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Title: Factors influencing muskrat (Ondatra zibethicus) choice of farm ponds in the Flint Hills.

Abstract Approved: Elmer J. Finck

The Habitat Suitability Index model was used to assess the habitat and to assess how useful the model is in predicting farm pond use in the Flint Hills of Kansas by muskrats (Ondatra zibethicus). Seven habitat variables were measured to see if they could be used to assess habitat usability including 1) percent shoreline dominated by emergent vegetation, 2) percent of emergent herbaceous vegetation consisting of Olney bulrush (Scirpus olneyi), American bulrush (S. americanus), or cattails (Typha sp.), 3) percent of herbaceous canopy cover within 10m of the water's edge, 4) amount of water supporting submerged or floating aquatic vegetation, 5) number of cattle hoof prints per square meter, 6) year pond was built, and 7) number of mussel shells per square meter. The first four variables were taken directly from the HSI model since they seemed the most applicable to farm ponds. The other three were measured to see if they might be important in assessing muskrat presence in farm ponds. Discriminant function analysis distinguished ponds with muskrats from those without muskrats (Wilks' Lamda of 0.206 significant at $p < 0.05$). A Mann-Whitney U-test showed that ponds with > 30 %

vegetation within 10m of shoreline have muskrats. A frequency diagram plot of landowner surveys indicated that all ponds that lack muskrats were used to water cattle. The mean of estuarine intertidal food/cover was significantly larger for farm ponds with muskrat than without muskrats. In general, my data showed that the HSI was not applicable for use in Flint Hill farm ponds, probably because of a lack of plants and habitat structure on which the HSI is based.

FACTORS INFLUENCING MUSKRAT (ONDATRA ZIBETHICUS) CHOICE OF FARM PONDS IN THE FLINT HILLS

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PREFACE

This thesis has been prepared in the style appropriate for The Prairie Naturalist and will be submitted for publication there.

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INTRODUCTION

Muskrats (Ondatra zibethicus) have been trapped for their pelts for over 200 years, prompting research to understand their habits and habitat. Management plans have been developed to maintain an adequate population of trapable muskrats. Farm ponds in the Flint Hills region of Kansas contain muskrats. However, the factors influencing choice of particular farm ponds by muskrats in the Flint Hills is unknown.

Habitat Suitability Index models, written by the U.S. Fish and Wildlife Service, provide a way of measuring habitat and its suitability to species. The Habitat Suitability Index Model (HSI) for muskrats, by Allen and Hoffman (1984), defines the habitat used by muskrats and may provide clues as to why muskrats choose one farm pond over another in the Flint Hills. However, the HSI for muskrats was written for riverine and estuarine habitats, and has not been tested in farm ponds.

The estuarine habitat part of the model was developed for the coastal marshes of the Atlantic and Gulf of Mexico regions of the United States. Therefore, it is possible that some of the HSI's variables will be unusable when dealing with farm ponds and that some new variables need to be added to make the model usable for farm ponds.

Palmisano (1971) studied muskrat abundance in relation to vegetation and Earhart (1969) studied the influence of soil texture on muskrat burrowing. However, no one has looked at both of these factors combined in farm ponds. Cattails (Typha sp.) are the most common form of emergent vegetation used as food by muskrats (Errington 1941). However, Shanks and Arthur (1952) found the frequency of pond use is no greater for ponds with good stands of emergent vegetation than for those completely void of vegetation. When softstem bulrush (Scirpus validus) and eel grass (Vallisneria americana) are present they make up fifty percent of the muskrat diet (Arata 1959). Other food items found in a muskrat feeding house include fish scales, heads of gizzard shad (Dorosoma cepedianum), crayfish chela, and grass pickerel (Esox vermiculatus) (Bellrose 1950). Freshwater mussels and crayfish have also been found to comprise a significant part of muskrat diets (Errington 1940, Neves and Odom 1989). Errington (1941) suggested that food may be an important limiting factor for muskrats. The presence or absence of these items in a farm pond may influence the use of particular farm ponds by muskrats.

