# EFFECT OF PREDATOR REMOVAL ON RING-NECKED PHEASANT POPULATIONS IN UTAH

By

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## ABSTRACT

Effect of Predator Removal on Ring-Necked

Pheasant Populations in Utah

by

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Ring-necked pheasant (*Phasianus colchinus*) populations have been declining in many areas of the United States, including the Intermountain West. I tested whether predator removal can increase pheasant populations. Predators were removed during winter and spring, the most critical time of survival for ring-necked pheasants. I analyzed the effects of mammalian predator removal on populations of pheasants, mammalian predators, avian predators and small mammals, as well as the subsequent effect on pheasant hunter success. The study was designed with two study sites; the first in Cache and Box Elder counties, Utah and the second in Sevier and Sanpete counties, Utah. In the Cache/Box Elder study site, there were 12 plots, each covering 10.5 $km^2$. These plots were arranged as 6 pairs, with 1 plot in each pair being randomly assigned as a treated plot and the other as an untreated plot. In the Sevier/Sanpete study site there were 2 pairs of plots, each covering 42 $km^2$. The study was considered a mixed-factor split-plot design. I analyzed the data using ANOVA in SAS. In the

Cache/Box Elder study site, there were no differences in pheasant or mammalian predator numbers between treated and untreated plots. A large residential predator population within the area of the Cache/Box Elder study site may have diminished my ability to adequately control mammalian numbers within treated plots. Perhaps high immigration rates of mammalian predators into the treated plots reduced the effects of removing predators. Additionally, large variance among plots and years contributed to decreased power and increased the probability of a Type II error. Consequently, I did not find that predator removal resulted in an increase of avian predators or small mammals in the Cache/Box Elder study site. In the Sevier/Sanpete study site, where the plots were 4 times larger than plots in Cache/Box Elder, treated sites had higher numbers of pheasants from winter through summer. However, the effects of the treatment were diminished during the fall season. Avian predators did not increase in treated sites in Sevier/Sanpete as a result of predator removal. The results of the hunter surveys at this study site were inconclusive.

(59 pages)

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# INTRODUCTION

In the past century, upland-nesting bird populations have been declining in many parts of the United States. For several species of the Family Phasianidae, such as ring-necked pheasant (*Phasianus colchicus*), populations have been in decline across the United States from all-time highs reported in the 1940s and 1950s. With the advent of the Conservation Reserve Program (CRP), pheasant populations have been recovering in the Midwest; however, populations in the Intermountain West continue to decline (Chesness et al. 1968, Trautman et al. 1974, Jarvis and Simpson 1978, Perkins et al. 1997, Warner et al. 1999). Although not native to the United States, the ring-necked pheasant has been a popular upland game species since the 1900s (Parsons 1953, Trautman et al. 1974). In the state of Utah, pheasants are the second most popular game species, and thus license fees for pheasant hunting provide an important source of revenue for state wildlife agencies. Hence, declines in ring-necked pheasant populations are of concern to both sportsmen and land managers (Riley and Shulz in press).

## Pheasants in Utah

Pheasants were introduced to Utah around 1890, mostly utilizing irrigated farmlands and roadsides for cover and food (Parsons 1953, Skousen and Brotherson 1982, Anderson 1996). Pheasant populations peaked in Utah in the 1950s, and then steadily decreased in number (Skousen and Brotherson 1982). In 1989, the number of pheasants harvested by hunters was 71% below the 1948 harvest, and 41% below the average harvest from 1948 to1988 (Mitchell 1990, unpublished report, Utah Division of

Wildlife Resources). Anderson (1996) reported that pheasant populations in northern Utah's Cache County experienced a 2.7% decline annually from 1962 to1996.

Farmers in northern Utah have followed the national trend of increasing the size of their fields, and removing fence lines and ditch banks that provided nesting and escape cover for pheasants (Heath 1984, Mitchell 1989). Between 1950 and 1990, the number of farms in Utah decreased by 50%, while the total farmland in Utah decreased by only 6%, indicating a consolidation of many small farms into fewer, larger farms. By 1989, the size of the average farm (352 hectares) had nearly doubled since 1950 (Mitchell 1990, unpublished report, Utah Division of Wildlife Resources). Urban and suburban development has also contributed to a decline in pheasant habitat in Utah, via a reduction in roadside edges, vacant lots, and farmland. Mitchell (1990) also noted that the human population of Utah increased 163% between 1948 and 1989. Mitchell (1989) found that increased development was especially apparent in Cache, Box Elder, Sanpete, and Duchesne counties. In the past, state and federal agencies have instituted programs to increase wildlife habitat. The "Acres for Wildlife" and the Soil Bank Act programs began in the 1950s, which resulted in the fallowing of about 84,170 hectares of agricultural lands in Utah (Bartmann 1966, Heath 1984, Berner 1988). This had a positive effect on pheasant populations, but eventually, the leases on those lands expired (Bartmann 1966). In the 1980s, under the CRP, farmland was set aside and seeded with perennial grasses throughout the Midwest and Intermountain West (Farmer et al. 1988, Best et al. 1997). Lands enrolled in the CRP showed increased density of pheasant nests and increased numbers of young pheasants (Best et al. 1997). However, the increase of potential pheasant predators into Utah continued to impact pheasant recruitment. Similarly, during the soil bank program era, Bartmann (1966) reported that mammalian predation was the largest single cause of pheasant nest failure on CRP lands.

**Reasons for Decline**

Pheasant populations were high in the early twentieth century when the birds were able to nest in the cover of edges, and fencerows created by agricultural practices (Anderson 1996) provided extensive cover. However, in the last 50 years there has been a trend toward larger agricultural fields, made possible through increased farming efficiency, with fewer fencerows, hedges, and irrigation banks per hectare of farmland. Additionally, urban and suburban expansion has reduced farmland. The end result is fewer areas of suitable cover available to pheasants.

In many contemporary agricultural lands, nesting cover occurs in fragments along irrigated banks, fencerows, and field edges. Nesting success in these fragmented, edge areas is often reduced because predators concentrate foraging in these areas (Keyser 1986, Schmitz and Clark 1999). Peterson et al. (1988) determined the basic management problem for upland-nesting birds as low recruitment, largely attributed to increased predation as a result of habitat loss and changing predator communities.

**Predators of Pheasants**

As land uses in the western United States have changed, so have predator communities and densities (Johnson and Sargeant 1977, Cowardin et al. 1983, Sargeant et al. 1984, Ball et al. 1995, Garretson et al. 1996, Cote and Sutherland 1997). For example, coyotes (*Canis latrans*) excluded red fox (*Vulpes vulpes*) populations from their territories (Johnson and Sargeant 1977, Sargeant 1982, Major and Sherbourne 1987, Dekker 1989). With the suppression of coyotes, the population of red foxes, and other medium-sized predators increased throughout the Midwest and West (Johnson and Sargeant 1977, Sargeant et al. 1984, Sargeant and Allen 1987). Red foxes, which were rare in Utah in the 1950s, are today widespread in the state (Zeveloff 1988).

Foxes are a more efficient predator of upland-nesting birds than coyotes and pose more of a threat to ground-nesting birds (Johnson and Sargeant 1977, Sovada et al. 1995). Raccoons (*Procyon lotor*), which predate eggs (Ough 1979, Greenwood 1982) and juvenile birds (Stoudt 1982), have also increased in number throughout the West, usually subsequent to human development (Durrant 1952, Stoudt 1982, Garretson et al. 1996). Additionally, populations of domestic dogs (*Canis familiarus*) and cats (*Felis domesticus*) have increased with human populations, and can pose a serious threat to ground-nesting birds (Rasmussen and McKean 1945). Stokes (1954) found several cases where domestic cats daily delivered pheasant chicks to their litters. Other predators of ground-nesting birds in Utah include striped skunks (*Mephitis mephitis*), badgers (*Taxus taxidae*), hawks (*Buteo spp.*), great horned owls (*Bubo virginianus*), and corvids (Rasmussen and McKean 1945, Trautman et al. 1974, Peterson et al. 1988, Garretson et al. 1996).

