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Quantifying the edge effects associated with predator removal blocks on the nesting success of upland ducks in North Dakota

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QUANTIFYING THE EDGE EFFECTS ASSOCIATED WITH PREDATOR REMOVAL BLOCKS ON THE NESTING SUCCESS OF UPLAND DUCKS IN NORTH DAKOTA

A Thesis

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Dedication

This thesis is dedicated to my parents, Bryant and Jean Kuhn, who have, and will continue to, support and encourage me in everything I do. I love you both.

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Thank you to my parents for their unwavering love and support. Last but not least, thank you to Ryan Darr, for his love and for supporting my decision to pursue graduate studies, even if it meant we would be far apart for several years.

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Abstract

Much evidence suggests that nest success is one of the key drivers of duck production. Accordingly, for the past thirty years, waterfowl managers have focused their efforts on increasing nest success. One way to increase nest success is through predator trapping. Previous studies have shown that predator trapping increases nest success on different sized trapped blocks. This study attempted to answer the question: does trapping affect nest success on areas directly adjacent to trapped block boundaries? I hypothesized that predator abundance outside trapped blocks would be reduced. I predicted that nest success would decline with distance from the boundary while predator abundance would increase with distance from the boundary. This study was conducted in the Drift Prairie section of the Prairie Pothole Region in northeast North Dakota during the summers of 2005 and 2006. A total of 3,231 nests were found inside of six trapped blocks and a total of 2,006 nests were found outside of five trapped blocks. Daily survival rates were estimated using Shaffer's logistic-exposure model and then related to distance from the center (for inside) or distance from the edge (for outside) of a trapped block, trapped block, field within a trapped block, and all interactions. Model fit was assessed using Akaike's information criteria as adjusted for small sample size. The most important variables for explaining variation in daily survival rates of nests, both inside and outside trapped blocks, were year, and field within a trapped block. Distance appeared to have a negligible effect on daily survival rates for nests inside and outside trapped blocks. Mean daily survival rates were higher inside trapped blocks. Trapping, therefore, did not appear to increase daily survival rates outside trapped blocks. Predator scent-stations were used in 2006 to obtain an index of predator activity. Distance from a trapped block edge did not affect visitation rates for any individual predator species or for all species combined, both inside and outside trapped blocks. There were,

however, significantly higher visitation rates inside versus outside trapped blocks for raccoons and for all species combined.

Introduction

The Prairie Pothole Region (PPR) of the United States and Canada is the primary breeding ground for most North American waterfowl (Bellrose 1980). Much evidence suggests that nest success is one of the key drivers of duck production in the PPR; however, nest success levels are often below the 15-20% necessary to maintain population levels (Klett et al. 1988, Kantrud 1993, Greenwood et al. 1995, Beauchamp et al. 1996, Sovada et al. 2000, Garrettson and Rohwer 2001, Hoekman et al. 2002, Drever et al. 2004).

There are many factors that contribute to nest failure, but predation by mammals, especially red fox (*Vulpes vulpes),* raccoon (*Procyon lotor)*, and striped skunk (*Mephitis mephitis),* is the primary cause (Greenwood 1986, Klett et al. 1988, Johnson et al. 1989, Sargeant et al. 1993, Greenwood et al. 1995). For the past thirty years, managers have focused their efforts on increasing nest success through habitat improvements (Rohwer et al. 2004). Efforts at habitat restoration have ranged from planting more grass and acquiring more nesting habitat to constructing nesting islands and other safe nesting sites (Duebbert and Lokemoen 1976, Giroux 1981, Duebbert et al. 1983). More direct efforts to reduce nest predation include the fencing of nesting cover to exclude predators (Lokemoen et al. 1982, Greenwood et al. 1990, Lokemoen and Woodward 1993). Unfortunately, most of the aforementioned techniques have proven less effective than hoped, prohibitively expensive, or not applicable to many areas. Nesting success has been suggested to be dependent upon habitat patch size, with larger patch sizes having higher success (Greenwood et al. 1995, Sovada et al. 2000, Reynolds et al. 2001). Habitat restoration, through the planting of grass, however, is expensive and nest success has been suggested to have a linear relationship with the amount of cover available (i.e. more cover equals higher success; Reynolds et al. 2001). Creating more cover is something that is difficult in the farmland matrix

of the PPR (Rohwer et al. 2004). Predator fences were initially thought to work well until it was discovered that they delayed the exit of ducklings and elevated duckling mortality (Peitz and Krapu 1994, Trottier et al. 1994). To mediate this problem, managers have added brood exits or opened fences into water. This solution speeds brood exit but also allows predators to enter the fenced area.

Lethal predator management has also been used to increase nest success. Early predator reduction efforts relied on poisons, which are now illegal for widespread use (Balser et al. 1968, Lynch 1972, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980). In 1993, the Delta Waterfowl Foundation initiated research to examine the efficiency of predator reduction through legal trapping. The initial study, conducted by Pam Garrettson from 1994 to 1996, compared nest success on nine, 41.5 km^2 trapped blocks with nine, 41.5 km^2 untrapped blocks. Trapping dramatically increased nest success, with trapped blocks experiencing nearly twice the nest success of untrapped blocks (42% vs. 23% respectively; Garrettson and Rohwer 2001). Other studies with different sized trapped blocks have shown similar results: trapping predators can substantially increase nest success (see Table 1). In addition, a study conducted by Aaron Pearse showed that trapping also increased duckling survival (Pearse and Ratti 2004).

Trapping predators on prime duck nesting habitat has proven to be a viable management option for increasing nest success. Nothing is known, however, about what happens to nest success on areas directly adjacent to trapped block boundaries. As a result, this study attempted to answer the following question: does trapping affect nest success on areas directly adjacent to trapped block edges? I hypothesized that predator abundance outside trapped blocks would be reduced. I predicted that nest success would decline with distance from the boundary while

Table 1. Research conducted on different sized predator trapped blocks and its effect on nest success.

Researcher	Date	Years of Study	Size of Trapped Block	Experimental vs. Control Nest Success (%)
Sargeant et al.	1995	4	0.61 - 3.01 km^2	14 vs. 6
Mense	1996	2	41.5 km^2	57 vs. 29
Hoff	1999	2	93.2 km^2	36 vs. 15
Garrettson and Rohwer	2001	3	41.5 km^2	42 vs. 23
Chodachek and Chamberlain	2006	2	2.6 km^2	53 vs. 29
Lester	unpublished	2	41.5 km^2	48 vs. 19
Oligschlaeger	unpublished	2	93.2 km^2	49 vs. 23

predator abundance would increase with distance from the boundary. I could not predict the shape of the decline, but I expected it to have a rather smooth shape due to reduced predator numbers (See Figure 1).

