueck 1985).

Micro-habitat variables included den height, den structure height (nearest 1 m), den cavity depth (nearest 10

cm), den opening dimensions, diameter at breast height (DBH, nearest 1 cm) and species (if the den was in a tree). Den height and den structure height were measured with an optical clinometer. For tree dens in wooded areas, the basal area of adjacent trees was measured with a 10 factor optical prism and divided into 3 categories; the number of trees <10 cm, 10-30 cm, and >30 cm. To prevent desertion of the den, all dens were marked and I returned after the litter had moved, to measure cavity depth and den opening dimensions.

Statistical Analysis

Survival   Survival rates and patterns of mortality were estimated using Kaplan-Meier (K-M) product limit procedures (Kaplan and Meier 1958). I modified a SAS (SAS Inst. 1985) computer code, originally written by White and Garrott (1989:236-239), which allowed staggered entry of captures (left truncation) and censoring of individuals. Censoring is defined as radio failure, dispersal, or living to 15 September of each year.

Logrank tests (Cox and Oakes 1984) were used to detect differences in survivorship functions between age classes and years. Pollock et al. (1989b) found logrank tests to be efficient when the survival curves have similar shapes, but may not be effective when two survival curves cross. Two-

tailed Z-tests were used to detect differences in survival
rates between groups at a given time (Pollock et al. 1989a).
Due to censoring, sample size was small near 15 September.
When near the end of the study a mortality occurred with only
1 animal at risk, causing $\hat{\underline{S}}$ to go to 0.00, an adjusted final
survival rate (Lawless 1982:88)

$$[\hat{\underline{S}}(t_j) + \hat{\underline{S}}(t_j + 0)] / 2$$

was calculated. Probability was considered significant for
the $\underline{Z}$ and logrank tests at $\underline{P} \le 0.05$.

Proportional hazards   Cox's proportional hazards model
was used to relate mortality of young raccoons in litters to
the important covariates related to their day-time den sites.
This multiple regression technique, which is appropriate for
survival data with censoring, uses explanatory variables to
predict survival times (White and Garrott 1990).

The computer program P2L, in the BMDP statistical
software package (Hopkins 1985), was used to run Cox's model.
A maximum likelihood method is used in the model building
approach and a log likelihood value is given for each model
comparison. Covariates with positive coefficients increase
the baseline hazard (decrease survival) and those with
negative values decrease the hazard. The coefficient size
indicates its relative effect on survival (Sievert and Keith

1985).

Due to the constraints of P2L and my data set, all measured covariates were not utilized in the model building procedure. Program P2L deletes an individual animal when any individual covariate value is missing for that observation. With only 33 individuals for which survival information could be obtained, reduction of that value might seriously restrict the precision of the model building process. I chose to keep all animals in the data set and eliminate a variable when a value was missing for that variable. Only those variables which had no missing values, across all 33 individuals, were used in the proportional hazards analysis. This may not have seriously affected the analysis because there were also no significant differences in usage of the deleted variables by yearling and adult female raccoons (Judson 1990). Those variables which were not included were den height, den structure height, den cavity depth, den opening dimensions, tree species and DBH, and basal area of adjacent trees.

I included 10 covariates in the model building procedure: age class of female parent (ADAGE, yearling or adult), number of habitat types used (NUMHAB), number of den types used (NUMDEN), type of habitat used with highest frequency (TYPEHAB, upland, lowland, or farmstead), type of den used with highest frequency (TYPEDEN, tree, building, ground hole, row crop, surface vegetation, brushpile, and other), and the

mean distances of day-time dens to the nearest inhabited building (MBLDG), road (MROAD), water (MWATER), edge habitat (MEDGE), and crop field (MCROP). I used a forward stepwise approach to enter covariates into the model. Initially, I set entrance into and removal of covariates from the model to P < 0.25 and P > 0.30, respectively. This approach allows most covariates, which may potentially be good explanatory variables, to enter the model (K. J. Koehler, Iowa State Univ., pers. commun.). Those covariates which met the P < 0.25 and P > 0.30 entrance and removal criteria were then used in a second run with P2L at a P < 0.10 and P > 0.15 criteria, to help refine the model.

In an attempt to build the most parsimonious model, with the fewest covariates, I used likelihood ratio tests to compare models which adequately fit the data. The null hypothesis was that the pooled model with fewer covariates fit the data as well as the unpooled model. The model with fewer covariates was rejected compared to one with more covariates when $P(\chi^2)$ < 0.05.

Multicolinearity between covariates was determined by examining the estimated asymptotic correlation matrix. Those covariates with r > 0.45 show strong correlation (Sievert and Keith 1985) and therefore provide redundant information. A model with fewer covariates was produced by successively removing and returning to the model individual covariates,

until no strong correlations remained.