Physical characteristics of ponds, such as presence of water and the soil type or mixture of soils present, may also influence pond suitability to muskrats. Soil type becomes important when muskrats dig burrows into the banks or dams of ponds. The shape and slope of the pond's banks may influence the suitability of ponds to muskrats (Earhart 1969). If the slope of the bank is < 10 %, muskrats will not be able to build burrows (Earhart 1969). A farm pond must contain water to supply emergent vegetation used as food, to provide cover, and easy mobility for the muskrats. Lakes with stable water levels have more muskrats than lakes with fluctuating water levels (Bellrose and Brown 1941), and farm pond water levels fluctuate greatly. If the water level drops it can leave muskrat burrows exposed, and if it rises too fast it can cause them to drown in their burrows (Errington 1937).

Another variable that may influence the use of ponds by muskrats is the proximity of a pond to a location with a muskrats population. The proximity of other ponds becomes important when young muskrats disperse from their natal site. They disperse after spending the first fall and winter in their parents home range (Errington 1939), and 57 % of the muskrat dispersing in spring in Minnesota are male (Errington 1940). Dispersal distance for muskrats varies from 152m to 34km (Takos 1944). The duration and time of year when a pond is connected by water to other ponds, creeks, and rivers that contain muskrats may also influence the chance of a pond being used. The distance from other individual muskrats may also be a reason why a habitat is chosen (Errington 1940).

The purposes of this study were twofold: 1) to determine which factors influence selection of farm ponds by muskrats in the Flint Hills and 2) to test the applicability of the HSI model to Flint Hills' farm ponds.

DESCRIPTION OF STUDY SITES

The study sites were located in Lyon, Chase, and Marion counties in the Flint Hills of Kansas on the Cottonwood River drainage (Appendix #1). Most of the ponds were used to water cattle and were 1ha or more when full. The typical habitat surrounding the ponds was tallgrass prairie consisting of big bluestem (Andropogon gerardii), Indian grass (Sorghastrum nutans), switchgrass (Panicum virgatum), and little bluestem (A. scoparius). Other grass species present were rough dropseed (Sporobolus asper), barnyard-grass (Echinochloa crusgalli), prairie threeawn (Aristida oligantha), Virginia wild rye (Elymus virginicus), Canada wildrye (E. canadensis), and witchgrass (P. capillare). The forb community included curliopladу's-thumb (Polygonum lapathifolium), pink smartweed (P. bicorne), pigweed (Amaranthus hybridus), prairie cone flower (Ratibida columnifera), plains indigo (Baptisia leucophaea), dock (Rumex stenophyllus), cocklebur (Xanthium strumarium), buffalo bur nightshade (Solanum rostratum), broom weed (Xanthocephalum dracunculoides), spike rush (Eleocharis macrostachya), pitcher sage (Salvia pitcheri), and common mullein (Verbascum thapsus). The tree species, which included: eastern cottonwood (Populus deltoides), black willow (Salix nigra), sandbar willow (S. interior), American elm (Ulmus americana), and honey locust (Gleditsia triacanthos), were usually found on the dam of the farm pond or along the shore opposite the dam. Plant names taken from

Great Plains Flora Association (1986).

MATERIALS AND METHODS

The HSI model for muskrats contains 9 habitat variables (Allen and Hoffman 1984). Seven of the 9 variables were examined in this study including: 1) percent canopy cover of emergent herbaceous vegetation (V_1), 2) percent of year with surface water present (V_2), 3) percent riverine channel dominated by emergent herbaceous vegetation (V_5), 4) percent herbaceous canopy cover within 10m of water's edge (V_6), 5) percent of emergent herbaceous vegetation consisting of persistent life form species (V_7), 6) percent emergent herbaceous vegetation consisting of Olney bulrush (*Scirpus olneyi*), common threesquare bulrush (*S. americanus*), or cattails (*Typha* sp.) (V_8), and 7) percent open water supporting submerged or floating aquatic vegetation (V_9) (Allen and Hoffman 1984). According to Allen and Hoffman (1984), variables V_1, V_2, and V_8, are for use in herbaceous wetlands to measure food and cover using life requisite equations 1 and 2 (Table 1). Variables V_1 and V_8 are also used with variables V_7 and V_9 to measure food and cover in estuarine intertidal habitat using life requisite equation 4 in Table 1. Equation 3 in Table 1 uses variables V_5 and V_6 to measure food in riverine habitat.