**Management Solutions**

In general, state wildlife agencies in the United States have used stocking, habitat manipulation, and predator control to increase pheasant populations. Releasing hand-reared pheasants in autumn to provide increased hunting opportunities has been a common practice in the United States since the early 1940s (Burger 1988). However, stocking is an expensive and often temporary solution (Henry 1986). Many biologists prefer habitat management efforts to predator control to enhance predator numbers.

In the past, some agricultural practices have had a detrimental effect on pheasant recruitment (Leedy and Dustman 1947). Mowing resulted in a 45% nest loss during a study by Eklund (1942). In this respect, delayed mowing may improve nesting success. In Utah, delaying the first hay mowing until late June would allow pheasant broods to hatch; however, this delay may also decrease the forage quality of the hay (Heath 1984). Additionally, roadside management can increase pheasant recruitment (Warner and Joselyn 1986). If mowing in these areas is delayed until after chicks hatch, roadside right-of-ways can provide important habitat nesting sites and travel corridors (Heath 1984). Federal and state programs, such as the CRP, have set aside agricultural land to improve pheasant habitat (Berner 1988). Similarly, conservation tillage -- reduced or no tillage -- has been proposed to provide fall and winter habitat to pheasants, thereby increasing their winter survival (Heath 1984, Snyder 1991).

When pheasant populations are low, predators are typically identified by hunters as the primary cause. Indirect methods of predator control, such as habitat manipulation and electric fences, have been used to increase the reproductive success of several upland-nesting bird species. Increased spatial heterogeneity of vegetation used for cover and nesting (Hill and Robertson 1988, Ball 1996), which may decrease predator foraging efficiency (Bowman and Harris 1980, Yahner and Mahan 1996), has been suggested as one method to control predation. Crabtree et al. (1989) found that increased spatial diversity of vegetation in nesting areas decreased predation of ground nests by skunks. However, if spatially diverse areas are small in number and size, predators may learn that they contain high densities of nests and concentrate their foraging in these areas. Conversely, increased vegetative diversity may increase alternative prey numbers, decreasing predation pressure on ground-nesting bird species (Clark et al. 1996).

Physically excluding predators is another potential method of control. Fences have been built around nesting areas and individual nests to keep predators away from nesting birds (LaGrange et al. 1995, Beauchamp et al. 1996, Cowardin et al. 1998). However, exclosures do not protect against all predator species. Most fences do not hinder small mammals, such as ground squirrels (*Citellus sp*.), minks (*Mustela vison*), and weasels (*M. frenata* and *M. erminea*) (Lokemoen et al. 1982). A further limitation of fences is their inability to exclude avian predators, such as American crows (*Corvus brachyrhynchos*), which are significant predators of upland-nesting birds and nests (Johnson et al. 1988).

Direct methods of predator control have also been used to increase reproductive success of ground-nesting birds by decreasing predator densities. Anti-fertility agents have been used to decrease mammalian predator populations by reducing their reproductive success (Balser 1964). However, their effectiveness with medium-sized mammals, such as raccoons and striped skunks, has not been thoroughly tested (Reynolds et al. 1988).

Predator removal also has been used as a management tool to increase bird production (Trautman et al. 1974). In studies where several mammalian predators were removed, mortality of upland-nesting birds and their broods decreased significantly, resulting in higher post-breeding populations than in areas where predators were not removed (Balser et al. 1968, Duebbert and Lokemoen 1980, Garretson et al. 1996, Cote and Sutherland 1997). Conversely, Sargeant et al. (1995) found that removing mammalian predators did not result in a higher breeding success in waterfowl. They suggested that this was in part due to a large diversity of both avian and mammalian predators within their study site. For similar reasons, both Greenwood (1986) and Clark et al. (1995) found that removing only 1 predator from the community (striped skunk and American crow, respectively) resulted in only a slight increase in waterfowl nesting success.

**Alternatives to Predator Removal**

Stocking pheasant has been a popular management scheme since the early part of the 20th century. During this time, managers also released pheasants to expand their ranges and reestablish spring sex ratios (Burger 1988, Hill and Robertson 1988). However, stocking is an expensive, and often temporary, solution to low pheasant numbers (Henry 1986). Hessler et al. (1970) found that pen-reared pheasants experienced 90% mortality within 28 days of their release. Avian predators were the most serious threat to pheasant survival in this case. During a study of spring-released pheasants, Leif (1994) attributed pen-reared pheasants' vulnerability to predation to less cautious behavior than wild-reared pheasants. Hill and Robertson (1988) also found that pen-reared pheasants have a lower breeding success than wild pheasants; hand-reared males were less able to establish territories and females were more susceptible to predation than the wild population. With this in mind, using pheasant stocking as a population management technique is not likely to be a cost efficient or viable option for increasing pheasant populations in the longterm. However, stocking provides a quick short-term benefit through increased hunter satisfaction via increased harvest rates, which is certainly an important consideration for wildlife management agencies.

Habitat improvement is also frequently considered when planning management to increase pheasant numbers. As mentioned earlier, federal and state habitat improvement initiatives, such as the advent of Soil Bank Act, which created the Conservation Reserve and the Acreage Reserve in the 1950s, increased quality habitat for pheasants in the United States (Berner 1988). It is surmised that improved habitat will provide pheasants with increased food and cover, thereby decreasing the size of their home range and decreasing predation (Gatti et al. 1989). However, this process can become quite expensive to the federal or state agency running the program, for farmers must be compensated for allowing their land to fallow. In 1961, MacMullen estimated that habitat management would cost $20 per acre of nesting cover provided. Yet, an increase in pheasant numbers is not the only benefit provided by CRP and similar programs. Fallowing the land reduces soil erosion and allows the land to replenish its nutrients. In addition, many small and medium-sized mammal species as well as songbirds benefit as a result of this added habitat (Best et al. 1997).

Roadside vegetation and small, unused areas adjacent to farms provide attractive nesting vegetation to pheasants. Studies show that preferred nesting habitat may be created by delaying, or ceasing, mowing of roadside vegetation (Warner and Joselyn 1986). Roadside vegetation can be increasingly beneficial if state transportation authorities agree to desist in herbicidal spraying in these areas (Heath 1984). However, although increased management of the roadside by ceasing herbicidal spraying may be a cost effective method of utilizing this habitat as an added food and cover resource for pheasants, herbicidal spraying is often important to the state in controlling exotic species of vegetation. Hence, it would be more beneficial to all parties to consider delayed mowing in these areas. In addition, roadside management can be used to connect sources of winter habitat and nesting cover, thereby creating a less patchy environment for pheasants (Henry 1986).

While habitat management is an inviting plan for many state agencies because more nesting habitat logically implies more pheasants, some issues must be considered. Studies have shown that small patches of good pheasant habitat in an area otherwise poor for pheasants may actually be detrimental for pheasant populations (Clark et al. 1999). Many mammalian predators are opportunists, predating upon whatever they find (Stuewer 1943). If the only resources are small patches of dense vegetation, mammalian predators will be able to search these patches more efficiently than a habitat with evenly distributed vegetation (Haensly et al. 1987, Clark and Bogenschutz 1999, Major et al. 1999). Angelstam (1986) found that patchy vegetation surrounded by less desirable vegetation actually increased predation in these areas. In his study he found that good habitats surrounded by urban environments suffered from predation more than any other area surveyed. Similarly, hen pheasants are attracted to strip vegetation (Haensly et al. 1987). Often the densities of pheasants within these strips of dense vegetation are extremely high. When agricultural fields, or areas of similarly low food potential for predators surround these strips of vegetation, predators may simply limit their search to the strips of vegetation. For example, Dijak and Thompson (2000) found that raccoons follow this foraging pattern. This occurrence is considered an ecological trap, whereby managers have simply created a situation where pheasants will certainly be predated. In support of the ecological trap hypothesis, Haensly et al. (1987) found that pheasant nest success was influenced by habitat pattern more than by vegetative structure. Similarly, Ball (1996) suggested connecting small units of good habitat to alleviate the pressure of predation in these areas.