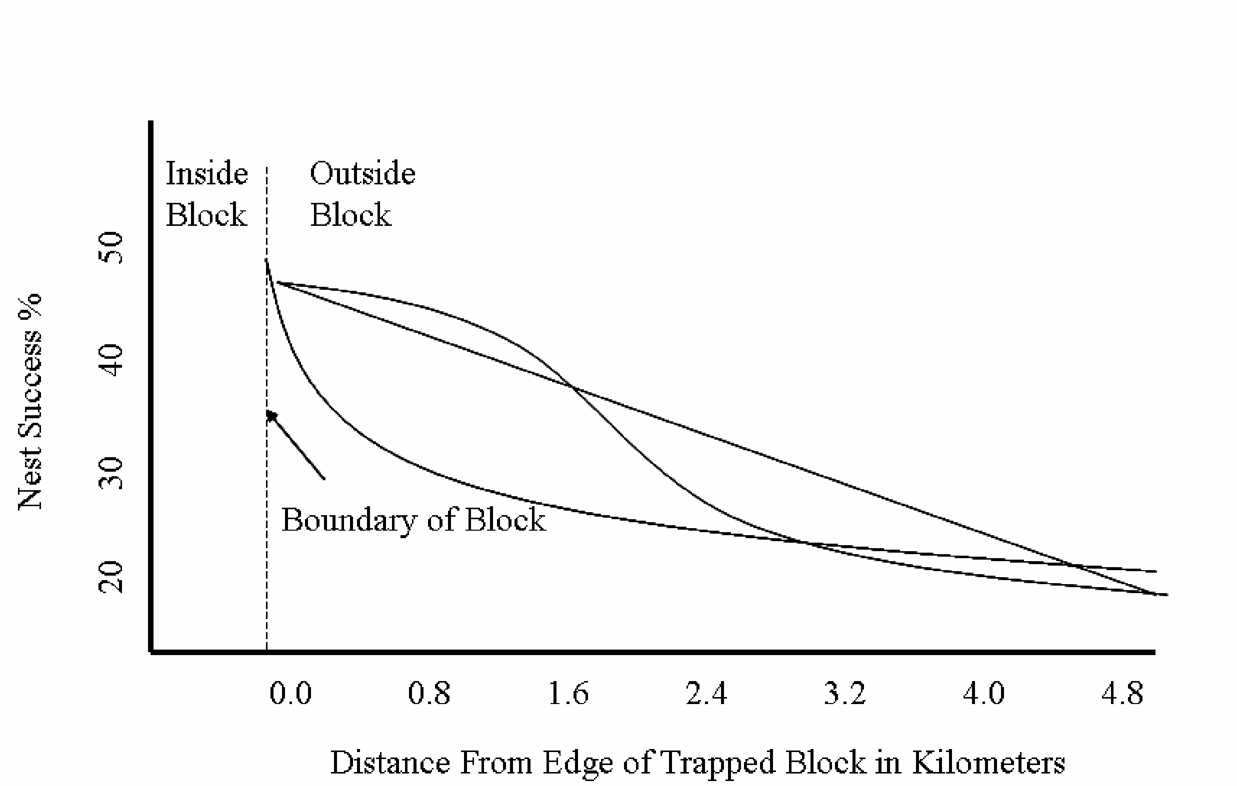

Figure 1. Possible shapes of the hypothesized nest success decline as you move further from a trapped block edge.

Study Site and Study Design

Nest Success

This study was conducted during the summers of 2005 and 2006 in the Drift Prairie section of the PPR in northeast North Dakota. Nest success of all upland nesting duck species was examined, but the primary focus was on the five most common species: blue-winged teal (*Anas discors),* gadwall (*A. strepera*), mallard (*A. platyrhynchos*), northern shoveler (*A. clypeata*), and northern pintail (*A. acuta;* Bellrose 1980, Johnson and Grier 1988). For both years, 32.4 ha fields of grass were searched for nests both inside of six trapped blocks and outside of five trapped blocks. In the 2006 season, one trapped block studied in 2005 was replaced with a new trapped block. Outside the trapped blocks, fields were searched in 0.8 km increments up to 4.8 km from the edge of the trapped block. Landowner permission often limited the number of fields that were available for nest searching. Owners of suitable fields were contacted for permission to search for nests. Fields were then randomly chosen only from those areas on which permission was granted. If there was no 32.4 ha field of grass available to search at any particular distance interval, then an additional 32.4 ha field at the same distance interval on another trapped block was selected. The number of 32.4 ha fields, both inside and outside trapped blocks, was kept as even as possible to prevent some trapped blocks from having disproportionate representation in the data.

Nest searching started in early May and continued until mid-July in both years. Nests were located by dragging a 50 m chain between two all terrain vehicles (Klett et al. 1986). Outside the trapped blocks, fields were searched at least twice per season. Inside the blocks, fields were searched three times per season. Nests were marked with a numbered wooden stake 10 m north of the nest and with a metal rod (3.2 mm diameter and 0.9 m length) at the nest bowl.

The following was recorded for each nest: species, date found, dates checked, clutch size, incubation stage (determined by candling of at least two eggs; Weller 1956) GPS coordinates, hatch date if successful, failure date if not successful, and cause of failure. Nests were checked approximately every eight days until fate was determined (Klett et al. 1986). A nest was considered successful if at least one egg hatched (Klett et al. 1986).

Predator Scent-Stations

During the 2006 field season, scent-stations were used to obtain an index of predator activity both inside and outside trapped blocks. Stations consisted of a 1 m in diameter circle of sand and mineral oil mixture (1 liter of oil to 22 liters of sand). The sand and mineral oil mixture served as a tracking medium and one sardine placed in the center of the sand served as a lure (Linhart and Knowlton 1975, Roughton and Sweeny 1982, Conner et al. 1983, Nottingham et al. 1989, Travaini et al. 1996, Sargeant et al. 1998, Sargeant et al. 2003).

Scent-stations were located at the edge of unpaved roads as close to the vegetation as possible. Inside the trapped blocks, stations were set up in 0.8 km increments, starting at the center of the block and progressing toward the perimeter of the block in all cardinal directions. Adjacent stations were put on alternate sides of the road.

Outside the trapped blocks, stations were put out in 0.8 km increments up to 4.8 km from the block edge in all cardinal directions. Lines were alternately started at either the block edge or 0.8 km from the block edge.

Scent-stations were set up in the afternoon on days with no rain in the forecast and checked once the following morning for tracks. All tracks were identified but only nest predators were included in the analysis. Predators used in the analysis included the coyote (*Canis latrans)*, raccoon, red fox, striped skunk, badger (*Taxidea taxus)*, mink (*Mustela vison)*,

and Franklin's ground squirrel (*Spermophilus franklinii;* Sargeant 1972, Fritzell 1978, Greenwood 1981, Sargeant et al. 1984, Arnold and Fritzell 1987, Choromanski-Norris et al. 1989, Sargeant et al. 1993, Sovada et al. 1995, Greenwood et al. 1999).