Variable V_1 was to be measured when emergent vegetation (cattails) was present at ponds and shaded the water. This did not occur in my study, but the variable has an index value of 0.08 at 0% presence (Allen and Hoffman 1984) and thus could be used in equations 1 and 4 (Table 1).

Table 1. Life requisite values for assessing suitability of muskrat habitat.

Equation #	Life requisite	Cover type#	Equation*
1	Cover	HW	$(V_1 \times V_2)^{1/2}$
2	Food	HW	$(V_1 \times V_8)^{1/2}$
3	Food	R	$\frac{V_6 + 2(V_5)}{2}$
4	Food/cover	EI	$[(V_1 \times V_7 \times V_8^2)^{1/4} \times (a)] + [V_9 \times (b)]$

HW = herbaceous wetland, R = riverine, EI = estuarine intertidal

* V_1 = percent canopy cover of emergent herbaceous vegetation

V_2 = percent of year with surface water present

V_5 = percent riverine channel dominated by emergent herbaceous vegetation

V_6 = percent herbaceous canopy cover within 10m of water's edge

V_7 = percent of emergent herbaceous vegetation consisting of persistent life form species

V_8 = percent of emergent herbaceous vegetation consisting of Olney bulrush, common threesquare bulrush, or cattail

V_9 = percent of open water supporting submerged or floating aquatic vegetation

a = the percentage of the total estuarine habitat being evaluated that supports > 10% emergent vegetation canopy cover

b = the percentage of the total estuarine habitat being evaluated that supports $\leq$ 10% emergent vegetation canopy cover.

Allen and Hoffman 1984

Variable V_2 was obtained by asking question # 6 on the landowner's survey (Appendix #2) and summarized in Table 2. Only four ponds built before 1950 were examined and none had gone dry (Table 2) since the 1950's, so all ponds were determined to have surface water present 100 % of the year.

Variable V_5 was measured when the emergent vegetation was present at a pond, specifically at the inflow side of a pond where the habitat would still be similar to a river or creek in size, shape, and flow. Most of the emergent vegetation was found in this area of the examined ponds. The horizontal component of vegetation that made contact with a 50m line transect was measured. Each species of emergent vegetation was identified and the height measured.

Variable V_6 was measured by randomly picking a spot along the shoreline and measuring 10m back from the water's edge with a tape measure. The distance from the water's edge to the start of the vegetation along the shoreline was measured. At that point, the vegetation was identified

Table 2. Pond water stability and muskrat presence in Flint Hills' farm ponds since they were built.

DRY[a]	MUSKRAT PRESENCE		
	NO	YES	TOTAL
NO	50.00%	37.50%	87.50%
YES	0.00%	12.50%	12.50%

[a]Periodic total drying of a pond

and the tallest vegetation within 10m of shore that had its base touching the tape was measured. Eleven measurements spaced 10m apart were taken for this variable on opposite facing shorelines. This method measured percent open shoreline and will be referred to as percent open shoreline instead of percent of herbaceous canopy cover within 10m of water's edge.

A m^2 quadrat was used to measure V_7. The quadrat was tossed randomly into clumps of emergent vegetation and the percentage of the vegetation filling the quadrat was estimated. The quadrat was tossed a total of 22 times per pond when emergent vegetation was present.

Variable V_8 was measured at the same time as V_7 only the percentages of Olney bulrush, common threesquare bulrush, and cattails were recorded separately for each species.

Variable V_9 was measured using a m^2 quadrat. The quadrat was tossed approximately 10m out from shoreline into the water. The percentage of submerged or floating aquatic vegetation in the quadrat was measured for each of 22 tosses. A 11.5m length of rope was tied to the quadrat to provide easy recovery of the quadrate from the pond's surface without entering the pond.