RESULTS

I tagged 64 young raccoons from litters of 23 females
during late spring and early summer of 1988 and 1989.
Instrumented young included 14 individuals from 12 litters in
1988 (5 from yearling, 8 from adult females and 1 unknown) and
20 from 11 litters in 1989 (4 from yearling and 16 from adult
females). In both years, the first individuals were
instrumented on 22 May. No more than 2 individuals from 1
litter were equipped with radio-transmitters at one time. In
1989, 4 individuals from 1 litter carried a transmitter during
a portion of the field season, though only 2 at the same time.
In all other cases, no more than 2 individuals per litter were
instrumented. Censoring occurred for 85% of all collared
animals; 22 due to radio-failure (1 failed, 21 were lost
before the end of the study) and 6 lived to the end of the
study (15 September).

Causes of mortality were considered independent for all
individuals, even when more than 1 individual was marked in a
litter. To test this assumption I calculated survival from a
group which contained only 1, randomly-selected, individual
per litter. Final survival rates were not significantly
different from the group which contained all individuals
(Z = -0.268, P = 0.394).

Causes of Mortality

Of all marked young, I observed only 9 mortalities, 5 in 1988 and 4 in 1989. Two known mortalities in 1988 were animals which were only ear-tagged; all other observed mortalities were radio-collared individuals. Mortality was caused by dogs, coyotes (Canis latrans), distemper, and vehicle collisions (Table 3). All mortalities occurred after litters moved from their natal den to a post-natal den site. There were no multiple mortalities within a litter on the same date and from the same cause. Age of young at death ranged from 64 to 156 days. One individual which was originally live-trapped alone was never relocated with its mother. Shortly after its capture it was killed by a dog, but because it was not relocated with its mother prior to death, I deleted it from the remaining analysis. I estimated survival of young from the remaining 33 instrumented individuals. Another individual died after 15 September and was considered censored for the survival estimation procedures.

Table 3. Causes and ages at death of young raccoons in
         Guthrie County, Iowa 1988-1989

| Cause of Death	n	Ages at Death (days)
Dog kills	4	64, 75, 77, 118
Vehicle Collision	2	102, 110
Coyote	1	109
Distemper	1	156
Unknown	1	128

Survival

Kaplan-Meier (K-M) survival distribution estimates for young born to yearling and adult females in 1988 suggest no significant differences in $\hat{\underline{S}}$ patterns between the age classes ($\chi^2 = 1.96$, df = 1, $\underline{P} = 0.16$) (Fig. 5). However, there was a difference in the final adjusted (Lawless 1982:84-88) survival of young born to yearlings ($\hat{\underline{S}} = 0.42$, SE = 0.15) and the survival of young born to adults ($\hat{\underline{S}} = 1.00$, SE = 0.00) in 1988 ($\underline{Z} = -7.668$, $\underline{P} < 0.001$).

In 1989, the final survival rate estimates were 0.67 (SE = 0.27) and 0.63 (SE = 0.18) for young born to yearling and adult females respectively, and the rates were not significantly different ($\underline{Z} = 0.113$, $\underline{P} = 0.545$) (Fig. 6). However a log rank test indicated the pattern of survival in 1989 was different between the age class groups ($\chi^2 = 10.84$, df = 1, $\underline{P} < 0.001$).

Because precision of K-M estimates is low with small sample size (Pollock et al. 1989a), I pooled years in an attempt to obtain the best survival estimates (Fig. 7). When survival estimates were calculated after pooling years, there were no significant differences detected in survival patterns, despite crossing survival functions ($\chi^2 = 0.85$, df = 1, $\underline{P} = 0.355$). But crossing survival functions may have reduced the efficiency of this test (Pollock 1989b). A final, adjusted

