VARIATION IN MALLARD HOME RANGE SIZE

AND COMPOSITION IN THE PRAIRIE PARKLAND REGION OF CANADA:

CORRELATES AND CONSEQUENCES FOR BREEDING FEMALES

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ABSTRACT

Wetland density is believed to be an important determinant of home range size variation in mallards (*Anas platyrhynchos*), but hypothesized effects of upland habitat and female size and age have not been adequately evaluated. Thus, I investigated correlates and consequences of home range size variation using radio-tracking data for 131 female mallards studied on 12 Canadian prairie parkland sites, 1995-1998. Home range size and habitat composition varied within and among study areas; overall, home range size variation was best modeled to include effects of seasonal and semi-permanent wetlands ($\beta = -0.06 \pm 0.01$ SE) and wood-shrub habitat ($\beta = -0.03 \pm 0.01$ SE). Contrary to predictions, I obtained no support for a positive association between home range size and female body size or a negative relationship between home range size and female age. After controlling effects of wetland density, mean home range sizes were larger on study areas with lower mallard breeding pair densities. I suspect that individual home ranges were smaller in areas of high pair density because of increased intraspecific competition for breeding space. A higher proportion of wood-shrub habitat may have contributed to smaller individual home range sizes because of greater relative availability of preferred nesting habitat. Likewise, a high proportion of wetlands in home ranges could enhance access to important resources such as food, leading to smaller home range sizes.

Reproductive and survival consequences were investigated using 8 variables to distinguish between three reproductive categories (females that either did not nest, nested but failed, or nested successfully) and two survival categories (dead versus alive) with discriminant function analysis. Successful females were clearly separated from

non-nesting females by having smaller home ranges (95% kernel estimate) with higher percentages of wood-shrub and habitat treatment but lower percentages of seasonal and semi-permanent wetlands. Females that did not nest were further distinguished from nesting females by being younger, structurally smaller and having larger home ranges composed of higher percentages of seasonal and semi-permanent wetlands. Date of first nesting (standardized by study area) was not associated with home range composition. Survival was also unrelated to either home range composition or female attributes. Overall, breeding performance was better described by variation in landscape characteristics than by female attributes, a finding that is consistent with other recent evidence from breeding ducks.

ACKNOWLEDGMENTS

DEDICATION

To my late grandfather, Jerome Mack, who provided me with opportunities and

experiences that initially fostered my love and fascination for the out-of-doors and most

importantly, waterfowl. The experiences of watching the spectacle of spring and fall

migrations, and duck hunting in the Nebraska Sandhills with him will be forever etched

in my memory.

QUOTATION

"Underlying the beauty of the spectacle there is meaning and significance. It is the elusiveness of that meaning that haunts us, that sends us again and again into the natural world where the key to the riddle is hidden."

Rachael Carson

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Introduction

Understanding spatial distributions of animals is fundamental to conservation

biology and wildlife management (Anderson and Titman 1992, Larkin and Halkin 1994,

Badyaev et al. 1996a, Pöysä et al. 1998). Therefore, ecologists often attempt to

determine factors (e.g., landscape characteristics, female attributes) that affect spacing

patterns, and evaluate whether variation in reproductive success or survival is related to

these factors (Greenwood et al. 1987, Rotella and Ratti 1992, Petit et al. 1995). This

knowledge has important conservation ramifications because wildlife managers

commonly attempt to improve vital rates via habitat manipulations at either a local or

landscape scales (Johnson et al. 1992, Cowardin et al. 1995, Ball 1996).

One challenge for biologists is to derive biologically meaningful and reliable

estimates of space use patterns. Spatial distributions are often determined by estimating

individual home range boundaries, core areas or territory sizes (McNab 1963, Schoener

1968, Blundell et al. 2001). A common and widely used definition of home range is,

"...the area traversed by the individual in its normal activities of food gathering, mating,

and caring for young. Occasional sallies outside the area, perhaps exploratory in nature,

should not be considered part of the home range." (Burt 1943:351). Dzubin (1955:293)

defined home range in waterfowl as, "… the area in which the pair is most active during

the breeding season (i.e., during prenesting, nesting, and incubation). The area must

include nests, foraging, and resting locations.". Since 'normal' activities are, at best, difficult to define (White and Garrot 1990), some authors (e.g., Anderson 1982, Worton 1987, 1989, Taulman and Seaman 2000, Blundell et al. 2001) define home range as the probability of locating an animal at a particular place by using a utilization distribution based on relative frequency of locations. The utilization distribution represents space use, which is generally described by home range size and habitat composition within the home range (Selonen et al. 2001). I used the combination of Dzubin's (1955) definition and the utilization distribution for describing home range in this study.