Figure 1 represents an example of a theoretical Suitability Index curve that could exist for the HSI. An index value is determined from the mean percentage of the

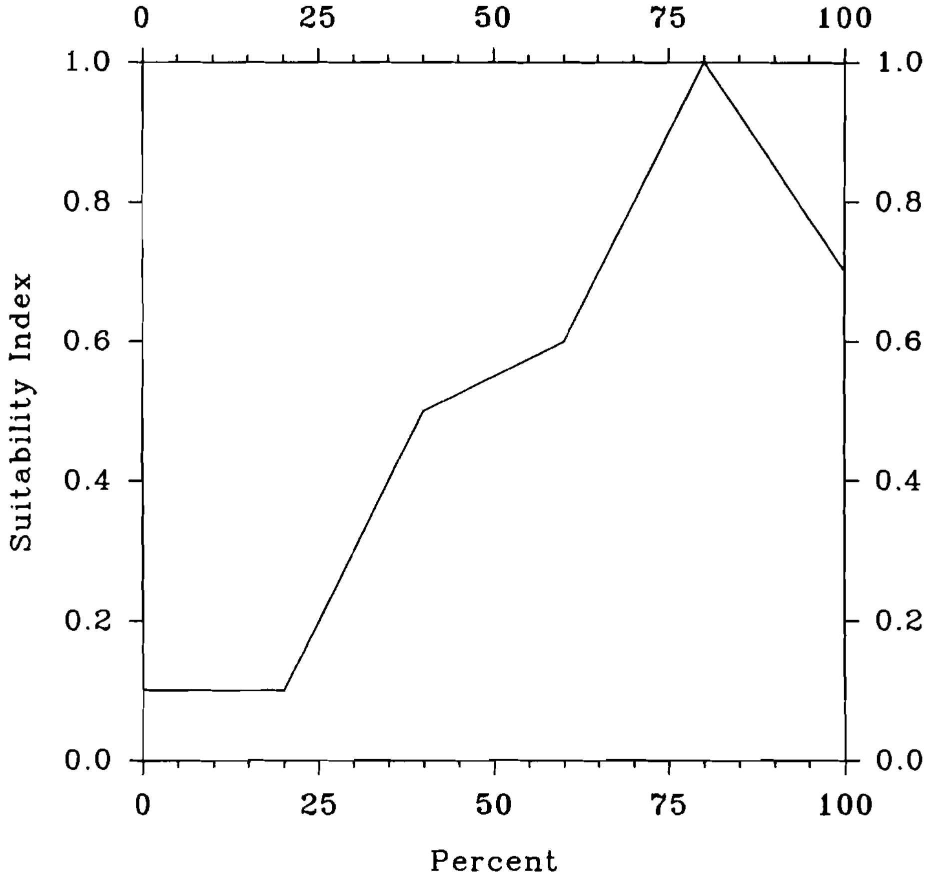

Figure 1. A theoretical suitability index graph for a Habitat Suitability Index model.

particular variable and is then used in the life requisite equations (Table 1) to calculate the over all suitability of the habitat.

The Lyon and Chase County United States Soil Conservation Service agents were contacted and the names of landowners with ponds at least 1ha in size were requested. The location and legal description of each farm pond were received from the county agents (Appendix #1). Landowners were then contacted to receive permission to survey their pond or ponds. A phone survey was conducted with each landowner when obtaining permission to survey the farm ponds. An example of the landowner survey is provided in Appendix 2.

To identify the amount of shoreline trampling caused by cattle, the number of hoof prints per square meter was measured by randomly tossing a m^2 quadrat 22 times along the shoreline and counting the number of hoof prints in each quadrat. Freshwater mussel shells per m^2 of shoreline were also measured the same way but in separate tosses. The shells were counted, and some were identified as pond mussels (Ligumia subrostrata).

Muskrat sign was identified at each farm pond using the descriptions of sign by Dozier (1948) and Lloyd Fox (personal communication). Dozier (1948) described sign as narrow channels or runs leading through marsh vegetation to a nest site, air bubbles under ice, bank burrows and tunnels, muddy water in burrow entrances, defecating posts (logs or rocks out of the water used as a latrine), and plant cuttings. Mussel middens were also used to indicate muskrat presence. Muskrats were assumed to be present if at least two of these signs were present.