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FIGURE 5. Kaplan-Meier estimates of survival of young raccoons born to yearling and adult females in Guthrie County, Iowa in 1988. L indicates the observation date prior to the date of the last individual's death
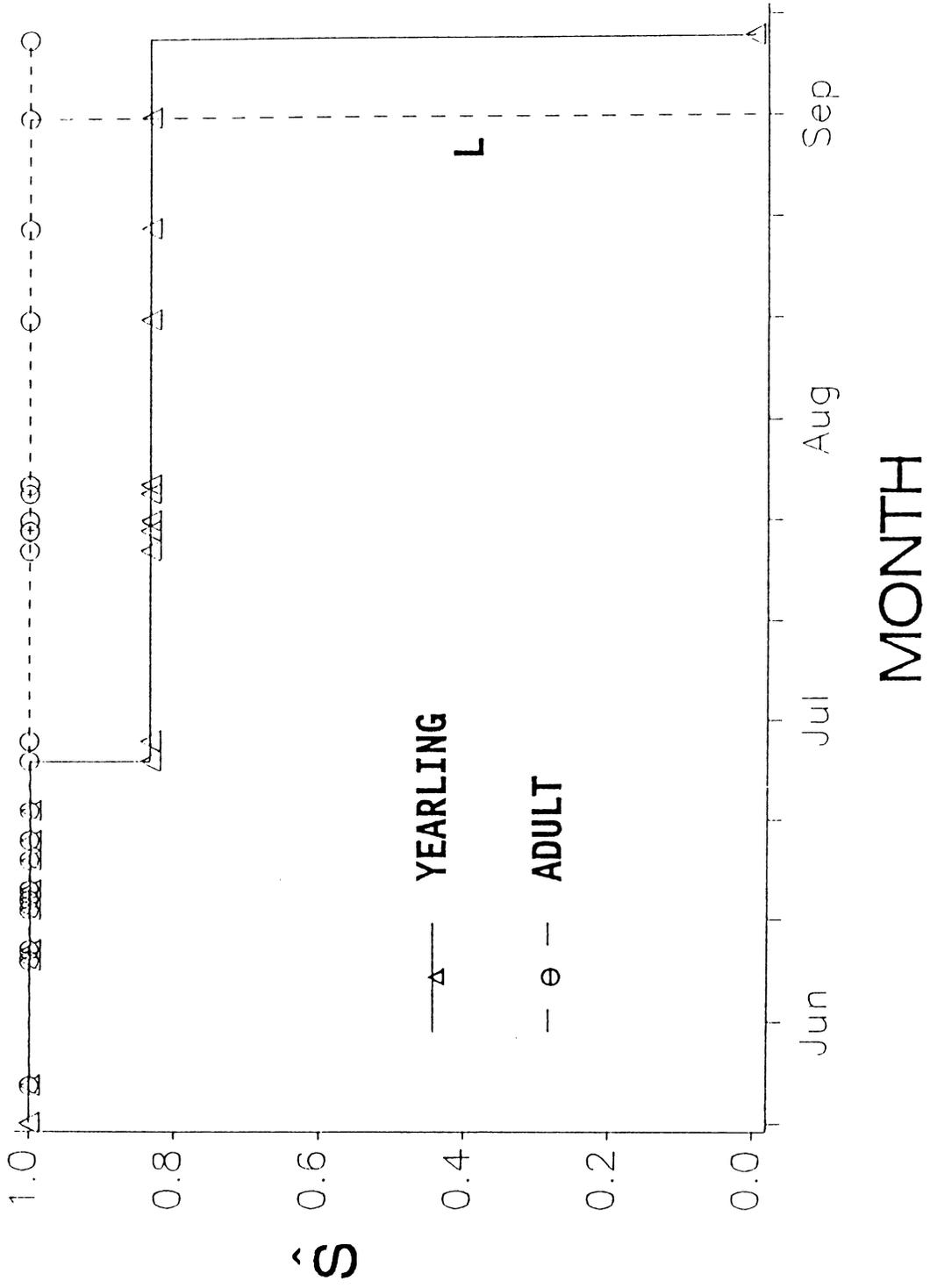
FIGURE 6. Kaplan-Meier estimates of survival of young raccoons born to yearling and adult females in Guthrie County, Iowa in 1989

Legend:
YEARLING —△—
ADULT —⊖—

S'