## Avian Predation

Avian predators are responsible for ground-nesting bird predation as well as mammalian predators (Einarson 1950, Parker 1984). Clark et al. (1995) reported that corvids are effective predators of game bird eggs, mostly early in the nesting season. Peterson et al. (1988) recognized red-tailed hawks as a major source of predation of ring-necked pheasants. Riley and Shulz (in press) include accipiters, other buteos as well as red-tailed hawks, and harriers on the list of avian predators of pheasants. However, removal of avian predators to increase game bird production can prove difficult. Clark et al. (1995) reported that when predator species can be eliminated effectively, nesting success of game birds will increase; however, just removing crows in their study did not increase nesting success of ducks.

## Predation Management and Pheasant Recruitment

Studies evaluating predator removal to increase phasianidae production have shown positive results. Beasom (1974) found that the removal of several predators, including coyotes, red fox, and raccoons, resulted in an increase in the breeding success of wild turkeys (*Meleagris gallopavo*), and a marginal increase in northern bobwhite (*Colinus virginianus*) breeding success. Likewise, Chesness et al. (1968) and Trautman et al. (1974) found that the removal of predators increased the breeding success of ring-necked pheasants.

The most crucial times for survival of ring-necked pheasants may be in winter and during the breeding season (Cote and Sutherland 1997). Hurst et al. (1996) found that reduced cover and food during winter makes pheasants more vulnerable to predation than at other times of the year. Schwartz and Buss (1957) and Balser et al. (1968) showed that hens are especially susceptible to predation during the breeding season. While several studies have addressed the impact of predator control during the spring nesting period, this study addressed whether controlling mammalian predator numbers from winter through the nesting period would increase pheasant survival and recruitment.

**Objectives**

This study addressed the effects of removing mammalian predators on ring-necked pheasant populations in Utah. The overall goal of the study was to determine the effect of predator removal on pheasant populations, predator numbers, and hunter satisfaction and harvest rates. I was particularly interested in measuring the impacts of mammalian predator removal during winter and spring, which are the critical periods of the ring-necked pheasant life cycle. I monitored changes in predator numbers through the period of predator trapping and the months immediately following it. I compared pheasant abundance in plots where predators were removed to those where they were not. I also evaluated the satisfaction of hunters each autumn, in addition to their average harvest rates. Additionally, I monitored the changes of avian predator numbers and small mammal numbers to predator removal.

# METHODS

## Study Area

The experiment was conducted in 2 study areas. The first area was located in Cache and Box Elder counties, Utah. The Cache/Box Elder study area contained six study sites, located throughout this study area, where there was good pheasant habitat. Cache Valley is characterized by grazing and farmlands planted primarily in alfalfa, barley, and wheat. There is also land set aside in the CRP. The climate in this area is semiarid continental. It receives an average of 40 to 50 cm of rain annually, mostly in spring. Small communities and townships are scattered throughout the valley around Logan, the largest town in the 2 counties (Erikson and Mortenson 1974).

The second study area was located in Sevier and Sanpete counties, Utah. There were two study sites in the Sevier/Sanpete study area, located within good pheasant habitat. The climate here is also characterized as semiarid continental. It receives 20-30 cm of rain annually, mostly in spring. The average annual temperature ranges from 7-10° C. Alfalfa, grain, and corn silage are the main crops within this area, in addition to small cattle and sheep ranches. There is also land set aside in the CRP. This study area includes several small communities and towns (USDA 1981).

In the Cache/Box Elder study area, the 6 study sites consisted of paired plots. Each of the plots was 10.5 $km^2$ in size. Each plot in a pair was located 3.25 km apart and consisted of similar topography and land uses (Chesness et al. 1968). I randomly selected 1 plot from each pair to serve as the treatment (treated) plot, and the other served as the control (untreated) plot.

In the Sevier/Sanpete study area, the 2 study sites consisted of 2 paired plots. Each of the 4 plots was 42 $km^2$ in size. The plots in each pair were located 3.25 km apart. One plot of each pair was randomly selected as the treatment (treated) and the other as the control (untreated).

**Independent Variable**

From 1996-1999, the United States Department of Agriculture/Wildlife Services (WS) removed mammalian predator species, beginning in December and continuing through June 1 each year of the study. Predator species that were removed included red fox, coyote, raccoon, striped skunk, badger, and mink. Removal methods met WS standards and included leghold traps, box traps, snares, denning, calling, and shooting. Cooperative agreements were signed with landowners that allowed WS employees access to conduct predator removal on private lands within the study sites.

The study in the Cache/Box Elder study area was implemented using a cross-over design. Cross-over designs are often used in studies where most of the uncontrolled variation in the experiment is caused by variations in the external conditions under which the experimental units respond (Cox 1958). Additionally, cross-over designs are often used when the researcher anticipates high levels of variability among subjects (Mead 1988). After the first 2 years of the study, in the Cache/Valley study area only, the treatment was switched between the 2 plots in each pair. Hence, plots that were treated during 1996-1997 were not treated during 1998-1999. Similarly, plots that were untreated in 1996-1997 received treatment 1998-1999. Using a cross-over design, we could compare treatment and control within the same unit, thereby eliminating between-unit variability as a part of the experimental error (Petersen 1985).

**Dependent Variables**

*Pheasant Numbers*.--To obtain an index of pheasant numbers, roadside surveys were conducted in each season to assess winter abundance, spring crowing numbers, summer brood abundance, and fall abundance. For each survey, I examined each plot on 3 separate occasions. Surveys were conducted in both study sites. In the Cache/Box Elder study sites, within each study plot I selected a total of 9.6 km of transects consisting of various types of roads. These transects were laid out such that they represented the habitats in each plot. Once selected, the same transects were used throughout the study. In the Sevier/Sanpete study sites, a total of 19.3 km of transects was selected within each study plot, using protocols similar to those used in the Cache/Box Elder study sites.

To survey a transect, I randomly selected which plot in each pair was to be surveyed first. A pair of treated and untreated plots was always surveyed on the same day. Surveys were not conducted when there was precipitation or winds greater than 15 kph, so that weather would not be a factor concerning the number of pheasants seen during each survey (Kimball 1949).

Winter pheasant abundance.--Winter abundance surveys were conducted in January and February to establish indices of winter populations in each plot. I began the surveys when there was snow cover so that pheasants would be more conspicuous. I drove the pre-selected transects within each plot at a speed of 24 kph beginning at dawn (Chesness et al. 1968). When pheasants were located, I recorded the number seen at their general location along the transect.

<u>Spring crowing counts</u>.--From April 15 through May 30 I recorded the number of breeding calls of male pheasants (hereafter called crowing-call), and the number of pheasants observed along each transect. This time period spans the period of the peak of pheasant crowing-calls (Gates 1966). Beginning at dawn, I stopped every 0.5-km along each transect in the survey. To begin, I shut off the engine, stepped outside, waited 30 seconds, and then recorded all the crows I heard during a 2-minute period. The next 3 minutes were spent viewing pheasants from my present location. At the end of the 3-minute period, I recorded the number of male and female pheasants that I had seen. Care was taken not to record an observed rooster if it was already recorded as calling.