Statistical Analyses

Nest Success

Daily survival rates for individual nests, both inside and outside trapped blocks, were estimated using Shaffer's logistic-exposure model (Shaffer 2004) and PROC GENMOD (SAS Institute 1999). Daily survival rates were related to four explanatory variables including, distance from center or edge of a trapped block, trapped block, field within a trapped block, year, and their interactions. Model fit was assessed using Akaike's information criterion as adjusted for small sample size (AICc; Burnham and Anderson 2002). Daily survival rates were modeled separately for nests found inside and outside trapped blocks.

Twenty-one candidate models were selected to model daily survival rates inside trapped blocks, including a constant survival model. The interaction between the variables field within a trapped block and distance was omitted due to unusual patterns in the data that prevented the model likelihood from being maximized. Unusual patterns in data tend to occur in complex candidate models or in studies in which sample size is not under strict control (T. L. Shaffer pers. comm.). Nineteen candidate models were selected to model daily survival rates outside trapped blocks, including a constant survival model. For analyses outside trapped blocks all interactions with the variable field within a trapped block were omitted due to unusual patterns in the data that prevented the model likelihood from maximizing.

Predator Scent-Stations

An Analysis of Covariance (PROC LOGISTIC, SAS Institute 1999) was used to test for a distance (from edge of a trapped block) effect on scent-station visitation rates inside and outside trapped blocks. Visitation rates were related to the following variables: distance from the edge of a trapped block (continuous), inside or outside a trapped block (categorical with two levels),

trapped block (categorical with five levels), and all interactions. Separate analyses were done for each predator species and for all predators combined.

A Logistic Regression (PROC LOGISTIC, SAS Institute 1999) was used to test for a difference between scent-station visitation rates inside and outside trapped blocks. Presence at a scent-station was related to the categorical variable inside or outside of a trapped block. Separate analyses were done for each predator species and for all predators combined.

Results

Nest Success

A total of 3,231 nests were found in both years inside the trapped blocks. Of those, 117 were destroyed by investigators or farm equipment and thus were not suitable for use in the analysis. A total of 2,006 nests were found in both years outside the trapped blocks. Of those, 54 were not suitable for use in the analysis.

Of the 21 candidate models for inside trapped blocks, the three most supported had ΔAIC_C values <2.007 and Akaike weights >0.182. The remaining models had ΔAIC_C values >28 and Akaike weights of zero (Table 2). The most supported model, with a ΔAIC_C value of zero and an Akaike weight of 0.497, included the variables field within trapped block, year, distance, and the interaction of field within trapped block and year. The second most supported model, with a ΔAIC_C value of 0.87 and an Akaike weight of 0.321, deleted only the distance variable. The third most supported model, with a ΔAIC_C value of 2.006 and an Akaike weight of 0.182, contained the distance variable and added an interaction of distance and year. Model-averaged regression coefficients for inside trapped blocks supported the above results (Table 3).

Outside trapped blocks, the three most supported models, of the 19 total candidates, had ΔAIC_C values <2.011 and Akaike weights >0.177. The remaining models had ΔAIC_C values >10.9 and Akaike weights <0.002 (Table 4). The most supported model, with a ΔAIC_C value of zero and an Akaike weight of 0.485, contained the variables field within a trapped block, distance, and year. The second most supported model had a ΔAIC_C value of 0.746 and an Akaike weight of 0.334 and deleted only the distance variable. In the third most supported model, which had a ΔAIC_C value of 2.011 and an Akaike weight of 0.177, distance was included

and an interaction of distance and year was added. Model-averaged regression coefficients for outside trapped blocks supported the above results (Table 5).

Mean daily survival rates inside trapped blocks for 2005 and 2006 respectively, were 0.9815 (Standard Deviation: 0.0125) and 0.9872 (Standard Deviation: 0.0115) and mean daily survival rates for outside trapped blocks in 2005 and 2006 respectively, were 0.9667 (Standard Deviation: 0.0191) and 0.9796 (Standard Deviation: 0.0149).

Predator Scent-Stations

During the 2006 field season, a total of 188 scent-stations were set up inside of five trapped blocks. Of those, 24 were destroyed and thus not used in the analysis. A total of 385 stations were set up outside of five trapped blocks. Of those, 42 were destroyed and thus not used in the analysis. Visitation rates for each species were low, with all but one predator (raccoon) having fewer than 18 total visits for both inside and outside trapped blocks (Table 6). Raccoons visited stations, both inside and outside trapped blocks, a total of 38 times (Table 6).

The distance effect was not significant for any predator species, individually or combined (Table 7; Figures 2-9). There was, however, a significant difference between visitation rates inside and outside trapped blocks for raccoons and for all predators combined (Table 8; Figures 2-9). With an odds ratio estimate of 2.358 (95% Confidence Interval: 1.115 – 4.975), raccoons were more than twice as likely to visit a scent-station outside a trapped block than inside. Likewise, with an odds ratio estimate of 1.845 (95% Confidence Interval: 1.193 – 2.849), all predators combined were almost twice as likely to visit scent-stations outside a trapped block than inside.

Table 2. Model selection criteria for all twenty-one logistic-exposure candidate models of daily survival rates inside trapped blocks, 2005-2006. Variables included were: 1) Distance from the center of a trapped block (D); 2) Field within a trapped block (F(B)); 3) Trapped Block (B); 4) Year (Y); and 5) All interactions, with the exception of the interaction of field within a trapped block and distance, which was omitted due to unusual patterns in the data that prevented the model likelihood from maximizing.

Model	K	$Log_e(L)$	AIC_C	ΔAIC_C	ω_i
$S_{F(B) + D + Y + F(B)*Y}$	88	-2491.72	5159.74	0.000	0.49652
$S_{F(B) + Y + F(B)*Y}$	87	-2493.16	5160.61	0.870	0.32134
$S_{F(B) + D + Y + D*Y + F(B)*Y}$	89	-2491.72	5161.75	2.006	0.18213
$S_{F(B) + D + Y}$	61	-2533.07	5188.29	28.550	0.00000
$S_{F(B) + D}$	60	-2534.59	5189.31	29.571	0.00000
$S_{F(B) + Y}$	60	-2534.93	5190.00	30.261	0.00000
$S_{F(B)}$	59	-2536.44	5191.01	31.268	0.00000
$S_{B + Y + D + B*Y + Y*D + D*B}$	20	-2629.17	5298.36	138.622	0.00000
$S_{B + Y + D + B*Y}$	13	-2639.51	5305.02	145.276	0.00000
$S_{B + Y + D + B*Y + Y*D}$	14	-2639.47	5306.96	147.213	0.00000
$S_{B + Y + B*Y}$	12	-2642.07	5308.15	148.407	0.00000
$S_{B + Y + D}$	9	-2648.91	5315.83	156.090	0.00000
$S_{B + Y}$	8	-2651.84	5319.67	159.930	0.00000
$S_{B + D + B*D}$	14	-2647.93	5323.86	164.119	0.00000
$S_{B + D}$	8	-2659.44	5334.88	175.134	0.00000
$S_{Y + D + Y*D}$	4	-2664.88	5337.75	178.009	0.00000
$S_{D + Y}$	3	-2666.43	5338.85	179.112	0.00000
S_{B}	7	-2662.43	5338.86	179.120	0.00000
S_{Y}	2	-2667.90	5339.80	180.056	0.00000
S_{D}	2	-2680.00	5364.00	204.262	0.00000
$S_{\text{Constant Survival}}$	1	-2681.55	5365.10	205.361	0.00000

Table 3. Model-averaged estimates of regression coefficients for inside trapped blocks, 2005-2006. Estimates are from logistic-exposure models relating daily survival rates to distance from the center of a trapped block, trapped block, field within a trapped block, year, and all interactions, with the exception of the interaction of field within a trapped block and distance, which was omitted due to unusual patterns in the data that prevented the model likelihood from maximizing.