MONTH

Jun   Jul   Aug   Sep
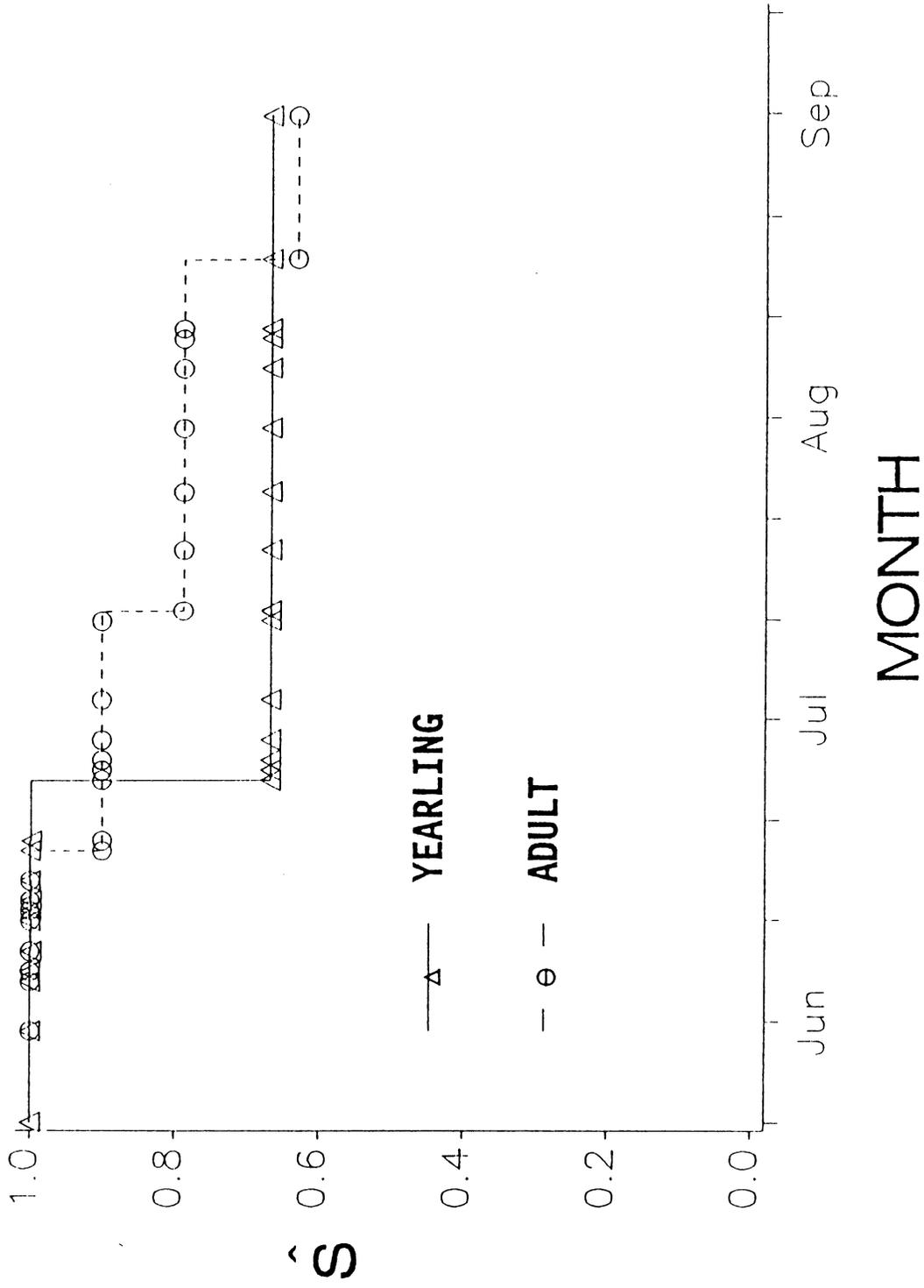
yearling survival rate ($\hat{\underline{S}}$ = 0.39, SE = 0.14) was significantly different ($\underline{Z}$ = 2.667, $\underline{P}$ = 0.004) than the adult rate, ($\hat{\underline{S}}$ = 0.76, SE = 0.12).

Prior to the final $\hat{\underline{S}}$ estimate, there was no significant difference between yearlings and adults in the 1988 ($\underline{Z}$ = 1.09, $\underline{P}$ = 0.863) (Fig. 5) at L, and pooled 1988-89 ($\underline{Z}$ = 0.009, $\underline{P}$ = 0.504) (Fig. 6) samples. Crossing survival functions in the 1988 and pooled 1988-89 samples also made it difficult to determine significance between yearling and adult survival patterns. For these reasons, and because pooling across age classes and years alleviated the need to calculate an adjusted final $\hat{\underline{S}}$ by increasing sample size, an overall $\hat{\underline{S}}$ for all young raccoons was calculated (Fig. 8). When all young raccoons born to yearling and adult females in both years were pooled, survival from 22 May until 15 September was 0.65 (SE = 0.12).

I estimated an annual survival rate for raccoons in their first year of life. I assumed the same daily survival for their first month of life as that which I calculated for the next 4 months. I combined this rate with the survival rate for juveniles (0.27) calculated by Hasbrouck (1991) for this population under a high harvest. Under this scenario annual survival of birth-year raccoons was estimated to be 0.20. Using Hasbrouck's survival rate under a normal harvest regime (0.46), I estimated the annual survival rate to be 0.32. Under normal harvest, but assuming the rate was as great as my