<u>Summer brood counts</u>.--Summer brood surveys were conducted from mid-July through August to estimate the annual productivity of pheasants. Beginning at sunrise, I surveyed transects within each plot while driving at a speed of 24 kph. I noted the number of pheasants and the sex of the adults. I defined a brood as a female with young. Adult pheasants without broods were also recorded.

<u>Fall abundance counts</u>.--Fall counts were conducted from September 15 through October 31 to count the number of pheasants seen in each plot. This survey provided an additional index of pheasant numbers, after fields are harvested, yet prior to the pheasant-hunting season. Beginning at sunrise, the transects within each paired plot were surveyed by driving approximately 24 kph. When pheasants were located, I recorded the number seen and their sex.

*Hunter Surveys*.-- Hunter surveys were conducted on the opening day of pheasant hunting season each year. Beginning 1 hour after the hunt opened, volunteers approached people who were hunting or had hunted in one of the plots. We asked the hunters how many pheasants they had shot (bag), the number of pheasants they had seen, how long they had hunted, and how satisfied they were with their harvest rate and general hunting experience. Hunting satisfaction was rated on a scale of 0-5, with 5 as the highest level of satisfaction.

*Predator Track Counts*.--Track counts were conducted in all plots to estimate the effect of trapping efforts on predator populations. Each year (1996-1999), I conducted predator track counts twice in each plot: after trapping (July through August); and pre-trapping (October through November). Track counts were used to calculate an index of mammalian predator abundance in both the treated and untreated plots. Track counts were initiated at least 24 hours after the area received precipitation. I surveyed both plots of each pair (treated and untreated) on the same day. The survey consisted of searching for predator tracks in 8 randomly selected quarter sections of each study plot. I surveyed potential track sites within each randomly selected quarter section, but spent no more than ½ hour in each section. Potential track sites included riverbanks, sandy areas, pastures, mud flats, and irrigation ditches.

*Avian Predator Counts*.--In many areas avian predators, such as crows, magpies and harriers, contribute to a loss of pheasant chicks (Ruff 1963). With a reduction of competition from mammalian predators, it is possible that avian predator numbers would increase in areas where predators were controlled, filling in the foraging niche provided by removal. To test this theory, I conducted avian predator surveys on 3 separate occasions within each study plot, during each May and June of the study.

During each survey, I counted the number of avian predators seen, as well as active nests of avian predators. Avian predators included American crows, ravens (*Corvus corax*), magpies, Northern harriers (*Circus cyaneus*), and hawks. I surveyed both plots within a pair on the same day, randomly selecting which plot was surveyed first. I began the survey 2 hours after sunrise, driving the transects within each plot at a speed of 24-38 kph. I stopped at 0.5-km intervals along each transect for 1 minute, to record the number of avian predators and active nests seen during this time. When an avian predator or its active nest was sighted, I noted the species and recorded its location along the transect. A nest was defined as active if a parent attended the nest or chicks were visible at the nest.

*Small mammal counts.*--Small mammals are known to be the staple diet of many mammalian predators (Norrdahl and Korpimaki 1995). Mammalian predators as large as coyotes depend on meadow voles (*Microtus pennsylvanicus*) and field mice (*Peromyscus maniculatus*) as the majority of their food. As a consequence of mammalian predator removal, populations of their prey may increase, possibly increasing agricultural crop losses.

To determine is this occurred, small mammal counts were conducted once a month, from June through September, at the Cache/Box Elder study area, in both treated and untreated plots. The small mammals of concern included meadow voles (*Microtus pennsylvanicus*), field mice (*Peromyscus maniculatus* and *P. leucopus*), house mice (*Mus musculus*), shrews (*Sorex cinereus* and *S. merriami*), and short-tailed weasels

(*Mustela vison*). I began small mammal trapping 10 days after the full moon, so trapping could be conducted during a period of relative darkness. In each plot, I set 3 lines of 9 traps each in agricultural areas, and 3 lines of 9 traps each in CRP or fallow fields. Peanut butter and oats wrapped in waxed paper were used to bait the traps. I set traps along the edge of a field, facing them in toward the field. The lines were set for 3 successive nights, with a pair of treated and untreated plots trapped at the same time.

**Data Analysis**

Data collected in the Cache/Box Elder study area were analyzed to determine the effect of predator removal on pheasant populations. I used a split-plot design to test the difference in pheasant number indices between treated and untreated plots each year. I tested for year and treatment effects, using a mixed-factor analysis of variance (SAS Institute Inc. 1988). My fixed effects were treatment, year, order (treated or untreated first), and season. My random effect was order(site), and treatment*order(site). This first term allowed for the analysis of between-site variability, by distinguishing between the 2 plots of a pair. The second random term analyzed a set of plots (treated or not treated) during the periods 1 and 2 of the study.

I also used this statistical design to test for differences between treated and untreated plots in the questions of the hunter survey, mammalian predator tracks, the numbers of avian predators, avian predator nests, and small mammal abundance. I considered statistical results with a *P*-value of less than 0.05 to be significant.

For predator track and small mammal counts, only 3 years of data were available. A simple ANOVA analysis could not be run to analyze all aspects of these data, given that to do so required 4 years. For the predator track data, I calculated the mean of 1996-1997 for treated and untreated plots, and compared these numbers to the average value for treated and untreated plots in 1998, to analyze the differences between the order of the treatment and the period of the study. For the same purpose, I combined small mammal count data from treated and untreated plots in 1998-1999 and compared them to treated and untreated predator track counts in 1997.

In the Sevier/Sanpete study area, there were 2 sets of treated and untreated plots. While we compared trends seen in the data, we did not conduct statistical testing on these data.

# RESULTS

## Number of Predators Removed

The mean annual number of predators removed from each of the treated plots in Cache/Box Elder study sites during 1997-1999 ranged from 28 to 45 (Table 1). In Sevier/Sanpete, on average 42 to 60 predators were removed annually from each treated plot during 1997 to 1999 (Table 2).

Table 1: Mean number of predators removed annually from treated plots (10.5 $km^2$), Cache/Box Elder study sites, 1997-1999.

| Predator | 1997 | 1998 | 1999 |
|---|---|---|---|
| Coyote | 0.3 | 0.5 | 0 |
| Mink | 0.5 | 0 | 2.2 |
| Raccoon | 8.2 | 23.3 | 13.8 |
| Red Fox | 11 | 9.7 | 17.5 |
| Striped Skunk | 7.8 | 8.8 | 5.2 |
| Total | 27.8 | 42.3 | 38.7 |

Table 2: Mean number of predators removed annually from treated plots (42 $km^2$), Sevier/Sanpete study sites, 1997-1999.

| Predator | 1997 | 1998 | 1999 |
|---|---|---|---|
| Coyote | 5.5 | 4.0 | 1.0 |
| Raccoon | 35.0 | 20.5 | 29.5 |
| Red Fox | 14.0 | 15.0 | 13.5 |
| Striped Skunk | 18.5 | 16.0 | 24.5 |
| Total | 73.0 | 55.5 | 68.5 |

**Pheasant Numbers**

Table 3: Mean number of pheasants seen per plot during each season in treated and untreated plots, Cache/Box Elder study sites, 1996-1999.

| | Winter | | Spring | | Summer | | Fall | |
|---|---|---|---|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated | Treated | Untreated | Treated | Untreated |
| 1996 | 4.2 ± 3.0 | 4.5 ± 3.0 | 9.8 ± 1.3 | 4.7 ± 1.3 | 2.8 ± 1.2 | 0.5 ± 0.3 | 6.3 ± 0.7 | 5.9 ± 1.5 |
| 1997 | 2.8 ± 1.0 | 4.7 ± 1.2 | 8.8 ± 3.7 | 8.1 ± 1.5 | 3.1 ± 1.3 | 2.4 ± 0.9 | 6.0 ± 2.3 | 3.9 ± 1.3 |
| 1998 | 1.4 ± 0.9 | 1.3 ± 0.5 | 7.3 ± 3.2 | 6.2 ± 1.7 | 2.8 ± 1.6 | 1.8 ± 0.9 | 9.4 ± 4.2 | 13.7 ± 3.1 |
| 1999 | 3.8 ± 3.4 | 6.2 ± 2.3 | 6.1 ± 1.9 | 12.4 ± 2.9 | 2.1 ± 1.7 | 0.7 ± 1.4 | 5.8 ± 1.5 | 16.1 ± 6.2 |

***Cache/Box Elder Study Sites.--***Data for each survey were analyzed separately over the 4 years of the study (Tables 3). The number of pheasants recorded in treated plots was not significantly different than in untreated plots during winter pheasant counts ($F$ = 1.23, $P$ = 0.29; Table A1), spring crowing counts ($F$ = 0.0, $P$ = 0.97; Table A2), summer brood surveys ($F$ = 2.03, $P$ = 0.18; Table A3), or fall pheasant counts ($F$ = 0.57, $P$ = 0.47; Table A4).