Effect	Coefficient	Standard Error	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	5.2711	1.08691	3.09726	7.44490
Distance	-0.0002	0.00026	-0.00075	0.00028
Distance x block	0	0	0	0
Distance x year				
2005	0	0.00008	-0.00016	0.00016
2006	0	0	0	0
Block	0	0	0	0
Block x year	0	0	0	0
Field (block) [a]				
Bowdon	0.4652	0.65686	-0.84854	1.77892
Cando	1.5450	0.79482	-0.04461	3.13466
Harlow	-0.1065	0.55199	-1.21045	0.99753
McVille	-0.0192	0.56115	-1.14154	1.10307
Minnewauken	-1.0312	0.46830	-1.96780	-0.09462
Pleasant Lake	-0.2083	0.63815	-1.48456	1.06805
Whitman	-1.1323	0.83285	-2.79799	0.53342
Field (block) x year [b]				
2005	-0.9392	1.12551	-3.19025	1.31180
2006	0	0	0	0
Year				
2005	0.4871	0.71816	-0.94924	1.92341
2006	0	0	0	0

[a] Due to the large number of fields, regression coefficients are shown for only one randomly chosen field for each block.

[b] Due to the large number of fields, regression coefficients are shown for only one randomly chosen field.

Table 4. Model selection criteria for all nineteen logistic-exposure candidate models of daily survival rates outside trapped blocks, 2005-2006. Variables included were: 1) Distance from the edge of a trapped block (D); 2) Field within a trapped block (F(B)); 3) Trapped block (B); 4) Year (Y); and 5) All interactions, with the exception of any interactions with field within a trapped block, which were omitted due to unusual patterns in the data that prevented the model likelihood from maximizing.

Model	K	$Log_e(L)$	AIC_C	ΔAIC_C	ω_i
$S_{F(B) + D + Y}$	87	-1891.89	3958.32	0.000	0.48500
$S_{F(B) + Y}$	86	-1893.27	3959.07	0.746	0.33408
$S_{F(B) + D + Y + D*Y}$	88	-1891.89	3960.33	2.011	0.17743
$S_{F(B) + D}$	86	-1898.39	3969.30	10.981	0.00200
$S_{F(B)}$	85	-1899.70	3969.91	11.587	0.00148
$S_{B + Y + B*Y}$	10	-2000.08	4020.16	61.839	0.00000
$S_{B + Y}$	7	-2003.13	4020.27	61.947	0.00000
$S_{B + Y + D + B*Y + Y*D}$	12	-1999.01	4022.04	63.718	0.00000
$S_{B + Y + D + B*Y}$	11	-2000.06	4022.13	63.806	0.00000
$S_{B + Y + D}$	8	-2003.12	4022.25	63.924	0.00000
$S_{Y + D + Y*D}$	4	-2010.81	4029.62	71.298	0.00000
$S_{B + Y + D + B*Y + Y*D + D*B}$	17	-1998.14	4030.31	71.990	0.00000
S_{Y}	2	-2013.32	4030.65	72.325	0.00000
$S_{D + Y}$	3	-2013.17	4032.33	74.011	0.00000
S_{B}	6	-2016.77	4045.55	87.231	0.00000
$S_{B + D}$	7	-2016.77	4047.55	89.232	0.00000
$S_{B + D + B*D}$	12	-2015.44	4054.89	96.569	0.00000
$S_{Constant\ Survival}$	1	-2036.02	4074.05	115.727	0.00000
S_{D}	2	-2035.95	4075.90	117.581	0.00000

Table 5. Model-averaged estimates of regression coefficients for outside trapped blocks, 2005-2006. Estimates are from logistic-exposure models relating daily survival rates to distance from the edge of a trapped block, trapped block, field within a trapped block, year, and all interactions, with the exception of any interactions with field within a trapped block, which were omitted due to unusual patterns in the data that prevented the model likelihood from maximizing.

Effect	Coefficient	Standard Error	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Intercept	4.5523	0.52721	3.49784	5.60668
Distance	-0.0002	0.00019	-0.00058	0.00020
Distance x block	0	0	0	0
Distance x year				
2005	0	0.00001	-0.00003	0.00002
2006	0	0	0	0
Block	0	0	0	0
Block x year	0	0	0	0
Field (block)[a]				
Bowdon	-0.1015	0.90226	-1.90605	1.70297
Cando	0.2820	0.62091	-0.95985	1.52379
Harlow	0.0642	0.61112	-1.15801	1.28648
McVille	0.5646	0.84047	-1.11636	2.24550
Pleasant Lake	0.2582	1.11534	-1.97244	2.48891
Whitman	-0.2129	0.50777	-1.22844	0.80262
Year				
2005	-0.3417	0.11175	-0.56517	-0.11817
2006	0	0	0	0

[a] Due to the large number of fields, regression coefficients are shown for only one randomly chosen field for each block.

Table 6. Number of scent-station visits per 0.8 kilometer increment for each predator species, inside and outside trapped blocks, 2006

Block		Distance (km)	Badger	Coyote	Franklin's Ground Squirrel	Mink	Raccoon	Red Fox	Striped Skunk	Total
Bowdon		-4	0	0	0	0	0	0	1	1
		-3.2	1	0	0	0	0	0	0	1
	Inside	-2.4	0	0	0	0	0	0	0	0
		-1.6	0	0	0	0	1	0	1	2
		-0.8	0	0	1	1	1	0	0	3
		0	0	0	0	0	1	0	0	1
		0.8	0	0	0	0	2	1	0	3
		1.6	0	0	0	0	1	0	0	1
	Outside	2.4	0	1	0	0	2	0	1	4
		3.2	0	0	0	0	1	0	0	1
		4	0	1	0	1	1	0	0	3
		4.8	0	1	0	0	0	0	0	1
Cando		-4	0	0	0	0	0	0	0	0
		-3.2	0	0	0	0	0	0	0	0
	Inside	-2.4	0	0	0	0	1	0	2	3
		-1.6	0	0	0	0	0	0	2	2
		-0.8	0	0	0	0	0	1	0	1
		0	0	0	0	0	1	0	0	1
		0.8	0	0	0	0	1	0	0	2
		1.6	0	0	1	0	0	1	0	2
	Outside	2.4	0	0	0	0	0	0	0	0
		3.2	0	0	0	0	0	0	0	0
		4	0	0	0	0	1	0	0	1
		4.8	0	0	0	1	0	1	0	2