FIGURE 7.   Kaplan-Meier estimates of survival of young raccoons born to yearling and adult females in Guthrie County, Iowa in 1988-1989. L indicates the observation date prior to the date of the last individual's death
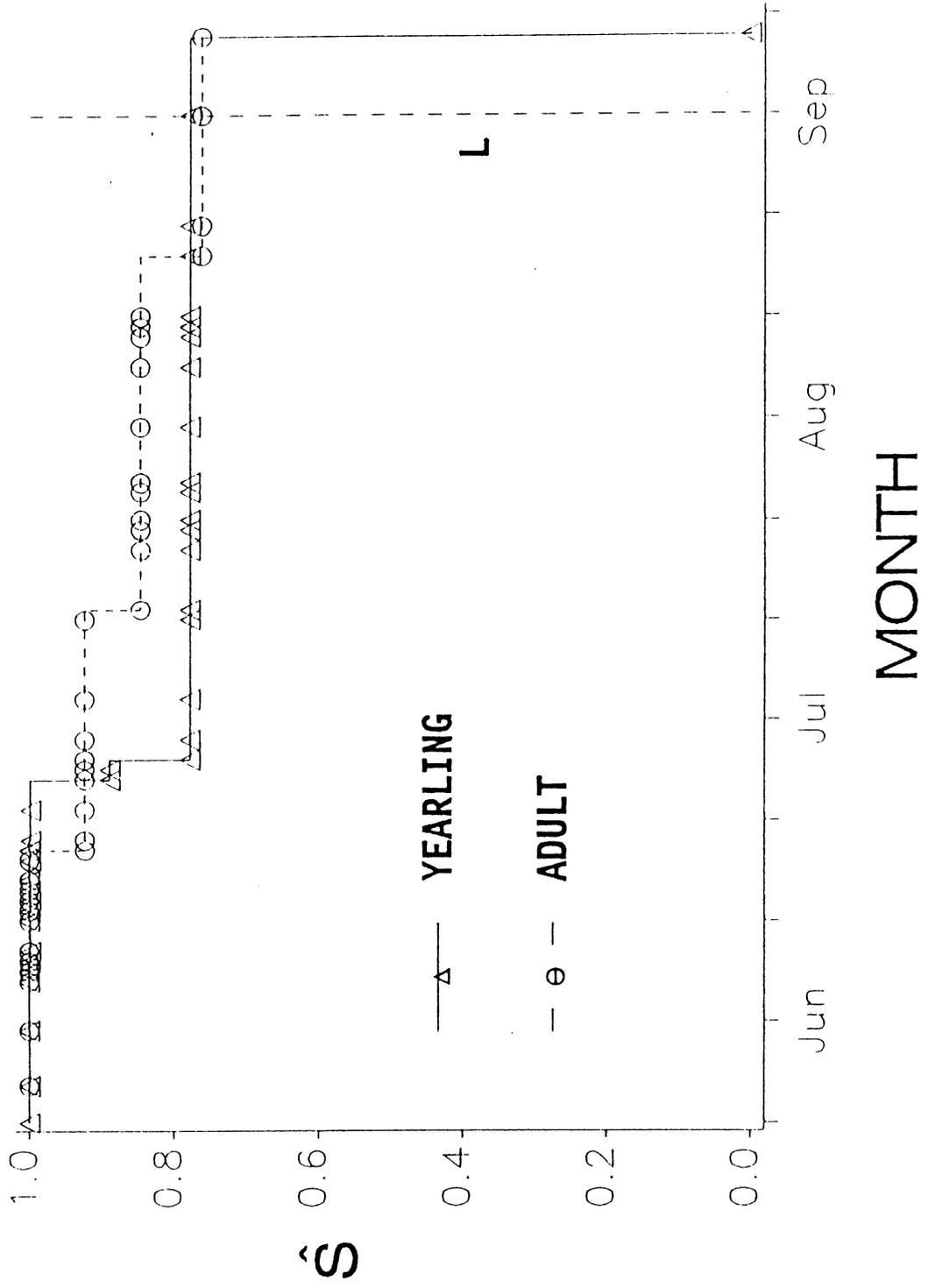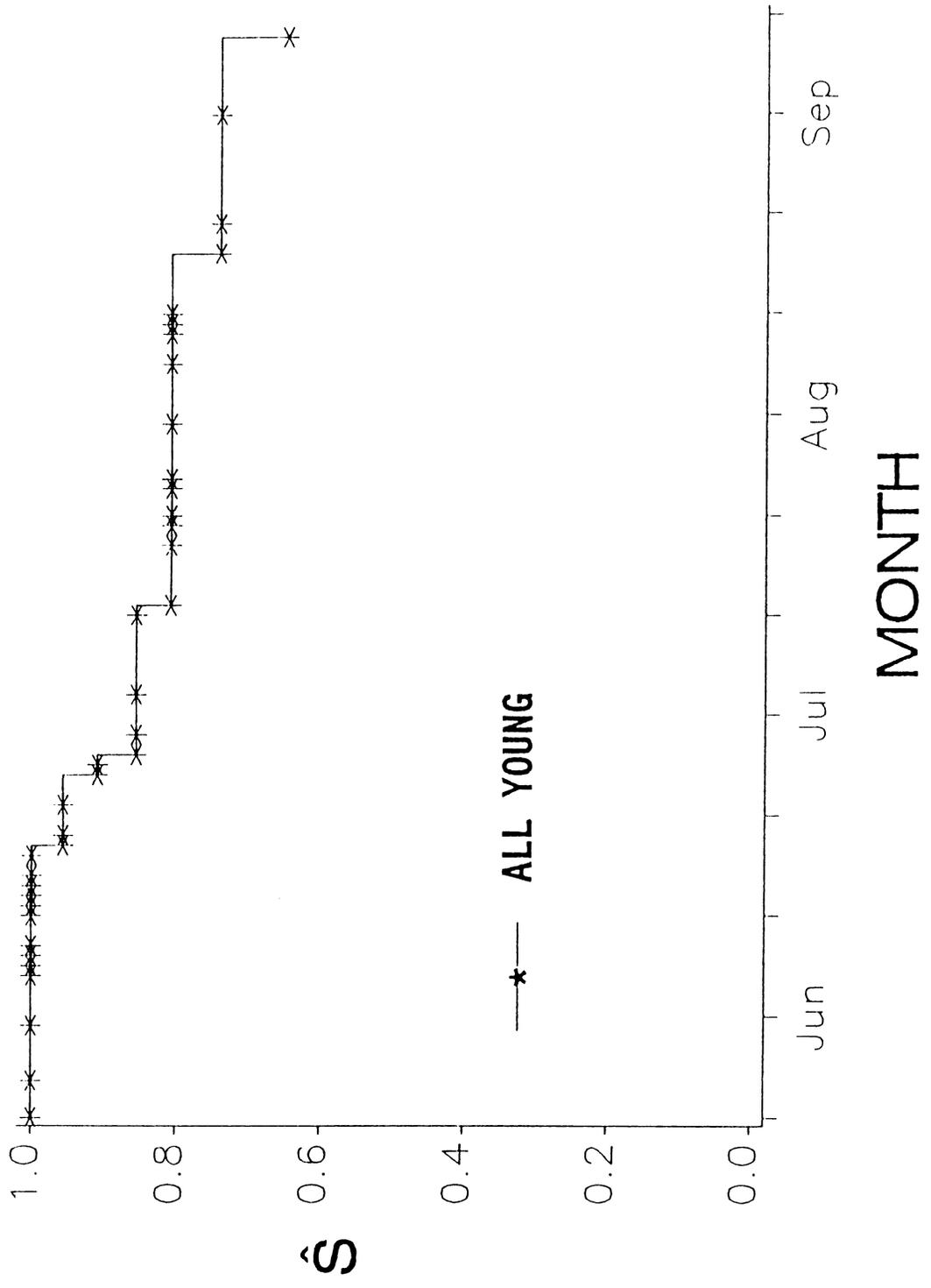
FIGURE 8. Kaplan-Meier estimates of survival of young raccoons in Guthrie County, Iowa 1988-1989