***Pooled Data.--***In the Cache/Box Elder study sites, data collected during all seasons were combined to compare the overall results from the entire year (Figure 1). Statistical analysis showed there was no difference in pheasant numbers between treated and untreated plots ($F$ = 0.10, $P$ = 0.76). There also was no “order effect” ($F$ = 2.56, $P$ = 0.14), indicating that the difference in results from 1996-1997 (period 1) to 1998-1999 (period 2) was not a result of the switching of treatments between plots during the winter of 1998. There was an interaction between treatment and year ($F$ = 3.97, $P$=

0.04), suggesting that the treatment may have had a greater impact in some years than others (Table A5).

***Sevier/Sanpete Study Site.***--Data for the Sevier/Sanpete study sites were collected through 4 years (Table 4). More pheasants were recorded in treated plots than in untreated plots 3 out of the 4 years during winter and autumn surveys. Annually, more pheasants were observed in treated plots than in untreated plots during the spring crowing and summer brood counts.

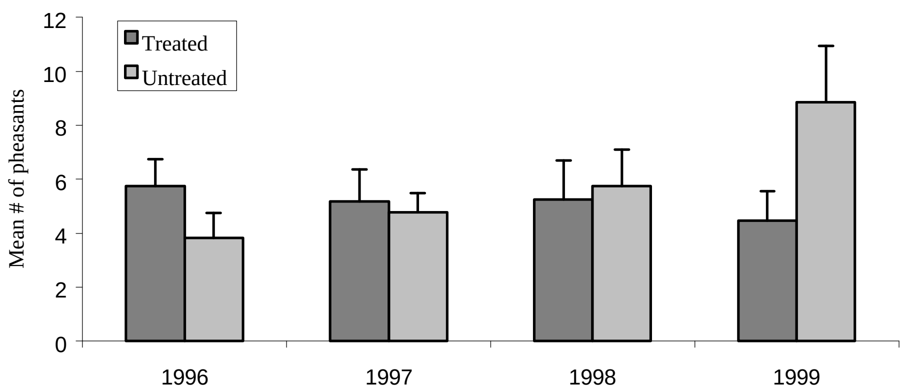


Fig. 1: Mean number of pheasants seen each year in treated and untreated plots, Cache/Box Elder study site, 1996-1999.

Table 4: Mean number of pheasants seen per plot during each season in treated and untreated plots surveys in Sevier/Sanpete study sites, 1996-1999.

| | Winter | | Spring | | Summer | | Fall | |
|---|---|---|---|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated | Treated | Untreated | Treated | Untreated |
| 1996 | 0.0 | 0.2 | 7.2 | 3.8 | 24.8 | 10.3 | 6.0 | 3.3 |
| 1997 | 8.5 | 1.5 | 34.2 | 24.2 | 15.2 | 5.7 | 21.0 | 7.2 |
| 1998 | 6.5 | 1.8 | 15.0 | 2.8 | 21.0 | 10.2 | 6.5 | 3.8 |
| 1999 | 33.0 | 0.5 | 8.3 | 3.3 | 1.8 | 4.2 | 5.5 | 2.7 |

Table 5: Mean number of pheasants bagged per hunter hour as recorded in treated and untreated plots during pheasant hunter surveys in all study sites, 1996-1999.

| | Cache/Box Elder | | Sevier/Sanpete | |
|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated |
| 1996 | 0.13 ± 0.02 | 0.17 ± 0.07 | 0.09* | 0.12[a] |
| 1997 | 0.15 ± 0.02 | 0.15 ± 0.03 | 0.15 | 0.18 |
| 1998 | 0.17 ± 0.04 | 0.19 ± 0.02 | 0.14 | 0.10 |
| 1999 | 0.21 ± 0.04 | 0.18 ± 0.07 | 0.09 | 0.08[a] |

a) only one plot was used during analysis

**Hunter Surveys**

***Bag Checks.--***In the Cache/Box Elder study sites, hunter harvest rates, in terms of average bag per hunter hour, were similar in treated and untreated plots ($F = 0.11$, $P = 0.75$; Tables 5, A6). Similar results were observed in the Sevier/Sanpete study sites (Table 5).

***Pheasants Observed by Hunters.--***In the Cache/Box Elder study sites, there was no difference in the number of pheasants that hunters observed in treated and untreated plots ($F = 0.04$, $P = 0.84$; Tables 6, A7). In the Sevier/Sanpete study sites, hunters reported more pheasants in treated plots in 1998, but more in untreated plots in 1997 and 1999 (Table 6).

***Hunter Satisfaction.--***There were no significant differences detected between the treated and untreated plots regarding hunter satisfaction in the Cache/Box Elder study sites ($F = 0.09$, $P = 0.77$; Tables 7, A8). In Sevier/Sanpete, hunters who were surveyed in untreated plots were more satisfied than hunters who were surveyed in treated plots during all years of the survey (Table 7).

Table 6: Mean number of pheasants seen per plot, as recorded by hunters in treated and untreated plots, during pheasant hunter surveys in all study sites, 1997 - 1999.

| | Cache/Box Elder | | Sevier/Sanpete | |
|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated |
| 1997 | 9.8 ± 1.2 | 14.3 ± 2.5 | 5.9 | 5.8 |
| 1998 | 15.6 ± 5.5 | 15.7 ± 2.9 | 7.4 | 5.4 |
| 1999 | 15.0 ± 2.9 | 17.7 ± 7.2 | 13.4 | 8.9 |

Table 7: Mean level of hunter satisfaction recorded in treated and untreated plots during pheasant hunter surveys in all study sites, 1997-1999.

| | Cache/Box Elder | | Sevier/Sanpete | |
|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated |
| 1997 | 2.57 ± 0.35 | 2.72 ± 0.31 | 2.21 | 2.70 |
| 1998 | 2.78 ± 0.58 | 2.83 ± 0.33 | 2.18 | 3.30 |
| 1999 | 2.53 ± 0.54 | 2.36 ± 0.58 | 1.14 | 1.32 |

Table 8: Mean number of predator tracks seen per plot, in summer and autumn, Cache/Box Elder study sites, 1996-1999.

| | Summer | | Autumn | |
|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated |
| 1996 | 21.50 ± 4.53 | 36.67 ± 8.30 | 78.67 ± 23.65 | 64.33 ± 13.80 |
| 1997 | 21.75 ± 3.83 | 24.83 ± 3.75 | 36.50 ± 4.91 | 45.83 ± 8.40 |
| 1998 | 10.89 ± 1.19 | 13.00 ± 2.57 | 24.61 ± 5.97 | 23.17 ± 3.01 |
| 1999 | 1.72 ± 0.62 | 3.89 ± 0.85 | XXXX | XXXX |

**Predator Track Counts**

Tracks indices in the Cache/Box Elder study sites were similar in treated and untreated plots during summer ($F$ = 1.70, $P$ = 0.22; Tables 8, A9) and in autumn ($F$ = 0.01, $P$ = 0.92; Tables 8, A10). The number of tracks counted during autumn was greater than that of the spring ($F$ = 54.84, $P$ = <0.001; Table 8).