table continued

Block		Distance (km)	Badger	Coyote	Franklin's Ground Squirrel	Mink	Raccoon	Red Fox	Striped Skunk	Total
Harlow		-4	0	0	0	0	0	0	0	0
		-3.2	0	0	0	0	0	0	0	0
	Inside	-2.4	0	0	0	0	0	0	0	0
		-1.6	0	0	0	0	0	0	0	0
		-0.8	0	0	0	0	0	1	1	2
		0	0	0	0	0	1	0	0	1
		0.8	0	0	0	0	0	0	0	0
		1.6	0	0	0	1	1	0	0	2
	Outside	2.4	0	0	0	0	3	0	1	4
		3.2	0	0	0	1	0	0	0	1
		4	0	0	0	1	1	1	0	3
		4.8	0	1	0	0	2	1	0	4
McVille		-4	0	0	0	0	1	0	0	1
		-3.2	0	1	0	0	0	0	0	1
	Inside	-2.4	0	0	0	0	0	0	0	0
		-1.6	0	0	0	0	0	0	1	1
		-0.8	0	0	0	1	1	0	0	2
		0	0	0	0	0	1	1	0	2
		0.8	0	0	0	1	2	0	0	3
		1.6	0	0	0	1	1	0	0	2
	Outside	2.4	0	0	0	0	1	2	0	3
		3.2	1	0	0	1	0	2	0	4
		4	0	0	1	0	0	0	0	1
		4.8	0	0	0	0	1	1	0	2

table continued

Block		Distance (km)	Badger	Coyote	Franklin's Ground Squirrel	Mink	Raccoon	Red Fox	Striped Skunk	Total
Whitman		-4	0	0	0	0	0	0	0	0
		-3.2	0	0	0	0	0	1	0	1
	Inside	-2.4	0	0	0	0	0	0	0	0
		-1.6	0	0	0	1	0	1	0	2
		-0.8	0	0	0	0	0	0	0	0
		0	0	0	0	1	1	0	0	2
		0.8	0	0	0	0	0	0	0	0
		1.6	1	0	0	0	2	0	3	6
	Outside	2.4	0	0	1	1	1	0	0	3
		3.2	1	1	0	0	3	1	0	6
		4	0	0	1	0	1	0	0	2
		4.8	0	1	0	0	0	1	1	3
		Total	4	7	5	13	38	17	15	

Table 7. Analysis of covariance of predator scent-station visitation rates by distance from the edge of a trapped block, 2006.

Predator Species	Likelihood Ratio			Distance						
	df	X^2	P	df	Estimate	X^2	SE	L 95% CI	U 95% CI	P
Badger	19	12.2636	0.8740	1	-0.2663	0.0001	27.1775	-53.5333	53.0006	0.9922
Coyote	19	23.6544	0.2097	1	1.5844	0.0011	46.9876	-90.5096	93.6785	0.9731
Franklin's Ground Squirrel	19	11.2753	0.9142	1	0.1804	0.0000	38.3347	-74.9541	75.3150	0.9962
Mink	19	15.8079	0.6701	1	1.9284	0.0032	34.2984	-65.2953	69.1520	0.9552
Raccoon	19	23.5758	0.2129	1	3.8219	0.0282	22.7779	-40.8220	48.4657	0.8668
Red Fox	19	23.8215	0.2031	1	0.9066	0.0014	24.4297	-46.9747	48.7879	0.9704
Striped Skunk	19	20.8911	0.3428	1	-1.8697	0.0061	23.8593	-48.6330	44.8936	0.9375
Predators Combined	19	23.5476	0.2141	1	0.2663	1.9374	0.1913	-0.1087	0.6413	0.1640

Table 8. Logistic regression analysis of predator scent-station visitation rates inside versus outside trapped blocks, 2006.

	Likelihood Ratio				Inside vs. Outside					
Predator Species	df	X^2	P	df	Estimate	X^2	SE	L 95% CI	U 95% CI	P
Badger	1	0.6307	0.4271	1	-0.4332	0.5593	0.5793	-1.5686	0.7022	0.4546
Coyote	1	2.9065	0.0882	1	-0.7858	2.1009	0.5422	-1.8484	0.2768	0.1472
Franklin's Ground Squirrel	1	1.2947	0.2552	1	-0.5789	1.0650	0.5610	-1.6783	0.5206	0.3021
Mink	1	0.9911	0.3195	1	-0.2939	0.9330	0.3043	-0.8902	0.3024	0.3341
Raccoon	1	5.5589	0.0184	1	-0.4280	5.0405	0.1907	-0.8017	-0.0544	0.0248
Red Fox	1	1.5965	0.2064	1	-0.3298	1.4866	0.2705	-0.8599	0.2003	0.2227
Striped Skunk	1	0.5374	0.4635	1	0.1927	0.5363	0.2632	-0.3231	0.7086	0.4640
Predators Combined	1	8.1209	0.0044	1	-0.3059	7.6171	0.1108	-0.5231	-0.0887	0.0058

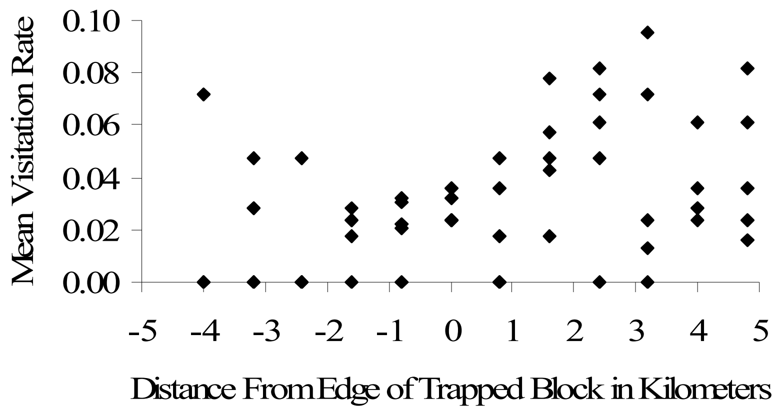

Figure 2. Mean scent-station visitation rates by distance for all predator species combined, 2006. A distance of zero equals the edge of a trapped block.