Core areas (i.e., activity centers) are defined as areas where an animal spends the majority of its time (Dzubin 1955, Gallerani Lawson and Rodgers 1997), usually because of reliable food resources, nesting sites or loafing areas (Samuel et al. 1985). These areas may not always be distinguished from peripheral areas of the home range (Kenward et al. 2001) because delineating core area boundaries is often arbitrary (Samuel et al. 1985). Therefore, I only estimated peripheral boundaries in this study.

Territory is defined as the area within the home range defended against conspecifics and can include either the entire home range or portions of it (Odum and Kuenzler 1955). However, because I did not record behavioral interactions between individuals, I could not estimate territory sizes.

The concept of home range for avian species is different from other vertebrates. Most home range studies estimate home range boundaries by connecting the outermost locations (minimum convex polygon [MCP], Odum and Kuenzler 1955). However, for birds, this method may overestimate home range size because habitat they fly over but do not use can be included within the MCP. Consequently, estimates of space

requirements and habitat necessary for successful reproduction or survival may be
inaccurate. This is especially true for waterfowl and other species that use patchy or
fragmented habitats (e.g., Frazer et al. 1990, Andren 1992, Telleria and Santos 1992,
Burger et al. 1994). Some home range estimation techniques (e.g., kernel estimators)
provide better estimates because, unlike MCP, they are based on the utilization
distribution and not the outermost locations. Thus, only areas used are included in home
range size estimation (Worton 1987, 1995, Seaman and Powell 1996, Seaman et al.
1999).

Waterfowl (Anatidae) are among the most studied families of birds (Batt 1992).
Much early waterfowl research was directed at understanding how and why ducks space
themselves on the breeding grounds (see Dzubin 1955, McKinney 1965, Titman 1973),
and focused primarily on *Anas* spp. Differences in how species space themselves are
believed to be related to differences in diet requirements, distribution of resources,
strength of pair bonds, and other ecological correlates (Nudds and Ankney 1982). For
instance, northern pintails (*Anas acuta*) rely on ephemeral wetlands that vary temporally
and spatially; thus, home ranges are large making defense impractical (Derrickson
1979). Pintails are promiscuous and more tolerant of one another relative to other
dabbling duck species, reducing the need for intraspecific aggression. Mallards (*A.
platyrhynchos*) are often considered generalists, rely more on seasonal and
semipermanent wetlands than ephemeral ones, and display an intermediate level of
aggression towards conspecifics. In contrast, northern shovelers (*A. clypeata*) have
substantially smaller home ranges presumably because they rely more on stable wetland
conditions than ephemeral ones and their food resources are distributed over smaller

areas and thus are more easily defended (McKinney 1965, Poston 1974, Nudds and Ankney 1982).

Despite much historical interest in waterfowl spacing behavior, vital information gaps remain. These gaps exist not only for lesser-studied species (e.g., shelducks and sheldgeese [*Tadornini*], whistling ducks [*Dendrocygnini*]), but also for the more extensively studied species (e.g., mallard, American black duck [*Anas rubribes*], wood duck [*Aix sponsa*]) (Bellrose 1976, Anderson and Titman 1992, Staus 1998). The mallard is the most studied waterfowl species, likely because of its holarctic distribution, relative ease of study (i.e., meeting sample size requirements), and its importance to the hunting community. Unresolved questions remain about mallard ecology (e.g., Nudds and Ankey 1982, Anderson and Titman 1992), especially how landscape features or female characteristics influence space use, and the consequences of home range size variation and habitat composition for reproductive success and survival. Although most studies have focused on whether or how ducks defend areas, McKinney (1965) believed the emphasis should be on which biological factors (e.g., landscape or female characteristics) influence home range size and Donaghey (1975) emphasized the importance of understanding biological consequences of home range size variation, not just behavioral mechanisms producing it. Anderson and Titman (1992) noted that these ideas had not been adequately addressed mainly because there have been very few large-scale studies about factors influencing individual home range size variation. That deficiency has persisted.

The main determinate of mallard home range size is believed to be wetland density (Dzubin 1955, Dwyer et al. 1979, Krapu et al. 1983, Reynolds 1996). However,

the moderate correlation (r = 0.543) between wetland abundance and mallard breeding densities found by Krapu et al. (1983) implies that home range size may be affected by wetland area or class, amount of perennial cover, spatial arrangement of habitat or some combination of these factors (Nudds and Ankney 1982, Krapu et al. 1997). Although ideas concerning landscape characteristics and female attributes have been tested in some other animals (see Korpimäki 1990, Badyaev et al. 1996b, Forero et al. 1999, Selonen et al. 2001), there have been no tests of these hypotheses in waterfowl. Furthermore, reproductive or survival consequences associated with home range variation have not been identified for female mallards.

