BOBCAT PREDATION ON QUAIL, BIRDS, AND MESOMAMMALS

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ABSTRACT

We reviewed 54 scientific articles about bobcat (*Lynx rufus*) food habits to determine the occurrence of quail, birds, and mesopredators including red (*Vulpes vulpes*) and gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), skunk (*Mephitis* spp.), and opossum (*Didelphis virginianus*). Quail (*Colinus virginianus, Cyrtonyx montezumae, Callipepla squamata, C. gambelii, C. californica, Oreortyx pictus*) were found in 9 diet studies and constituted >3% of the bobcat diet in only 2 of 54 studies. Birds occurred in 47 studies, but were also a minor dietary component in most studies. Although mesopredators were represented as bobcat prey in 33 of 47 studies, their percent occurrence within bobcat diets was low and showed regional patterns of occurrence. Bobcats are a minor quail predator, but felid effects on mesopredators and secondary impacts on quail need to be studied.

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Key words: bobcat, California quail, *Callipepla californica, C. gambelii, C. squamata, Colinus virginianus, Cyrtonyx montezumae,* depredation, diet, food habits, Gamble's quail, *Lynx rufus,* mesomammal, mesopredator, Montezuma quail, mountain quail, northern bobwhite, *Oreortyx pictus,* scaled quail

INTRODUCTION

The role of bobcat depredation on quail is often debated by hunters, wildlife managers, and state agency personnel. Although researchers have studied predators of specific quail populations, a particular quail species was often the research focus while a variety of predators were monitored (Burger et al. 1995, Taylor et al. 2000). Food habit studies focusing on particular predators have often been overlooked by quail researchers and managers. One reason is this information is spread among a variety of literature sources and under titles exclusive of quail. Consequently, quail managers, biologists, and researchers are unaware of these sources that focus on bobcat diets.

Our paper extensively reviews literature about the food habits and foraging ecology of bobcats in North America to determine the relative importance of quail in bobcat diets. The presence of birds in bobcat diets was recorded because some studies failed to identify avian species. Also, the relative use of avian prey relative to mammalian prey is important to understanding bobcat diets and potential for depredation of quail.

Bobcats and other predators (i.e., skunks, raccoons, opossums, and red and gray foxes) in each locale form predator complexes that can have unpredictable and difficult to assess impacts on quail and other bird populations. Bobcats are predators on other mesopredators within their communities, and the reduction of bobcat populations with predator control or fur harvest may have an indirect effect on the population sizes and distributions of potentially more serious quail predators. Consequently, we gathered information on the presence of known mesopredators in the diets of bobcats.

METHODS

We reviewed studies examining bobcat food habits in various locations over North America. Most of the studies were conducted in the United States, although a few occurred in Canada or Mexico.

Sources for 'data mining' and information collection of bobcat food habits included journal articles, conference proceedings, books, theses, and dissertations. A Microsoft Excel spreadsheet was developed to organize selected dietary information, including the presence of quail, birds, and mesopredators.

Additional information gathered from each source included study location, dominant habitat or plant community, and method used. Method was recorded as analysis of 1) scats, 2) gastrointestinal tracts (stomach, intestine, and colon), 3) caches or carcasses, and 4) visual observation of depredation events. Sometimes multiple methods (e.g., scat and stomach anal-

Table 1. Selected prey items reported in bobcat diet studies from North American between 1939–2000. Results are reported as maximum percent occurrence for each prey type unless otherwise noted.