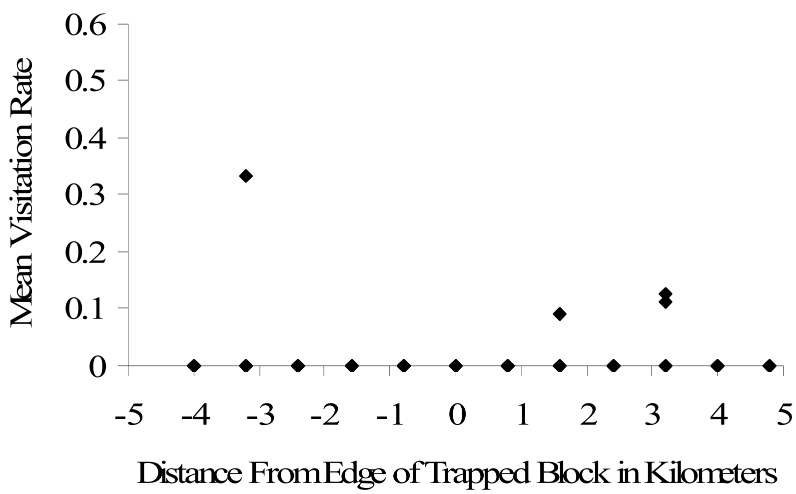

Figure 3. Mean scent-station visitation rates by distance for badger, 2006. A distance of zero equals the edge of a trapped block.

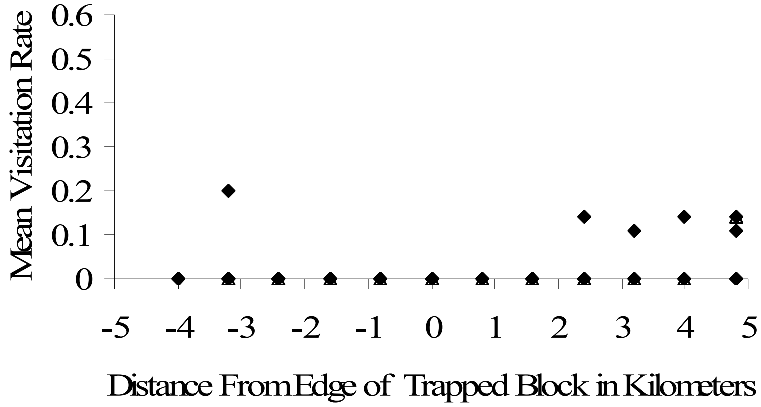

Figure 4. Mean scent-station visitation rates by distance for coyote, 2006. A distance of zero equals the edge of a trapped block.

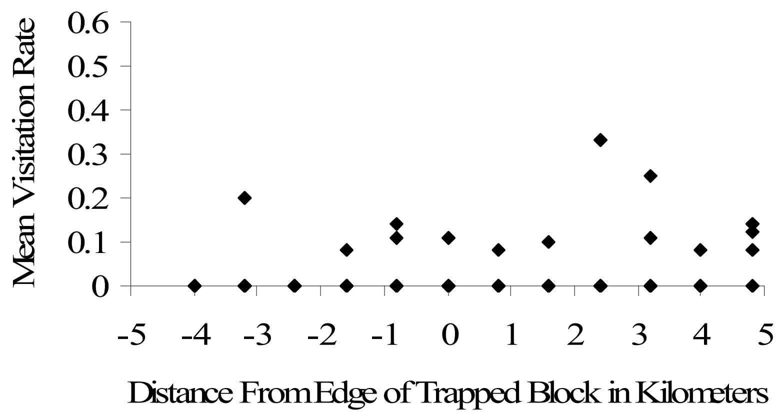

Figure 5. Mean scent-station visitation rates by distance for red fox, 2006. A distance of zero equals the edge of a trapped block.

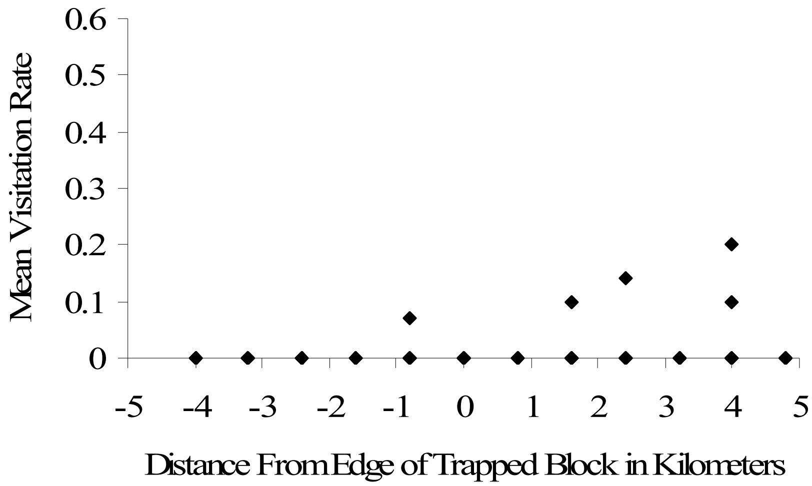

Figure 6. Mean scent-station visitation rates by distance for Franklin's ground squirrel, 2006. A distance of zero equals the edge of a trapped block.

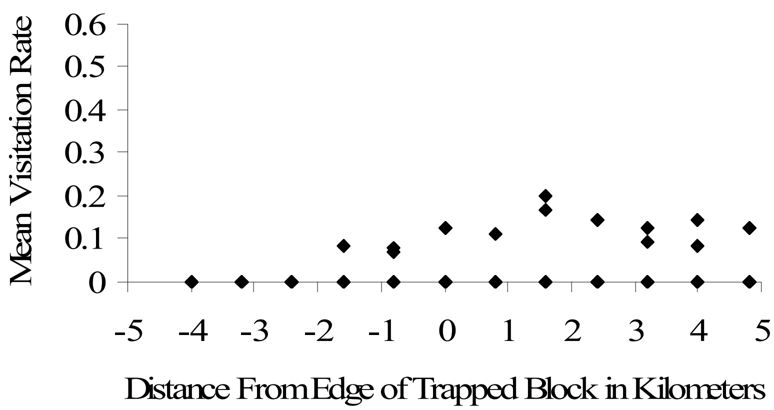

Figure 7. Mean scent-station visitation rates by distance for mink, 2006. A distance of zero equals the edge of a trapped block.

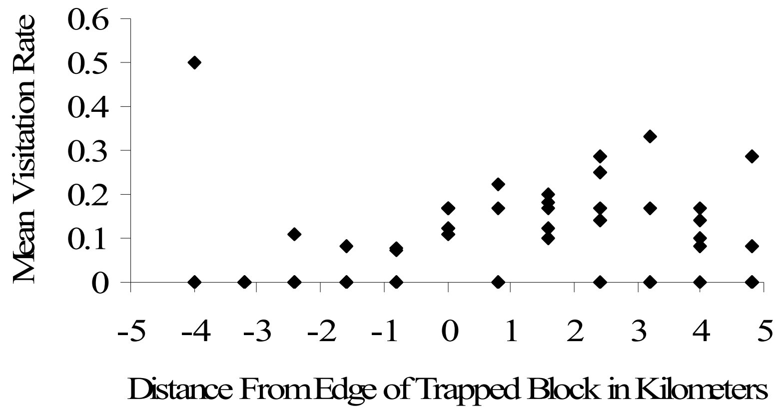

Figure 8. Mean scent-station visitation rates by distance for raccoon, 2006. A distance of zero equals the edge of a trapped block.