**Avian Predator Counts**

Most of the avian predators counted during surveys were magpies and Swainson's hawks. Red-tailed hawks also were common in the Cache/Box Elder study sites. Avian predator numbers were similar between treated and untreated plots ($F$ = 0.13, $P$ = 0.73; Tables 9, A11). There were fewer avian predators observed in 1998-1999 than in 1996-1997 ($F$ = 31.23, $P$ = <0.001; Tables 9, A11). In the Sevier/Sanpete study sites, avian predator numbers were similar in treated and untreated plots annually (Table 9).

**Active Nests of Avian Predators**

In the Cache/Box Elder study sites, there were no differences in the number of active nests observed in treated and untreated plots ($F$ = 0.04, $P$ = 0.84; Tables 10, A12). In Sevier/Sanpete, untreated plots had a higher number of active nests than treated plots in 1997. During 1998 and 1999, the number of active nests in treated and untreated plots was similar (Table 10).

**Small Mammals**

There were no differences in the number of small mammals trapped in treated and untreated plots in the Cache/Box Elder study sites ($F$ = 2.27, $P$ = 0.16; Figure 2, Table A13). There was a large increase in the number of small mammals trapped among years ($F$ = 844.9, $P$ = <0.001, Table A13).

Table 9: Mean number of avian predators seen per plot during surveys in all study sites, 1996-1999.

| | Cache/Box Elder | | Sevier/Sanpete | |
|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated |
| 1996 | 20.7 ± 6.9 | 14.9 ± 2.6 | XXX | XXX |
| 1997 | 12.9 ± 2.8 | 14.1 ± 2.9 | 14.3 | 15.2 |
| 1998 | 8.0 ± 2.6 | 7.0 ± 2.3 | 6.0 | 5.3 |
| 1999 | 5.9 ± 1.0 | 7.0 ± 1.0 | 7.2 | 10.3 |

Table 10: Mean number of active avian predator nests per plot, recorded during surveys in all study sites, 1996-1999.

| | Cache/Box Elder | | Sevier/Sanpete | |
|---|---|---|---|---|
| | Treated | Untreated | Treated | Untreated |
| 1996 | 2.5 ± 0.9 | 1.5 ± 0.4 | XXX | XXX |
| 1997 | 2.9 ± 1.2 | 1.5 ± 0.8 | 8.5 | 18.0 |
| 1998 | 1.8 ± 0.8 | 3.6 ± 1.5 | 0.2 | 0.5 |
| 1999 | 2.5 ± 1.0 | 2.6 ± 1.1 | 1.2 | 1.7 |

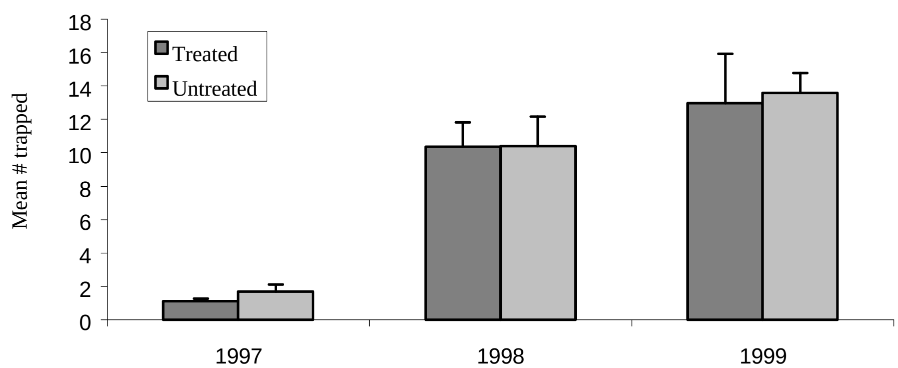


Fig. 2: Mean number of small mammals trapped per plot in treated and untreated plots, Cache/Box Elder study area, 1997-1999.

## DISCUSSION

My results suggest that predator removal did not enhance pheasant recruitment in the Cache/Box Elder study area. I found that although predators were removed, pheasant numbers in these plots were not different than in untreated plots over all seasons. The results of data analysis for pheasant numbers indicated a treatment*year interaction, which suggests that the numbers of pheasants within our study plots fluctuated throughout the study. Pheasant populations from one year to the next are affected by several factors including winter mortality, and hen and chick survival. Winter weather can affect pheasant populations through direct mortality as well as a reduced fitness for hens for the following spring (Warner and David 1982, Gabbert et al. 1999). With reduced fitness from harsh winter, hens are more likely to fall victim to predation (Wood and Brotherson 1981). Wood and Brotherson (1981) also found that in Utah, variable springtime weather conditions influence the mortality of pheasant hens through the occurrence winter conditions during the nesting season. Additionally, this reduction in fitness may cause enough stress to cause expiration later in the nesting season. Clark and Bogenshutz (1999) suggest that even under the best conditions, nesting success of pheasants is variable.

The implementation of certain agricultural practices may also influence mortality. For example, the mowing of vegetative cover such as alfalfa for hay coincides with the pheasant nesting season. Hens that do not flush off their nests may be killed as their nests are destroyed by machinery (Eklund 1942). Additionally, nests not directly destroyed in mowed areas are then exposed to predation, often from avian species such as crows and hawks (Rasmussen and McKean 1945, Craighead 1956). Hens that survive mowing to renest may experience increased mortality after the breeding season, possibly from malnourishment or predation due to lethargy (Schwartz and Buss 1957). Additionally, renests may have a lesser success rate than those nests laid in the beginning of the nesting season. Buss et al. (1952) found that eggs that hatch earlier usually result in a higher population of pheasants in the fall than in years when eggs hatch later in the season. Skousen and Brotherson (1982) reported that in Utah, eggs show a reduced hatching rate as temperature increases throughout the summer.

There were no differences between treated and untreated plots during pheasant hunting opener in either hunter harvest rates or the number of pheasants seen by hunters. Had predator removal resulted in an increase in pheasants, I would have expected hunters who hunted the treated plots to have higher harvest rates than those hunting in the untreated plots. Additionally, I would have expected more pheasants to be seen by hunters hunting in the treated areas. These data further support the hypothesis that seasonal predator removal on small plots had little effect on pheasant populations in the fall in this study.

There is considerable diet overlap between avian and medium-sized mammalian predators. Hence I hypothesized that avian predator numbers would increase in treated plots in response to foraging niches caused by mammalian predator removal. I also hypothesized that small mammal numbers would increase in number in treated plots, in response to the reduction of medium-sized mammalian predators. An increase in small mammal numbers also might influence an increase in avian predators within treated plots.

I did not observe any difference in avian predators. This may have been because our sites were only treated for 2 years in Cache/Box Elder counties. Most avian predators in our study sites are migratory. It is possible that the treatment would need to be in effect for more years before avian predators would respond to the vacant foraging niches available in the summer, thereby increasing in number in these areas. However, a lack of increase in avian predator numbers in treated sites may be due in part to the fact that I did not detect any difference in small mammal numbers between treated and untreated plots. This is similar to Beasom's study (1974) in which he found that predator removal did not result in an increase in rodent populations.