Reference	State	Method	N	Quail distr.[1]	Quail	Grouse	Other birds	Opossum	Raccoon	Porcupine	Skunk spp.	Red fox	Gray fox	Comments
NORTHEAST														
Fox & Fox 1982	WV	Stomach	172	P[2]	—	3.5	5.9	5.2	1.2	—	—	0.6	—	
Litvaitis, Clark & Hunt 1986	ME	Intestines	170	A[3]	—	—	33.3	—	—	15.4	—	—	—	
Manville 1958	MI	Stomach & intestines	8	A	—	—	—	—	—	P	—	—	—	
Litvaitis, Stevens, & Mautz 1984	NH	Intestines	388	I[4]	—	—	P	—	—	P	—	—	—	
Mills 1984	CAN	Scat	47	A	—	—	8.5	—	—	—	—	—	—	Nova Scotia, Canada
		Stomach	70	A	—	1.4	4.3	—	—	2.9	1.4	—	—	
Parker & Smith 1983	CAN	Stomach	377	A	—	7.0	7.0	—	—	—	—	—	—	Cape Breton Isl., N.S.
Livaitis, Major, & Sherburne 1986	ME	Scat	308	A	—	—	13.3	—	—	2.8	—	—	—	
Pollack 1951	N. Eng.	Stomach & intestines	208	I	—	1.4	3.4	—	—	18.3	—	—	—	
		Scat	250	I	—	2.0	1.6	—	—	6.8	—	—	—	
Rollings 1945	MN	Stomach	50	A	—	1.0	1.0	—	—	10.0	1.0	—	—	Frequency of occurrence
Westfall 1956	ME	Instestines	88	A	—	6.8	6.8	—	—	11.4	2.3	—	—	
Hamilton & Hunter 1939	VT	Stomach	140	A	—	5.5	1.0	—	—	7.1	4.4	0.8	0.7	Percentage by bulk
McCord 1974	MA	Scat	43	P	—	—	<5.0	—	Tr[5]	—	—	—	—	
Major & Sherburne 1987	ME	Scat	109	A	—	—	15.0	—	—	—	—	—	—	
Dibello et al. 1990	ME	Scat	452	A	—	—	8.5	—	P	P	—	—	—	
Litvaitis & Harrison 1989	ME	Scat	346	A	—	—	9.7	—	—	P	—	—	—	
Litvaitis et al. 1984	NH	Intestines	388	I	—	—	P	—	—	P	—	—	—	
Litvaitis, Sherburne, & Bissonette 1986	ME	Scat	452	A	—	—	13.3	—	—	2.8	—	—	—	
Berg 1979	MN	Stomach	73	A	—	—	P	—	—	12.0	—	—	—	Percent frequency
SOUTHEAST														
Kitchings & Story 1979	TN	Scat	31	P	—	—	14.0	5.0	—	—	5.0	—	—	Percent frequency occurrence
Miller & Speake 1978	AL	Stomach	136	P	—	—	11.1	5.9	0.7	—	—	—	—	
		Intestines	137	P	—	—	8.0	5.1	—	—	—	—	—	
		Scat	218	P	0.9	—	13.8	5.5	—	—	—	—	—	
Story et al. 1982	TN	Scat	176	P	—	—	13.1	20.0	9.0	—	10.0	—	—	Percent frequency of occurrence
Progulske 1955	VA	Scat	124	P	—	—	16.9	3.8	—	—	—	—	—	
	Appalach	Scat, stomach & intestines	233	P	—	—	6.9	6.5	2.1	—	1.3	—	0.9	
Kight 1962	SC	Scat	317	P	2.6	—	11.0	0.8	0.4	—	—	—	—	Frequency occurrence
Buttrey 1979	TN	Stomach, intestines & scat	48	P	—	—	12.2	—	—	—	—	—	—	
Maehr & Brady 1986	FL	Stomach	413	P	6.0	—	55.0	7.0	4.0	—	—	—	—	Frequency
Wassmer et al. 1988	FL	Scat	146	P	1.4	—	17.2	3.4	1.4	—	—	—	—	
CENTRAL PLAINS														
Beasom & Moore 1977	TX	Stomach	125	P	6.0	—	32.0	—	—	—	—	—	—	
Fritts & Sealander 1978	AR	Stomach	150	P	1.0	—	7.0	9.0	5.0	—	4.0	1.0	—	
Leopold & Krausman 1986	TX	Scat	344	P	—	—	P	—	—	—	—	—	—	
Blankenship 2000	TX	Scat	653	P	0.2	—	32.8	—	0.3	—	—	—	—	
Litvaitis 1981	OK	Scat	40	P	—	—	27.5	—	—	—	—	—	—	Grouped birds and eggs
Mahan 1980	NE	Stomach	57	P	1.8	—	8.8	—	—	1.8	—	—	—	
Rolley 1985	OK	Stomach	549	P	—	—	13.0	P	—	—	—	—	P	Percentage of total prey
Rolley & Warde 1985	OK	Stomach	145	P	—	—	11.0	P	—	—	—	—	P	
Lehmann 1984	TX	Stomach	—	P	—	—	Tr	—	—	—	—	—	—	
Trevor et al. 1989	ND	Stomach	74	A	—	—	6.9	—	—	1.4	1.4	—	—	

Table 1. continued.