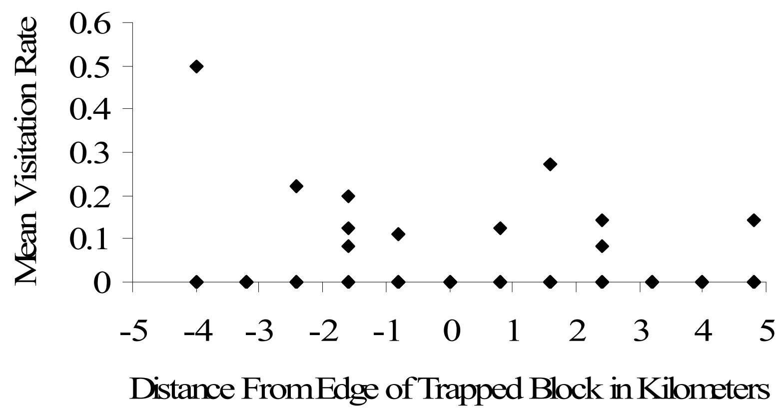

Figure 9. Mean scent-station visitation rates by distance for striped skunk, 2006. A distance of zero equals the edge of a trapped block.

Discussion

Nest Success

The hypothesis for this study was that predator numbers would be reduced outside trapped blocks due to large predator home ranges that presumably straddled or crossed the boundaries of trapped blocks (Sargeant 1972, Fritzell 1978, Lindzey 1978, Andelt and Gipson 1979, Laundre and Keller 1984, Chromanski-Norris 1989, Sargeant et al. 1993). When the predators occupying these home ranges suffered mortality, it was hypothesized that they would leave not only an unoccupied area inside the block, but also one outside the block, leading to higher daily survival rates outside trapped blocks. This hypothesis was clearly rejected. There was a sharp drop off in daily survival rates at the boundaries of trapped blocks and then almost no impact of distance on nest success.

Outside trapped blocks, daily survival rates appeared to be most affected by the variables year and field within a trapped block. All three of the most supported models contained both variables (Table 4). Distance was in two of the three best models suggesting its effect on daily survival rates was negligible. The logistic-exposure daily survival rates for individual nests illustrate this negligible trend with distance from the edge of a trapped block (daily survival rates are based upon the most supported model for outside trapped blocks; Figures 10 and 11). While there is little obvious distance effect, it is clear from the figures that individual fields show a high level of variation. The high variation in daily survival rates for individual fields (Figures 10 and 11) suggests that the field effect was more substantial than the distance effect and that the field effect has little relation with how far the field was from the trapped block edge. The importance of individual fields on daily survival rates may reflect differences in duck nesting habitat (Duebbert and Lokemoen 1976, Klett et al. 1988, Reynolds et al. 2001) or it may reflect predator

abundance (Sargeant 1972, Fritzell 1978, Choromasski-Norris et al. 1989, Sargeant et al. 1993). The numbers of duck nests and predators, as well as the amount and type of vegetation cover are highly variable between and even within individual fields (Horn et al. 2005). Some fields may also be closer to abandoned houses or other man-made structures that are attractive to raccoons (Sargeant et al. 1993). The difference in daily survival rates between years is also evident when comparing Figures 10 and 11.

Daily survival rates inside trapped blocks appeared to be most affected by the variables, year, field within a trapped block, and the interaction of field within a trapped block and year. All three appeared in the three most supported models (Table 2). The distance variable was only included in two of the three best models suggesting its effect on daily survival rates was negligible (Table 2). The logistic-exposure daily survival rates for individual nests illustrate this negligible trend with distance from the center of a trapped block (daily survival rates are based upon the most supported model for inside trapped blocks; Figures 12 and 13). As with outside trapped blocks, the high level of variation in daily survival rates for individual fields (Figures 12 and 13) suggests that the field effect was more substantial than the distance effect and that the field effects are reflecting more than just distance from the center of a trapped block. The variation within years, as with outside trapped blocks, is also evident when comparing figures 12 and 13.

While distance did not appear to have a significant effect on daily survival rates inside or outside trapped blocks, mean daily survival rates were higher, in both years, inside trapped blocks. With daily survival rates not varying much by distance, either inside or outside trapped blocks, and inside having higher mean daily survival rates, it appears as though daily survival rates drop off quickly at the edge of a trapped block. Based upon these results, predator

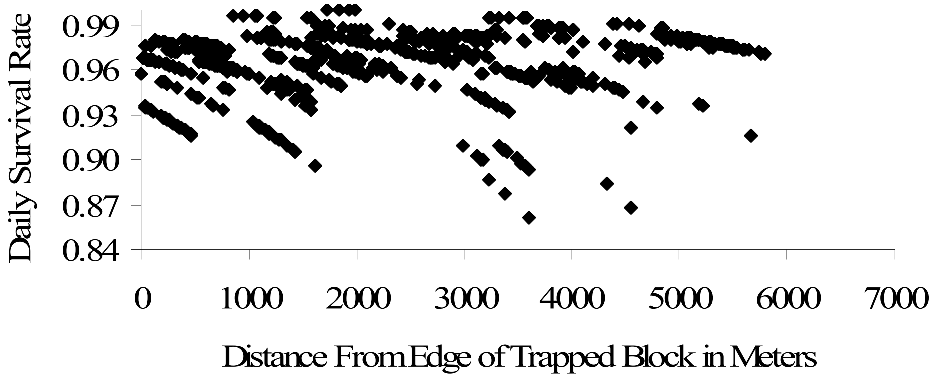

Figure 10. Logistic-exposure daily survival rates by distance for individual nests outside trapped blocks, 2005.

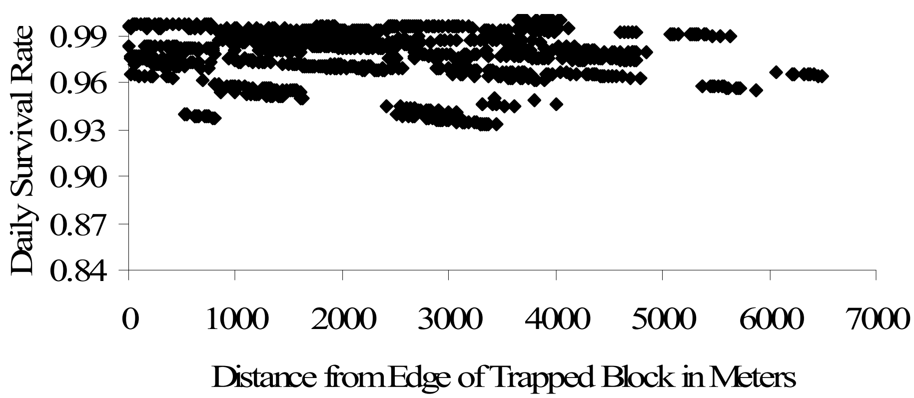

Figure 11. Logistic-exposure daily survival rates by distance for individual nests outside trapped blocks, 2006.