The data were split into two groups before being analyzed. One group of the data was numerical data collected from field sampling. Data set two contained variables that were non-numeric i.e., contained the answers from the questions on the landowner surveys that were conducted. SAS/STAT (1989) was used to statistically analyze the data from the first data set. A discriminant function analysis was performed on all the variables from data set one.

RESULTS

In 7 out of 8 cases the discriminant function analysis was able to distinguish ponds with muskrats from ponds without muskrats. The function also classified the ponds that lack muskrats correctly 100 percent of the time. The Wilks' Lambda value of 0.206 was significant at $p<0.05$.

A Mann-Whitney U-test was used to see if any differences could be detected within variables for ponds with and without muskrats. Percent open shoreline was the only variable significantly different at $p<0.05$ for the two tailed test (Table 3) between ponds with and without muskrats. Thus indicating that ponds with muskrats have less open-shoreline and more vegetation along the shore, which agrees with the HSI model. The HSI shows an index curve that has suitability increasing as the amount of open-shoreline decreases (Allen and Hoffman 1984).

A Spearman rank correlation (Zar 1984) found no significant correlations among the following variables: percent open shoreline; percent of emergent herbaceous vegetation consisting of Olney bulrush, common threesquare bulrush, or cattails; amount of water supporting submerged or floating aquatic vegetation; number of cattle hoof prints per m^2; year pond was built; and number of mussel shells per m^2.

Frequency tables of the second data set were also plotted using SAS/SAST (1989) to compare ponds with and without muskrats (Tables 2, and 4-7). These tables were

Table 3. Means of means from the variables measured in Flint Hills' farm ponds.

	Muskrats Present		Mann-Whitney U
Variable	Yes	No	Scores
OPENSHOR	31.44 ± 29.57[a]	51.24 ± 17.70	52.0*
AQUAT10	61.32 ± 39.21	34.47 ± 27.99	48.0
HTVEG	89.45 ± 51.71	59.36 ± 23.36	43.0
CATTAILS	6.38 ± 10.25	3.84 ± 10.85	38.5
HOOFS10	3.66 ± 5.28	2.20 ± 3.18	35.5
MUSSEL	1.21 ± 1.92	0.13 ± 0.35	43.5
DATEB	1964.63 ± 16.42	1966.88 ± 20.75	46.0

[a] ± Standard Error, * Significant at p = 0.05, Openshor = measure of open shoreline within 10 m of shoreline, Aquat10 = Aquatic or floating submerged vegetation within 10m of shoreline, Htveg = height of tallest vegetation within 10m of shoreline, Cattails = cattails, Hoofs10 = hoof prints/m^2, Mussel = mussel shells/m^2, Dateb = Date pond was built

Table 4. Pond function and percent occurrence of muskrats in Flint Hills' farm ponds based on a landowner survey.

USE OF POND	MUSKRATS PRESENT		
	YES	NO	TOTAL
CATTLE	18.75	43.75	62.50
FLOOD CONTROL	6.25	0.00	6.25
RECREATION	12.50	0.00	12.25
FLOOD CONTROL AND CATTLE	0.00	6.25	6.25
AESTHETIC VALUE	6.25	0.00	6.25
RESEARCH	6.25	0.00	6.25

Table 5. Percent occurrence of muskrats in harvested and unharvested ponds in the Flint Hills of Kansas.

HARVESTING	MUSKRATS PRESENT		
	NO	YES	TOTAL
YES	0.00	21.43	21.43
NO	57.14	21.43	78.57

Harvesting information was known for 14 of the16 ponds

Table 6. Water influx and muskrat presence in Flint Hills' farm ponds.

FLOW	MUSKRAT PRESENCE		
	YES	NO	TOTAL
INTERMITENT[a]	43.75	43.75	87.50
SPRING FEED	6.25	6.25	12.50

[a]Flow of water caused by run-off

Table 7. Surrounding land use and muskrat presence in Flint Hills' farm ponds.