estimate of the upper confidence limit of 0.89, first year
survival could be as high as 0.47.

Proportional Hazards

In the first attempt to explain these survival patterns,
I allowed all ten covariates to enter the model. With
entrance and removal criteria of P < 0.25 and P > 0.30,
respectively, the following 5 covariates were entered: 1)
NUMHAB, 2) NUMDEN, 3) MBLDG, 4) MROAD, and 5) MCROP (Table 4).

The other five covariates failed to meet the entrance
criteria of P < 0.25: 1) ADAGE (P = 0.678), 2) TYPEHAB (P =
0.689), 3) TYPEDEN (P = 0.465), 4) MWATER (P = 0.763), 5)
MEDGE (P = 0.740).

The five covariates which met the original criteria were
re-run in the P2L program, with an entrance and removal
criteria of P < 0.10 and P > 0.15. A model was constructed
which included NUMHAB, NUMDEN, and MROAD. All covariates were
strongly correlated (r > 0.45).

To explore the covariance structure of the variables, I
constructed all possible two-covariate models from the 3
remaining covariates. In both of the two-covariate models
which included MROAD, this covariate failed to meet the
entrance criteria (P < 0.10) and was therefore dropped from
each of the models. The other two-covariate model, which

Table 4. Chi square (χ^2) and probability of a larger χ^2 for
entry of covariates into the Cox regression model
for survival of raccoon young in Guthrie County, Iowa
1988-1989

Covariates	χ^2	$\underline{P}$
Mean distance to occupied building (MBLDG)	3.71	0.054
Mean distance to road (MROAD)	2.24	0.135
Mean distance to crop (MCROP)	1.45	0.229
Number of habitat types used (NUMHAB)	7.78	0.005
Number of den types used (NUMDEN)	9.67	0.002

included NUMHAB and NUMDEN, met the selection criteria and a model was constructed. A low covariance ($\underline{r}$ = -0.036) existed between these 2 covariates in the constructed model.

To be sure that I had found the most parsimonious model, I developed individual models with only NUMHAB or NUMDEN as the independent variable. A likelihood ratio test between the two-covariate model and the NUMHAB model was significant (χ^2 = 5.02, df = 1, $\underline{P}$ = 0.025), indicating the two covariate (more parameters) model was better than the single covariate model. The test between the two-covariate model and the NUMDEN model was also significant (χ^2 = 3.13, df = 1, $\underline{P}$ = 0.077), again indicating the two-covariate model, with both NUMHAB and NUMDEN included, was a better model to predict mortality of young raccoons.