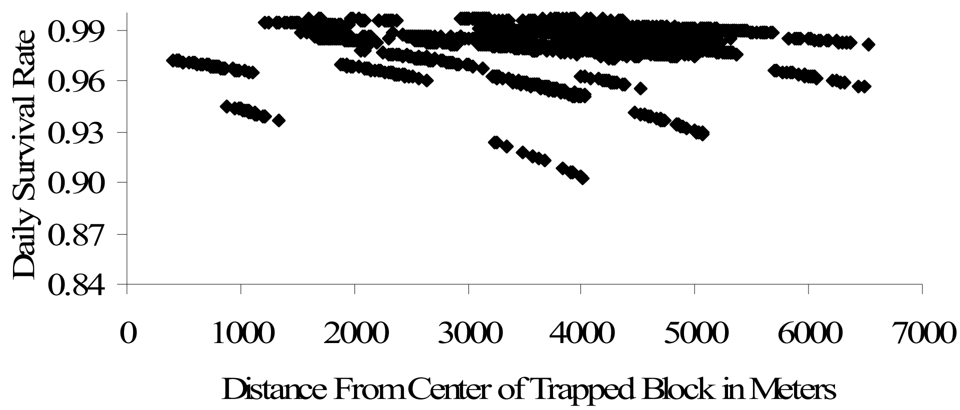

Figure 12. Logistic-exposure daily survival rates by distance for individual nests inside trapped blocks, 2005.

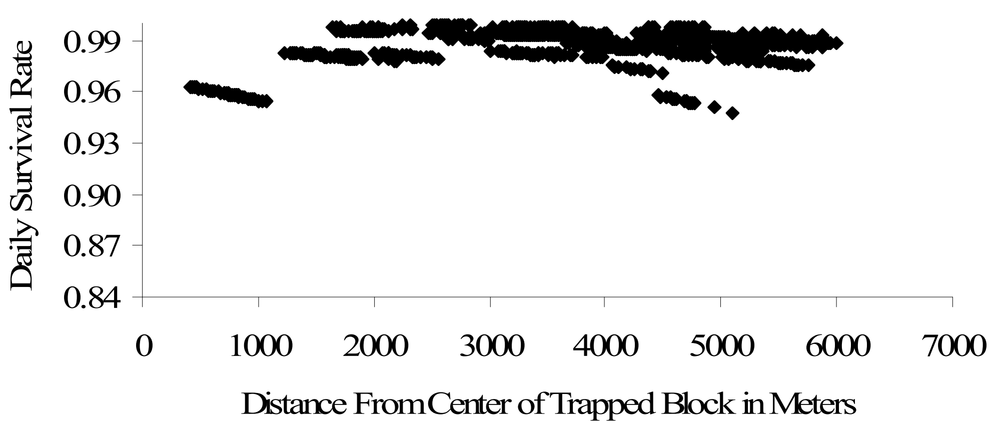

Figure 13. Logistic-exposure daily survival rates by distance for individual nests inside trapped blocks, 2006.

reduction appears to be having a very local effect. As with previous studies, predator trapping appears to elevate daily survival rates on those areas directly trapped (Sargeant et al. 1995, Mense 1996, Hoff 1999, Garrettson and Rohwer 2001, Chodachek and Chamberlain 2006) but does not appear to elevate daily survival rates on areas not directly trapped.

Perhaps, the trapped block is serving as a population "sink," with predators being attracted to the vacancies located within and directly around it. As predators suffer mortality inside the trapped block, they may be quickly replaced by a flux of immigrants from the outside, causing consistently higher numbers of predators outside trapped blocks.

Predator Scent-Stations

It was predicted that predator numbers would gradually increase as you moved further from the edge of a trapped block. With no distance effect on scent-station visitation rates outside trapped blocks, this prediction was not upheld.

Distance did not appear to affect visitation rates for individual predator species, or for all species combined, both inside and outside trapped blocks (Table 7). The lack of a significant distance effect for scent-station visitation rates coincided with the negligible effect of distance on daily survival rates. Visitation rates, however, were very low for most individual species (Table 6 and Figures 2-9), so the power of the test is low.

When looking for differences in visitation rates between inside and outside trapped blocks, only those for raccoon and all predators combined were significant (Table 8; Figures 2 and 8). Raccoons visited scent-stations more than any other species (Table 6). The large number of visits for raccoons may reflect abundance or a behavior that makes them more likely to visit a scent-station than other species (Sargeant et al. 1993). The significant difference between visitation rates inside and outside trapped blocks for raccoons and for all predators combined

coincided with the differences in daily survival rates found inside and outside trapped blocks. Daily survival rates were higher inside trapped blocks than outside trapped blocks and scent-station visitation rates were lower inside trapped blocks than outside trapped blocks.

Conclusion

Based upon the results of this study, trapping clearly increases daily survival rates on the areas directly trapped but does not appear to elevate daily survival rates beyond the borders of trapped blocks. Scent-station surveys of predators suggest higher overall visitation rates outside trapped blocks than inside. This study was the first to examine daily survival rates outside trapped blocks. Further research will be required to determine if trapping truly does have little effect on areas outside trapped blocks. In addition, larger scale scent-station surveys that are repeated during the same field season are needed to more adequately measure predator activity (Sargeant et al. 2003). Based upon the results of this study, managers hoping to increase duck production should not expect to gain additional ducks from areas adjacent to trapped block edges.

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Vita

Margaret (Peggy) Jean Kuhn was born on May 31, 1981 in Brattleboro, Vermont. She grew up in Westminster, Vermont with her parents Bryant and Jean Kuhn and her two younger brothers Matt and Adam. She spent her early years hiking and riding her horses through the Vermont woods. It was through this exposure to nature, and with the encouragement of her parents, that she decided to make a career in the wildlife sciences.

In the fall of 1999, she enrolled at the University of Vermont as an environmental studies major. Upon graduation in December of 2003, she embarked on two wildlife internships. The first was at the Cape Cod National Seashore in Massachusetts, where she monitored the nest success of piping plovers and least terns. The second was at the Attwater's Prairie Chicken National Wildlife Refuge in Texas, where she worked with the critically endangered Attwater's prairie chicken. Upon completion of these internships, she decided to further her education by attending graduate school.

She was accepted into the School of Renewable Natural Resources at Louisiana State University as a Master of Science candidate in the fall of 2005. Her research was conducted in northeastern North Dakota. During the summer of 2006, she was awarded the Best Master's Student Presentation Award at the Delta Waterfowl Research Symposium. During the spring of 2007, the Renewable Natural Resources Department awarded her the Clark M. Hoffpauer Outstanding Graduate Student Award. The degree of Master of Science in Wildlife will be awarded in August of 2007.