The inability to detect a difference in pheasant, avian predator, and small mammal numbers may be caused by a lack of treatment effect in this study. Analysis of the predator-track counts conducted during the post-trapping period suggests that trapping initially reduced the number of predators slightly, but this effect did not continue through the fall. The lack of difference in summer and fall track counts implies that once trapping stopped, predators may have immigrated into the treated plots from outside the treatment areas. Furthermore, similar numbers of mammalian predators were removed from treated plots each year of the study, thus indicating that predators were increasing in number between the end of one treatment period and the beginning of another. Duebbert and Kantrud (1974) also found that seasonal trapping had little long-term effect on predator numbers. Similarly, Chesness et al. (1968) found that predator numbers returned to pretreatment levels soon after predator removal ended.

The timing of predator removal may have influenced the effect of this treatment on pheasant recruitment. Mammalian predation of pheasants and their nests is highest during June (Roberson 1987, Utah Department of Wildlife Resources unpublished report); therefore, low numbers of predators at this time should benefit pheasant recruitment. In this study, trapping was conducted from December to the beginning of June. The lack of an increase in pheasant populations could be because the treatment duration was not long enough. Buss et al. (1952) found that wet, cool months resulted in a 2-week delay in hatch dates for pheasants compared to warmer, drier years. Perhaps in the Cache/Box Elder study area, pheasants have a later nesting period, due to extended cold weather in this region. Thus pheasants would be nesting primary throughout June and July. In this study, predators quickly returned to the area once removal efforts ended in the beginning of June. Hence, predator numbers would have been increasing in the plots during the critical time in the pheasant nesting period. In this respect, predation control may have been more effective if it were extended through June to allow pheasant hens time to finish nesting efforts, thereby decreasing predation of nesting hens and their eggs. Duebbert and Lokemoen (1980) controlled predators in their study on waterfowl from May to August, with a positive increase in nest hatching success. In Texas, Beasom (1974) had a marginal increase in grouse recruitment when intensive trapping was conducted from February through June. Duebbert and Lokemoen (1980) continuously trapped their study areas for 2 years and this resulted in a 96% successful hatch rate of ducks.

One limitation of the study may have been the small size of the plots in the Cache/Box Elder study area. It may have been easy for pheasant chicks to disperse out of treated or untreated plots, because the plots were only 5.25 km wide. If this happened, it would mask any effect on increased pheasant recruitment. Chesness et al. (1968) argued that pheasants nesting in a larger study site would be less likely to disperse from the site, given that the area of the plot in relation to its edge would be greater than in small-sized plots. In study a by Hanson and Progulske (1973), the average home range for hens with broods was 36 ± 19ha. Thus dispersal out of a plot 1000 ha (10 $km^2$) in size is feasible.

It is possible that the treated plots in the Cache/Box Elder study area, being 10.5 $km^2$, created a small sink whereby the immigration of predators into them negated any reduction in predator numbers caused by the treatment. Sargeant et al. (1995) also found that it was difficult to effectively remove predators from small (<25 $km^2$), scattered tracts in an area where the mammalian predator community was diverse. The Cache/Box Elder study area does indeed have a diverse predator community, consisting of at least 5 mammalian predator species and 3 avian species during the pheasant nesting season.

If those species that are controlled for have high dispersal rates, as well as high dispersal distances, such as raccoons, these species will quickly fill in the gaps of territories provided by predator removal. In an area that can support a large population of several species of mammalian predators, such as Cache Valley, predator removal must be effective for all the species of concern, which includes those with high dispersal rates, such as raccoons, and low dispersal rates, such as skunks.

There have been several predator removal studies conducted in larger areas to promote ground-nesting game species that were successful (Balser et al. 1968, Chesness et al. 1968, Beasom 1974, Trautman et al. 1974). Garretson et al. (1996) removed red foxes, raccoons, and skunks from plots 41.4 $km^2$, and found that treated sites had much higher duck nest success rates than untreated plots. Additionally, Trautman et al. (1974) reported an increase in pheasant recruitment in treated plots that were 259 $km^2$ in size when fox, raccoons, badgers, and skunks were removed. Larger studies are often more effective because more immigrants are required to fill in the vacant territories left by predator removal. Additionally, it will take animals with smaller home range sizes or dispersal distances longer to find these open territories.

In the Sevier/Sanpete study area, larger plot sizes were used to test the effect of increased scale on the efficacy of predator removal. The use of larger plots required sacrificing replications. As a result, statistical analyses were not conducted on the data from these plots. However, predator removal did result in an increase of pheasant numbers. There was consistently twice the number of pheasants seen in treated plots than in untreated plots. During the trapping period, there were more pheasants observed in treated plots than untreated plots during the winter counts for the last 3 years of the study, and in every year of the spring crowing counts. After the trapping period, there continued to be more pheasants recorded in the treated plots than in untreated plots--during 3 of the 4 years of the study during the summer counts, and for all 4 years of the autumn counts.

Although there were consistently higher numbers of pheasants seen in treated plots than in untreated plots, hunters did not have a higher pheasant harvest. Additionally, hunters did not consistently observe a greater number of pheasants in treated plots. Finally, hunter satisfaction was higher in untreated plots than in treated sites, each year of the study. One plausible reason to explain this occurrence may be that pheasant stocking occurred near one of the untreated plots during some years of the study. Stocking would not have affected fall pheasant surveys, because these surveys were completed before stocking began on the night before opening day of the pheasant hunt; however, stocked pheasants may have influenced the number of pheasants observed during the hunt, and hunter satisfaction in one of our untreated plots.

Although pheasant populations responded to predator removal, avian predator numbers and the number of their active nests did not differ between treated and untreated plots in this study site. However, the Sevier/Sanpete study area is possibly limited in the number of areas suitable for avian predator nesting, such as large trees for hawk nesting. There are very few tall trees in this region, most located next to houses or along irrigation ditches and streams. However, there are many small, shrubby trees that may provide suitable habitat for magpies.

These results suggest that predator removal may have been more effective when applied to a larger study area. Although predator numbers returned to similar levels each year of the study, as seen by the predator take each trapping period, pheasant recruitment was better in the Sevier/Sanpete study area than in the Cache/Box Elder study area. Perhaps it took a longer time for predator numbers to return to the sink created by predator removal in the larger study plots, thereby allowing enough time for pheasants to raise their broods before predator numbers returned to pre-trapping levels. Data from the avian predators surveys from both study sites suggest that avian predators do not respond to mammalian predator numbers by increasing in those areas where mammalian predators were removed. A plausible explanation for this may be that avian predators are migratory, and thus are not in the study areas long enough to detect a difference in mammalian predator numbers in these areas.

Hunter harvest rates were not positively affected by the increase in pheasant numbers in treated sites in the Sevier/Sanpete study area. Although each study plot had a different level of hunter access within, hunters were approached as they were exiting the field after hunting, to ensure that the hunters we surveyed did have access to hunt. Hence all results are calculated by surveys from hunters that did hunt during the opening day and thus reflected conditions in only the areas open to hunting within our study plots.

# CONCLUSION

This study demonstrated that predator removal is not always an effective measure to improve pheasant recruitment. There are many factors involved in the process of increasing pheasant recruitment through predator removal. First, one must consider the predator community and the effort involved in decreasing the population of these animals. It has been shown in past studies that it is difficult to decrease the number of predators in an area if the predator community is diverse (Sargeant et al. 1995). In Cache and Box Elder counties, the increase in agriculture and urbanization has created environments suitable for many mammalian species. For example, without irrigation ditches and human sources of water, most of Utah would be too dry to support raccoon populations (Durrant 1952). Human development has created cover for many species from an increase in barns, old houses, basements, log piles, etc. Often with an increase in agriculture, comes an increase in small mammals such as field mice and house mice, which support populations of foxes, raccoons, and badgers.