The negative coefficient values for NUMHAB ($\hat{\beta}$ = -1.7736, SE[$\hat{\beta}$] = 1.1478) and NUMDEN ($\hat{\beta}$ = -1.7020, SE[$\hat{\beta}$] = 0.9969) indicate both covariates have a negative influence on the hazard and therefore a positive influence on survival. As the number of den types and habitat types used by females and their young increased, so did the youngs' chance of survival.

DISCUSSION

There have been many causes of mortality of young raccoons reported, including disease, parasites, predators, and human-related factors (Kaufmann 1982). As I observed in my study, and as most other investigators have found, most mortality in young raccoons is related to human activities. Free-roaming dogs and collisions with vehicles cause much of the mortality in most years, though disease may play an important role in some years (Kaufmann 1982). Predation is no longer a major factor in most raccoon populations, since the reduction of many of North America's large predators (Cowan 1973).

Of the mortality I observed in the marked raccoon litters, there was none which occurred before the litters had shifted from their natal dens to post-natal ground-type dens. Mech et al. (1968) observed mortality of 2 whole litters in the natal den, but concluded both may have been experimenter induced. It appears as though mortality is uncommon in young raccoons until they reach the age when they become active and leave the natal den site.

An overall survival rate of 0.65 for young raccoons between 1 and 5 months old appears reasonable but it is difficult to compare to other findings. In the literature many of the survival estimates are undifferentiated by age, or

provide annual estimates for juveniles through their first
year, including harvest and post-harvest season mortality.
The methods used in many of the studies were incapable of
producing statistically reliable estimates. Stuewer (1943)
marked individual young in the den, then later recaptured or
visually observed individuals, and concluded that juvenile
mortality was low. While Woods (1978) "estimated" survival
(0.818) of pre-harvest age raccoons by subtracting the number
of juveniles harvested in the fall from the total projected
productivity of the population. Root (1981) calculated an
estimate of survival (0.20) for juvenile raccoons (< 1.5 yrs)
using lifetable analysis from harvest data.

Some of the problems I faced using K-M procedures might
have been alleviated, others could not. Small sample size, as
a result of capture difficulties, created 2 potential
problems. Even when all instrumented animals (33) were pooled
into one group, the minimum sample size of 40-50 tagged at all
times, necessary to obtain good precision (Pollock 1989a),
was not met. The low precision due to small samples resulted
in large confidence intervals associated with the estimates.
Small sample size also forced me to use an adjusted survival
rate (Lawless 1982) for 2 $\hat{\underline{S}}$ estimates which went to 0.00. In
any sample near the end of the trial, when the only
individuals left at risk die, an adjusted rate can be
calculated. However, I feel in this situation the adjustment

in $\hat{S}$ produced a negatively biased estimate, and may not reflect the ecological events in the population.

One might expect a lack of nurturing experience to cause lower survival of young born to a yearling parent versus an older-aged parent. This was a hypothesis I proposed, though small sample size may have precluded confirming the hypothesis. The drop in $\hat{S}$, due to the adjustment, for young from yearlings in the 1988 (from 0.83 to 0.42) and pooled 1988-89 (from 0.78 to 0.39) made it appear as though there were significant differences in final survival rates between young born to yearlings and adults. However there were no significant differences in survival of young of yearling and adult females, just prior to the end of the study.

There was no significant difference in the final $\hat{S}$ between age classes in 1989. I used this fact as further justification for pooling across age classes to calculate a final survival estimate for all individuals.

The logrank test is a simple test used to compare 2 survival curves and is easily applied with a staggered entry approach (Pollock et al. 1989a), but may not always be effective when survival curves cross (Pollock et al. 1989b). This occurred in the 1989 yearling versus adult and the pooled 1988-89 yearling versus adult estimates. Due to this problem, I was unable to determine if differences were significant between survival curves in the preceding 2 tests.

The effect of high censoring may have positively biased my estimates of survival. Kalbfleisch and Prentice (1980) found that censoring in excess of 50% inflates survival estimates. Censoring may have been reduced if a more reliable expandable radio-collar was used. The expansion system worked adequately, but the break-away system caused many collars to fall off prematurely.

Including all instrumented young in the survival estimates, even if there were multiple instrumented individuals per litter, may violate the assumption of independence of K-M. However there was no significant difference between the final $\hat{\underline{S}}$ of this group and a group which included only 1 randomly selected individual per litter. Causes of mortality also appeared more independent as the young became active. Kaufmann (1982) noted that weaning of young raccoons occurs close to the time they begin to actively follow the female outside the den. This activity corresponds to their change from their natal den sites to post-natal ground-type dens. I observed no mortality of young raccoons prior to this shift in den usage. Boutin et al. (1988) also showed that mortality factors affecting young muskrats from the same litter (<u>Ondatra</u> <u>zibethicus</u>) were independent after weaning.