Reference	State	Method	N	Quail distr.[1]	Quail	Grouse	Other birds	Opos-sum	Rac-coon	Porcu-pine	Skunk spp.	Red fox	Gray fox	Comments
SOUTHWEST														
Anderson 1987	CO	Visual obs.	—	I	—	—	C	—	—	—	—	—	—	Snow cache
Gashwiler et al. 1960	UT & NV	Stomach	53	I	—	—	5.7	—	—	3.8	—	—	—	
		Scat & intestines	81	I	—	—	2.5	—	—	—	—	—	—	
Jones & Smith 1979	AZ	Scat	176	I	—	—	12.0	—	—	—	2.0	—	—	
Delibes & Hiraldo 1987	Mexico	Scat	540	P	—	—	1.9	—	—	—	0.2	—	—	
NORTHWEST														
Bailey 1972	ID	Scat	55	I	—	P	~22.0	—	—	—	—	—	—	Primarily sage grouse
Bailey 1979	ID	Stomach	233	I	—	6.0	25.0	—	—	—	—	—	—	Percent frequency occurence
Brittell et al. 1979	WA	Stomach	76	I	—	—	5.2	—	—	—	—	—	—	Percent frequency
Knick et al. 1984	W	Stomach	324	I	—	Tr	6.0	—	—	—	—	—	—	
Koehler & Hornocker 1989	ID	Scat	160	I	—	—	12.0	—	—	—	—	—	—	Percent frequency
Nussbaum & Maser 1975	OR Coast Range	Scat	143	P	—	0.7	13.3	—	—	—	—	—	—	
	OR Cascade Range	Scat	34	P	—	2.9	2.9	—	—	—	—	—	—	
Toweill 1982	OR	Stomach & intestines	98	P	1.0	—	12.0	—	—	6.0	—	—	—	

[1] Quail Distr.—Distribution of quail species (*Colinus virginianus, Cyrtonyx montezumae, Callipepla squamata, C. gambelii, C. californica, Oreortyx pictus*) based on Brennan 1999 for *C. virginianus* and National Geographic Society (1987) for other species.
[2] P—Indicates presence.
[3] A—Indicates quail are absent from the study area.
[4] I—Indicates sporadic/inconsistent quail distribution within state or study area.
[5] Tr—Indicates item found in trace quantities.

ysis) were used within the same study. We determined sample sizes for each study and each method of analysis.

Percent occurrence within bobcat diets was determined for most studies for quail, birds, and mesopredators. We noted the absence of quail distribution with those study sites where bobcat food habit studies occurred.

RESULTS

We examined 54 scientific sources for information on bobcat food habits. This survey included 38 journal articles, 10 symposia proceedings, 3 dissertations, 1 thesis, 1 book chapter, and 1 technical report. Only articles which yielded results from individual studies were used. Previous literature summaries often failed to provide the specific information that we required, and they were not used in the data summaries.

Lagomorphs and rodents were dominant constituents of bobcat diets. Forty-seven studies found either quail, birds, or mesopredators in bobcat diets (Table 1), whereas 7 studies found none of these elements. Dietary studies lacking quail, birds, and mesopredators included Marston (1942), Dill (1947), Cook (1971), Beale and Smith (1973), Litvaitis et al. (1982), Litvaitis et al. (1986b), and Koehler and Hornocker (1991).

The following methods were used in the 47 studies: 18 used scats alone, 22 used both stomachs and intestinal analyses, 6 used stomachs and scats, and 1 used observations of caches, carcasses and predation events.

Of the 35 bobcat diet studies that occurred within known or presumed quail distributions, 9 (25.7%) studies identified quail remains. Four of these studies were conducted in the southeast, 4 in the central plains, and 1 in the northwest. Percent occurrence of quail in the bobcat diets of these studies was consistently low (Table 1).

Birds were identified in 46 (85.2%) of the studies (Table 1) and percent occurrence of this group was usually <10%. Grouse were found in 11 (20.4%) of 47 studies.

Percent occurrence of medium-sized mammalian predators was usually <20% in bobcat diets (Table 1). Opossums occurred in 7 of 8 studies from the southeast and 3 of 10 studies from the central plains (Table 1). Opossums were absent from bobcat diets in the southwest, northwest, and only occurred in 1 of 18 studies from the northeast. Raccoons occurred in 11 of 47 studies, with 6 of these from the southeast. Porcupines (*Erethizon dorsatum*) were most commonly found in bobcat diets from the northeast (14 of 18 studies). Eleven of the 47 studies identified skunk (*Mephitis* spp.) remains.