CROPS	PRESENCE OF MUSKRATS		
	YES	NO	TOTAL
FIELD	18.75	12.50	31.25
GRASSLAND	31.25	37.50	68.75

used to describe the ponds by showing use of ponds, harvesting of muskrats, and stability of water presence. All ponds that lacked muskrats are used mainly to water cattle while ponds with muskrats were used for cattle and several other uses (Table 4).

The data collected for the variables from the HSI were plugged into the life requisite equations in Table 1. A Mann-Whitney U-test was done on the data from the R food and EI food/cover columns of Table 8. The mean for river food with muskrats 0.49 ± 0.12 was not significantly different than the mean without muskrats 0.49 ± 0.16 $U' = 35.5$ $p>0.05$ for a one tailed test. The mean of estuarine intertidal food/cover with muskrats 64.9 ± 32.6 is significatly larger than without muskrats 39.5 ± 22.9, $U' = 50$ $p<0.05$, indicating that the life requisite values for ponds with muskrats are greater than ponds without. The HSI model (Allen and Hoffman 1984) predicts that ponds with muskrats should have larger life requisite values.

Table 8. Life requisite values for Flint Hills' farm ponds relative to muskrat habitat suitability.

		Life Requisite Values			
Pond #	Presence	HW Cover	HW Food	R Food	EI Food/Cover
LY-1	YES	0.28	0.09*	0.50	80
LY-2	YES	0.28	0.15*	0.41	78
LY-3	YES	0.28	0.09	0.35	10
LY-4	YES	0.28	0.09	0.59	100
LY-5	NO	0.28	0.09	0.23	70
LY-6	YES	0.28	0.09	0.28	88
LY-7	NO	0.28	0.09	0.30	10
LY-8	YES	0.28	0.11*	0.56	72
CS-1	NO	0.28	0.09	0.41	54
CS-2	NO	0.28	0.09	0.55	70
CS-3	NO	0.28	0.16*	0.62	41
CS-4	NO	0.28	0.09	0.80	41
CS-5	NO	0.28	0.09	0.52	10
CS-6	NO	0.28	0.09	0.51	20
CS-7	YES	0.28	0.09	0.56	81
MR-1	YES	0.28	0.09	0.68	10

* Emergent vegetation present, HW = herbaceous wetland, R = riverine, EI = estuarine intertidal LY = Lyon county, CS = chase county, MR = Marion county

DISCUSSION

The Habitat Suitability Index for muskrats (Allen and Hoffman 1984) was found to be unsuitable for farm ponds in the Flint Hills even when alterations were made to the model to fit the Flint Hills. Some of the variables from the HSI gave constant but unsuitable values because they were not present (Figure 1). Possibly the model was not suitable in the Flint Hills because muskrats use food sources other than cattails and bulrush. The HW food and HW cover columns of Table 8 showed what happens when the variables were not present in the habitat and a low index value from the suitability graphs (Allen and Hoffman 1984) were used. These results were not surprising as the model was written for use in riverine and estuarine habitat along the Atlantic and Gulf of Mexico coasts of the U.S. Thus, a new model should be developed to assess the suitability of habitat for muskrats in Flint Hills, farm ponds.

The purpose of HSI models is to determine the quality of habitat and not to determine the population density (Bart et al. 1984). Bart et al. (1984) field-tested the original HSI models for muskrats and suggested that the models should not be made from the literature alone, but also developed through field work and thus these models could be made simpler.

Bishop et al. (1979) found that muskrat populations decrease when higher percentages of emergent vegetation were present and populations increased when emergent vegetation decreased. They suggest that other factors were controlling muskrat populations. Although, Bishop et al.'s (1979) findings do not agree with what is considered to be typical, thus factors other than vegetation may be influencing muskrats in the Flint Hills.

Muskrats in Flint Hills farm ponds were most likely bank dwellers because of a lack of emergent vegetation that could be used for housing and food. Muskrats show a preference for banks that are high and have firm soil for burrowing and they appear to prefer bank burrows over houses made of vegetation (Dozier 1948).