There may certainly be causes of mortality which could be hypothesized to be dependent within the litter (e.g.,

disease). Even though this may occur, I observed no multiple mortalities within a litter from the same cause. The mortality I observed in young raccoons appeared more independent than dependent.

If the independence assumption had been violated, the estimate of survival would not be biased (i.e. would still be accurate). But, the violation would have reduced the variance of the estimates too much (Pollock et al. 1989a), thus increasing the probability of Type II errors.

Although estimates are less than ideal, because of sampling problems, I feel the 0.65 estimated survival rate from 1-5 months age closely resembles actual survival in the population. When I combined my estimates with Hasbrouck's (1990) high harvest survival (0.27) and normal harvest survival (0.46) rates, both scenarios produced low annual survival estimates for birth-year raccoons (0.20 and 0.32, respectively). With survival at either of these levels, it appears that replacement of females would not be occurring and population levels would decline. However Hasbrouck noted no difference in densities through years. If densities are to remain unchanged, the population must be compensating for these losses. Compensation may include immigration or increased survival within the population. Contrary to what Hasbrouck found, if densities were indeed being lowered, it would appear that the population would decline under either of

the preceding harvest regimes.

If I use my upper confidence limit of survival (0.89), instead of the mean survival estimate, and Hasbrouck's normal harvest survival rate, I calculated an annual survival rate estimate of (0.47). With an average of 3.7 young produced per female (Glueck 1985) and using the preceding rates, each female would have 1.7 young survive to spring, which approaches replacement. This suggests that under normal harvest levels the population may be replacing itself annually. Under a high harvest regime it appears as though the population may significantly decline, though compensatory survival may preclude this from occurring. Density dependent harvest (i.e. lower harvest rate with low raccoon densities), which occurs when population levels are low, may also be a factor which allows the population to recover.

In an attempt to uncover covariates which were related to young mortality and which could be manipulated or controlled by a manager, I measured micro- and macrohabitat variables associated with individual den sites. Several (mostly micro-habitat) variables were deleted from the analysis because they contained missing data points. Among the deleted variables were den height, den structure height, den cavity depth, den opening dimensions, basal area of adjacent trees, and tree species and DBH. Although there were no differences in these variables between yearling and adult female raccoons

(Judson 1990), they may still be potentially important to survival. From the ten variables which were used, the model which best fit the data included 2 covariates: 1) the number of different habitat types in which day-time den sites were located; and 2) the number of different day-time den types used. Both covariates had a positive influence on survival, indicating the relative importance of diverse denning habitat to young raccoons.

One might expect lower survival among young that moved their den locations more often versus more sedentary individuals. However, I found that young raccoons improve their chance of surviving by increasing the number of habitat types and den types they use. By utilizing a wide variety of dens in different habitat types, litters may reduce their chances of a predator locating their den. Another explanation may involve an increased availability of essential resources to those individuals which use a wide variety of habitats. Wildlife biologists should use diversity as a priority in purchase of lands to be managed for raccoons. Managers could also improve monotypic landscapes by creating edge habitat in wooded areas and building brushpiles with the removed trees.

White et al. (1987) and Carroll (1990) used proportional hazards to relate body condition of mule deer (Odocoileus hemionus) fawns and gray partridge (Perdix perdix), respectively, to their over-winter survival. Other studies

have attempted to specifically relate habitat variables to mortality using proportional hazard techniques. Sievert and Keith (1985) found lower survival of snowshoe hares (_Lepus americanus_) in areas with poor understory cover, but Hasbrouck (1991) failed to relate habitat to mortality of harvest-age raccoons. Despite mixed success, using habitat variables to predict mortality could become a significant tool for relating habitat to population changes.

My proportional hazard results and survival estimates may have been influenced by the experimentally-induced high exploitation (Hasbrouck 1991) which ran concurrent with my study. There is currently little information of this type available for the early life stages of raccoons. My results help fill a major gap in our knowledge of exploited raccoon populations and provide useful information for their management.

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SUMMARY

I removed 64 young raccoons from their dens and ear-marked them during the spring and summer of 1988 and 1989. I attached expandable radio-collars to 33 of those individuals. Litters were later relocated at their other day-time den sites. There were significant differences in use of den types and habitat types between litters born to yearlings and adults. There were also significant differences between the age classes in the mean distances of their dens to the nearest occupied building, road, water, edge habitat, crop field, and their last den location.

Survival rates for young born to yearling mothers were different from young born to adult females. The difference may have been spurious, due to the effect of a small sample size of young at the end of the study of individuals born to yearling females.

Proportional hazard techniques revealed that the number of different den and habitat types used by the litter have a positive influence on survival of young raccoons.

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