Second, the duration and timing of predator removal may affect pheasant recruitment. Studies that were successful in increasing pheasant numbers used predator removal for extended periods of time--some throughout the duration of their study. Additionally, the size of the treated area may also affect the extent of decreased predator numbers. Small treatment areas do not appear to be able to decrease predator numbers sufficiently enough to increase pheasant recruitment; instead they become a sink for other predators to move into. Additionally, predation management may possibly be expensive. Chesness et al. (1968) reported that their study had a cost of $21.00 per predator taken or $4.50 for every pheasant chick produced.

One must keep also keep in mind the condition of the pheasant habitat in the areas to be studied. Even if predators are essentially eradicated from an area, if it does not include suitable habitat for nesting, cover, and food resources, little increase in pheasant recruitment will occur. With this in mind, predator removal used in conjunction with habitat improvement may achieve the greatest increase in pheasant recruitment.

Managers should weigh beforehand the cost of the predator removal required to increase pheasant recruitment to the possible extent for the area in consideration. Medium-sized predators are important to the natural balance of the environment. Mass removal of this foraging niche affects aspects of the resource balance in minute ways that are often hard to calculate. Additionally, values of the public have changed since projects concerning predator removal began. The public places a higher value on predators than in past years (Messmer and Rohwer 1996). The benefits of predators to the public are often intangible, yet nonetheless important. Often, the public does not condone large-scale predator removal projects and these projects are under increasing scrutiny. In the future, attempts to increase recruitment may benefit the most by combining habitat improvement and management with predator control.

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# APPENDIX

Table A1: ANOVA comparing pheasant numbers recorded in treated and untreated plots during winter surveys, Cache/Box Elder study sites 1996-1999.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.42 | 0.53 |
| Treatment | 1 | 0.91 | 0.36 |
| Year | 1 | 3.06 | 0.1 |
| Order*Treatment | 1 | 0.17 | 0.69 |
| Order*Year | 1 | 0.02 | 0.89 |
| Treatment*Year | 1 | 0.92 | 0.35 |

Table A2: ANOVA comparing pheasant numbers recorded in treated and untreated plots during spring crowing counts, Cache/Box Elder study sites 1996-1999.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 2.16 | 0.17 |
| Treatment | 1 | 0.00 | 0.97 |
| Year | 1 | 1.52 | 0.23 |
| Order*Treatment | 1 | 0.08 | 0.79 |
| Order*Year | 1 | 0.31 | 0.59 |
| Treatment*Year | 1 | 4.11 | 0.06 |

Table A3: ANOVA comparing pheasant numbers recorded in treated and untreated plots during summer brood count surveys, Cache/Box Elder study sites 1996-1999.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.12 | 0.74 |
| Treatment | 1 | 2.03 | 0.18 |
| Year | 1 | 0.28 | 0.6 |
| Order*Treatment | 1 | 1.45 | 0.26 |
| Order*Year | 1 | 0.59 | 0.45 |
| Treatment*Year | 1 | 1.16 | 0.3 |

Table A4: ANOVA comparing pheasant numbers recorded in treated and untreated plots during fall surveys, Cache/Box Elder . study sites 1996-1999.

| Effect | DF | F Value | Pr >F |
|---|---|---|---|
| Order | 1 | 2.66 | 0.13 |
| Treatment | 1 | 0.57 | 0.47 |
| Year | 1 | 1.21 | 0.29 |
| Order*Treatment | 1 | 3.24 | 0.1 |
| Order*Year | 1 | 0.17 | 0.68 |
| Treatment*Year | 1 | 0.08 | 0.78 |

Table A5: ANOVA comparing pheasant numbers in treated and untreated plots with seasons combined, Cache/Box Elder study sites 1996-1999.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 2.56 | 0.14 |
| Treatment | 1 | 0.10 | 0.76 |
| Year | 1 | 1.14 | 0.29 |
| Season | 3 | 28.16 | <0.001 |
| Order*Treatment | 1 | 0.00 | 0.97 |
| Order*Year | 1 | 0.04 | 0.85 |
| Order*Season | 3 | 0.54 | 0.65 |
| Treatment*Year | 1 | 3.97 | 0.05 |
| Treatment*Season | 3 | 1.44 | 0.23 |
| Year*Season | 3 | 1.69 | 0.17 |

Table A6: ANOVA comparing hunter harvest rates recorded in treated and untreated plots during pheasant hunter surveys, Cache/Box Elder study sites 1996-1999.

| Factor | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.13 | 0.73 |
| Treatment | 1 | 0.06 | 0.82 |
| Year | 1 | 0.14 | 0.71 |
| Order*Treatment | 1 | 0.29 | 0.6 |
| Order*Year | 1 | 0.05 | 0.92 |
| Treatment*Year | 1 | 0.44 | 0.51 |

Table A7: ANOVA comparing pheasants counted by hunters as recorded in treated and untreated plots during pheasant hunter surveys, Cache/Box Elder study sites 1997-1999*.

| Factor | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.1 | 0.76 |
| Treatment | 1 | 0.05 | 0.83 |
| Order*Treatment | 1 | 0.14 | 0.71 |

*the mean of 1998 and 1999 was combined and compared to the mean of 1997.

Table A8: ANOVA comparing the level of satisfaction recorded in treated and untreated plots during pheasant hunter surveys, Cache/Box Elder study sites 1997-1999*.

| Factor | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.01 | 0.91 |
| Treatment | 1 | 0.12 | 0.73 |
| Order*Treatment | 1 | 0.62 | 0.46 |

*the mean of 1998 and 1999 was combined and compared to the mean of 1997.

Table A9: ANOVA comparing the number of tracks seen in treated and untreated plots during summer counts, Cache/Box Elder study sites, 1996-1999.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.02 | 0.90 |
| Treatment | 1 | 1.7 | 0.22 |
| Year | 1 | 16.9 | 0.0005 |
| Order*Treatment | 1 | 51.05 | <0.0001 |
| Order*Year | 1 | 0.17 | 0.68 |
| Treatment*Year | 1 | 0.28 | 0.61 |

Table A10: ANOVA comparing the number of tracks seen in treated and untreated plots during fall counts, Cache/Box Elder tudy sites 1996-1998*.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.01 | 0.92 |
| Treatment | 1 | 0.28 | 0.61 |
| Order*Treatment | 1 | 36.62 | 0.0001 |

*the mean of 1996 and 1997 was combined and compared to the mean of 1998.

Table 11: ANOVA comparing the number of avian predators located in treated and untreated plots in the Cache/Box Elder study sites 1996-1999.

| Effect | DF | F value | Pr >F |
|---|---|---|---|
| Order | 1 | 0.05 | 0.84 |
| Treatment | 1 | 0.13 | 0.73 |
| Year | 1 | 0.57 | 0.46 |
| Order*Treatment | 1 | 31.23 | 0.0002 |
| Order*Year | 1 | 0.01 | 0.94 |
| Treatment*Year | 1 | 0.38 | 0.54 |

Table 12: ANOVA comparing the number of active avian predator nests counted in treated and untreated plots during surveys, Cache/Box Elder study sites 1996-1999.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.02 | 0.88 |
| Treatment | 1 | 0.04 | 0.84 |
| Year | 1 | 0.97 | 0.34 |
| Order*Treatment | 1 | 0 | 0.97 |
| Order*Year | 1 | 0.85 | 0.37 |
| Treatment*Year | 1 | 0.11 | 0.75 |

Table 13: ANOVA comparing the number of small mammals trapped in treated and untreated plots, Cache/Box Elder study sites 1997-1999*.

| Effect | DF | F Value | Pr > F |
|---|---|---|---|
| Order | 1 | 0.08 | 0.78 |
| Treatment | 1 | 4.29 | 0.07 |
| Order*Treatment | 1 | 8.44 | < 0.0001 |

*the mean of 1998 and 1999 were combined and compared to the mean of 1997.