A decline in the number of muskrats in the southwestern third of Minnesota from 823,000 in 1973 to 239,000 in 1976 was estimated during a period of drought (Berner 1980). During my study, the Flint Hills experianced a drought. Many of the ponds that were examined had water levels that were lower than what was presumed to be a typical water level in the ponds, which may explain why I did not see muskrat sign on ponds that once had muskrats.

Muskrats in rivers tend to be more opportunistic feeders than muskrats that were in estuarine habitats (Allen and Hoffman 1984). Thus, they tend to use terrestrial food to a greater extent than other muskrats (Allen and Hoffman 1984). Evidence of carnivorous activity has been found in muskrats though it is an uncommon event (Lacki _et al_. 1989). White suckers (_Catostomus commersoni_), snails

(*Cipangopaludina chinensis*), and mussels (*Elliptio complanata*) are species consumed by muskrats (Lacki et al. 1989). The most common species found in mussel middens made by muskrats in Iowa is *Strophitus rugous* (Bovbjerg 1956). Parmalee (1989) found the remains of two softshell turtles (*Trionyx spiniferus spiniferus*) that had been the victims of muskrat predation. One would expect that muskrat diets in the Flint Hills' farm ponds would be more carnivorous than muskrats in developed marshes.

Muskrats may not inhabit farm ponds in the Flint Hills for a number of reasons. One reason may be that there is a lack of emergent vegetation that causes muskrats to leave the ponds or not select them. Erickson (1966) suggests the following reasons for the absence of muskrats in Indiana farm ponds: pond age, trampling by cattle, pond age and trampling, pond age and location, trampling and water level fluctuation, rip-rap and shale, or sandy banks. Erickson (1966) concludes that water level fluctuation and trampling of pond banks by cattle causes muskrat desertion. In my study, density of cattle did not account for nonuse of farm ponds. However, no muskrats were found in ponds strictly used for watering cattle.

Muskrats use emergent vegetation or other forms of vegetation as a food source (Allen and Hoffman 1984). Therefore, muskrats tend to feed on the emergent vegetation species that is most abundant in a marsh or pond (Neal 1968, McCabe and Wolfe 1981, Lacki et al. 1989). Neal (1968) also found that muskrat home ranges appear smaller when the density of vegetation is greater than in ponds with more sparse vegetation. The maximum home range of a muskrat is 485m and the regular activity range equals 48m (Beshears and Haugen 1953). When muskrats are forced to build burrows in marginal habitat during times of dense populations these houses are abandoned because of low water and lack of suitable forage (Messier et al. 1990).

A habitat model developed by Brooks and Dodge (1980) for riverine environment identified habitat which is favorable for muskrats. Other variables not considered by Brooks and Dodge (1980) were height, slope, structure of the bank, and bank composition that were found to be important by Erickson (1966). These variables should be considered when looking at ponds.

Since ice covers most of the water in Manitoba during the winter, food is the limiting factor most of the time during the winter (McLeod 1948), which may be the case in Flint Hills' farm ponds. During times of ice it may be hard for the muskrats to find food in the ponds.

The discriminant function analysis developed for my data showed that it could distinguish the farm ponds with muskrats from those without muskrats. The percent of open shoreline was significantly higher for ponds used by muskrats than not used by muskrats. The Estuariane intertidal life requisite values (Table 8) were significantly greater for ponds with muskrats than ponds without muskrats.

Diet analysis needs to be carried out to see what the muskrats are eating in the Flint Hills. Muskrats consume fresh water mussels in rivers (Neves and Odom 1989) and in lakes (Convey et al. 1989). Convey et al. (1989) found that muskrats in narrow lakes in central Alberta prefer northern floater unionoid mussels (Anodonta grandis) that are 55-75mm long. Muskrats consume crayfish in Flint Hills farm ponds (R. J. Tippin personal communication).

An underlying rock layer that is close to the surface in the Flint Hills may affect muskrat distribution. This rock layer was observed at several ponds as being within approximately a meter of the soil surface. Three of the ponds that were examined had been dug down into the rock layers. Thus, portions of the pond banks that contained sufficient slope > 10 % (Earhart 1969) for muskrat burrowing contained solid rock or rock and soil mixtures that were not good for burrow construction. Some of the ponds that did not have sufficient slope along the shoreline had sufficient slope in the dam for burrows. Although, most dams that were examined appeared to have been rip-raped as suggested by Beshears and Haugen (1953), Earhart (1969), Gablehouse et al. (1987) to prevent muskrats from burrowing.