DISCUSSION

Numerous studies have summarized the prey consumed by bobcats through most of their range (Mc-

Cord and Cardoza 1982, Anderson 1987, Rolley 1987, Lariviere and Walton 1997). The dominance of lagomorphs and rodents in their diets has been previously demonstrated (McCord and Cardoza 1982, Anderson 1987, Rolley 1987, Lariviere and Walton 1997), and observed again during this literature survey. However, the primary purpose of this effort was to evaluate the occurrence of less common elements in bobcat diets. Although each method (e.g., scat versus stomach analysis) has problems and biases, we were able to identify emerging patterns regarding quail, birds, and mesopredators.

Quail occurred in >3% of bobcat scat and gastrointestinal samples in only 2 of 54 studies. Beasom and Moore (1977) found 6% occurrence of northern bobwhite in bobcat stomachs during 1971 and 4% occurrence in 1972. Maehr and Brady (1986) found 6% frequency of occurrence of northern bobwhite in bobcat stomachs analyzed. Thus, quail were generally absent from bobcat diets or represented a low percentage when present. Comparing quail distribution with location of the bobcat diet studies was useful in developing a better assessment of quail presence in bobcat food habits. Bobcat diet studies occurring outside the presumed quail distribution would not detect quail as a diet component.

Birds as a group were found in 87% of the bobcat diets, but the avian component was always considerably less than the lagomorph or rodent components. The literature survey by Lariviere and Walton (1997) concluded that Galliformes were the most important taxa of birds consumed by bobcats, but Passeriformes, Strigiformes, Gruiformes, Accipetridae, and Anatidae were also consumed (Fritts and Sealander 1978, Maehr and Brady 1986, Anderson 1987). The appearance of grouse in bobcat diets was noted for studies from the northeast and northwest. Bird egg remains were sometimes found in bobcat scats but generally not identified to species (Jones and Smith 1979).

Bobcats are primarily nocturnal predators with crepuscular, bimodal peaks of activity (Buie et al. 1979, Miller and Speake 1979) and reduced midday activity (Buie et al. 1979, Witmer and DeCalesta 1986). In contrast, quail and most bird species are active during diurnal periods. This incongruence in activity periods is probably a major explanation for the infrequency of birds, particularly quail, in bobcat diets. Because bobcats rely primarily on visual and auditory senses for hunting and less on olfactory senses, the likelihood of bobcat-quail encounters are reduced at night.

The occurrence of mesopredators in bobcat diets was also low. However, opossums, raccoons, foxes, and skunks were occasionally encountered. The population densities of mesopredators are usually lower than those of lagomorphs and rodents, and the removal of a few individual predators by bobcats may have relatively greater impacts on the density of mesopredators than smaller mammals.

The interactions of multiple, sympatric predators on one another and their prey form a complex system which has the potential to affect quail as well as other prey. For example, striped skunks (*Mephitis mephitis*), opossums, and raccoons can be important predators of adult quail and quail eggs (Brennan 1999, Fies and Puckett 2000). These predators are themselves prey for bobcats, coyotes, and mountain lions whose actions may effect the impact on quail and other small prey. Such a complex system is difficult to study and often requires long time periods and considerable resources to obtain reliable data (Blankenship 2000). Although bobcat depredation on quail is a direct trophic link, bobcat predation on mesopredators may have subtle and indirect consequences for quail populations.

The relative role of mammalian and avian predators on quail varies depending on the location of the study, characteristics of predator communities, and habitat attributes (Burger et al. 1995, Taylor et al. 2000). Our understanding of the complex interplay of predator communities upon their prey is very limited. For example, interference competition between coyotes (*Canis latrans*) and bobcats has been suspected with coyotes dominant over bobcats (Litvaitis and Harrison 1989). Coyotes have been documented to kill bobcats (Litvaitis and Harrison 1989, Knick 1990). Removal of selected predators (e.g., coyotes) may result in the release of other predators (e.g., foxes, skunks, raccoons, and opossums) (Henke and Bryant 1999) with unintended depredation consequences. It is possible that the intensive removal of bobcats may allow rodents and lagomorphs to increase, thereby attracting other predators which may result in more depredation on quail and their nests. However, even if bobcats and other predators consumed a higher percentage of quail, it would not necessarily mean that such depredation had a negative effect on the ultimate size of the quail population. Other factors (e.g., habitat quantity and quality) may represent a dominant or limiting effect.

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