Radio tracking of muskrats should be done to see if muskrats stay in one pond or using several ponds that are close together. One group of ponds (4 ponds) in my study was within one section and each pond contained a muskrat at one time. It was presumed that the muskrat or muskrats were using all four of these ponds at the same time. Since, none of the four ponds probably had the resources to maintain more than a single muskrat because the ponds were small.

Brooks and Dodge (1986) suggest that ponds should be assessed individually for burrows and houses because of the variable densities that are possible. Rivers and streams can be assessed together (Brooks and Dodge 1986). The possibility of variable densities may indicate that no model or one factor can be found to identify what makes one pond more suitable than another for muskrats. However, my study indicated that the factors influencing farm pond use by muskrats can be identified in the Flint Hills and other tallgrass prairie regions of the United States.

LITERATURE CITED

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APPENDIX

APPENDIX 1. Location of the study sites by legal description.

Site #	Legal Description	County	Muskrat Presence
LY-1	Cen. N. 1/2 Sec.13, T20, R10E	Lyon	YES
LY-2	Cen. N. 1/2 Sec.13, T20, R10E	Lyon	YES
LY-3	NE. 1/4 Sec. 9, T20, R12E	Lyon	YES
LY-4	NE. 1/4 Sec.13, T20, R10E	Lyon	YES*
LY-5	W. 1/2 Sec. 1, T20, R10E	Lyon	NO
LY-6	Cen. S. 1/2 Sec.12, T20, R10E	Lyon	YES
LY-7	NE. 1/4 Sec.12, T20, R10E	Lyon	NO
LY-8	NW. 1/4 Sec.17, T20, R10E	Lyon	YES
CS-1	SE. 1/4 Sec. 7, T20, R 8E	Chase	NO
CS-2	SW. 1/2 Sec.33, T19, R 8E	Chase	NO
CS-3	SE. 1/4 Sec.18, T19, R 6E	Chase	NO
CS-4	NE. 1/2 Sec.18, T17, R 7E	Chase	NO
CS-5	NE. 1/4 Sec. 1, T18, R 7E	Chase	NO
CS-6	NW. 1/4 Sec. 6, T18, R 8E	Chase	NO
CS-7	NE. 1/2 Sec.34, T17, R 7E	Chase	YES
MR-1	NE. 1/4 Sec. 3, T20, R 2E	Marion	YES

* East pond of the two ponds

Appendix 2. Landowner survey form.

Name of the land owner_____________________ Site no.______

Land owner phone #___________________ Date called____________

Legal description ______________________ County_____________

1. When was the pond built?

2. What is the main use of the pond?

3. Do cattle have access to the pond?

4. Have you seen any muskrats or has anyone told you that muskrats are using the pond?

5. Has trapping of muskrat been allowed on the pond?

6. When was the last time the pond went dry?

7. Is there a continuous flow of water out of the pond at all times?

8. Is any planting of crops done near the pond?

9. What kind of access can I have to the pond?

Charles B Marchbanks

Signature of Graduate Student

Elmer J. Finck

Signature of Major Advisor

I, Charles Burke Marchbanks, hereby submit this thesis to Emporia State University as partial fulfillment of the requirements of an advanced degree. I agree that the requirements of an advanced degree. I agree that the Library of the University may make it available for use in accordance with its regulations governing materials of this type. I further agree that quoting, photocopying, or other reproduction of this document is allowed for private study, scholarship (including teaching), and research purposes of a nonprofit nature. No copying which involves potential financial gain will be allowed without written permission of the author.

Charles B Marchbanks

Signature of Author

10 June, 1992

Date

Factor influencing muskrat (Ondatra zibethicus) choice of farm ponds in the Flint Hills

Title of Thesis

Doug Cooper

Signature of Graduate Office Staff Member

July 14, 1992

Date Received