Most research concerning female mallard home range size has been conducted outside the prairie parkland region of Canada (see Gilmer et al. 1975, Dwyer et al. 1979, Kirby et al. 1985), but this region supports a large percentage of North America's breeding mallards and is critical to sustaining or increasing mallard populations (Canadian Wildlife Service [CWS] and United States Fish and Wildlife Service [USFWS] 1986). Smith (1971) speculated that mallard space requirements differed among geographic regions, yet results from studies in one region have been used to address habitat management planning and implementation in others. For example, results from research conducted in semi-arid prairie regions of North Dakota (Dwyer et al. 1979) have been applied to the prairie parkland region of Canada (Sankowski et al. 1995). As a result, habitat programs for specific regions may not be well designed.

The North American Waterfowl Management Plan (NAWMP) was created to address decreasing duck populations throughout the continent (CWS and USFWS 1986). Within NAWMP, several "joint ventures" were created to address waterfowl

concerns in specific geographic regions. The Prairie Habitat Joint Venture (PHJV) was

formed to implement upland habitat management programs (e.g., planted nesting cover,

delayed hay, idle-parkland, grazing systems) designed to enhance waterfowl

reproductive success and thereby attain specific population goals for the prairie parkland

region of Canada. Subsequently, the PHJV Assessment study was designed to evaluate

the success of these programs as well as biological assumptions underlying the

implementation of management alternatives (Sankowski et al. 1991, 1995). Home range

information gathered in previous studies (e.g., Dzubin 1955, Titman 1973) was used

initially to guide program implementation (Nelson and Wishart 1988). Upland habitat

projects were distributed spatially to allow access by as many breeding females as

possible. However, limited data from Canada, and estimates of larger home range sizes

in the northern United States (Cowardin et al. 1985) has led to considerable uncertainty

with PHJV conservation planning models. Nudds and Ankney (1982) and Anderson and

Titman (1992) suggested that additional research on ecological correlates of home range

size variation would be highly beneficial to understanding waterfowl biology and

management because population models could then be designed to work more reliably

in specific geographic areas targeted for management. My overall goal was to examine

variation in home range size and evaluate consequences for free-ranging female

mallards using data collected on multiple PHJV Assessment study areas during 1995-

1998.

1.2   Organization of thesis

Specific objectives in this study were to (1) identify correlates of home range size

of breeding female mallards and (2) to assess whether specific features of home ranges

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and/or female attributes were associated with greater reproductive success or survival. Chapter 2 describes study areas and general methods used in subsequent chapters. In Chapter 3, I estimate female mallard home range size, and examine correlates (e.g., landscape characteristics and female attributes) of home range size variation. Then, I evaluate consequences (i.e., reproductive success, survival) of home range size and composition for female mallards (Chapter 4). My final chapter (Chapter 5) concludes with a synopsis of major findings, management recommendations, and suggestions for future work.

CHAPTER 2: STUDY AREAS AND GENERAL METHODS

2.1   Study areas

I investigated home range variability and consequences for breeding female mallards on 12 study areas (Figure 2.1) used by the PHJV Assessment from 1995-1998 (Sankowski et al. 1991, 1995). Each study area (64-km^2) was categorized by one of three treatment levels (low, medium, high) relative to the percentage of the area enrolled in PHJV habitat conservation programs (e.g., planted nesting cover, delayed hay, grazing systems, fall seeded crops). Low treatment study areas had <3% of the total study area enrolled in PHJV habitat programs, medium treatment study areas had between 4-11%, and high treatment study areas had >11%. Location, year and treatment type are described in Table 2.1 and more detailed locations and descriptions for each study area are available in Joynt et al. (1996, 1998, 1999) and Emery et al. (1997).

Intensive agriculture practices (primarily cereal grain and oil-seed farming, and forage production and pasture for livestock) have eliminated most native aspen parkland, shrubland and grassland on all study areas. Land not in agriculture production contained wetland basins of all classes and cover types (see Stewart and Kantrud 1971), scattered blocks of deciduous trees (*Populus* spp.), patches of idle grassland (both tame and native), fence lines, and road and railway allowances. Wetland habitat has also been reduced and/or altered because of the same agricultural practices listed above (Turner et al. 1987). Emergent wetland and wet meadow vegetation consisted primarily of cattail
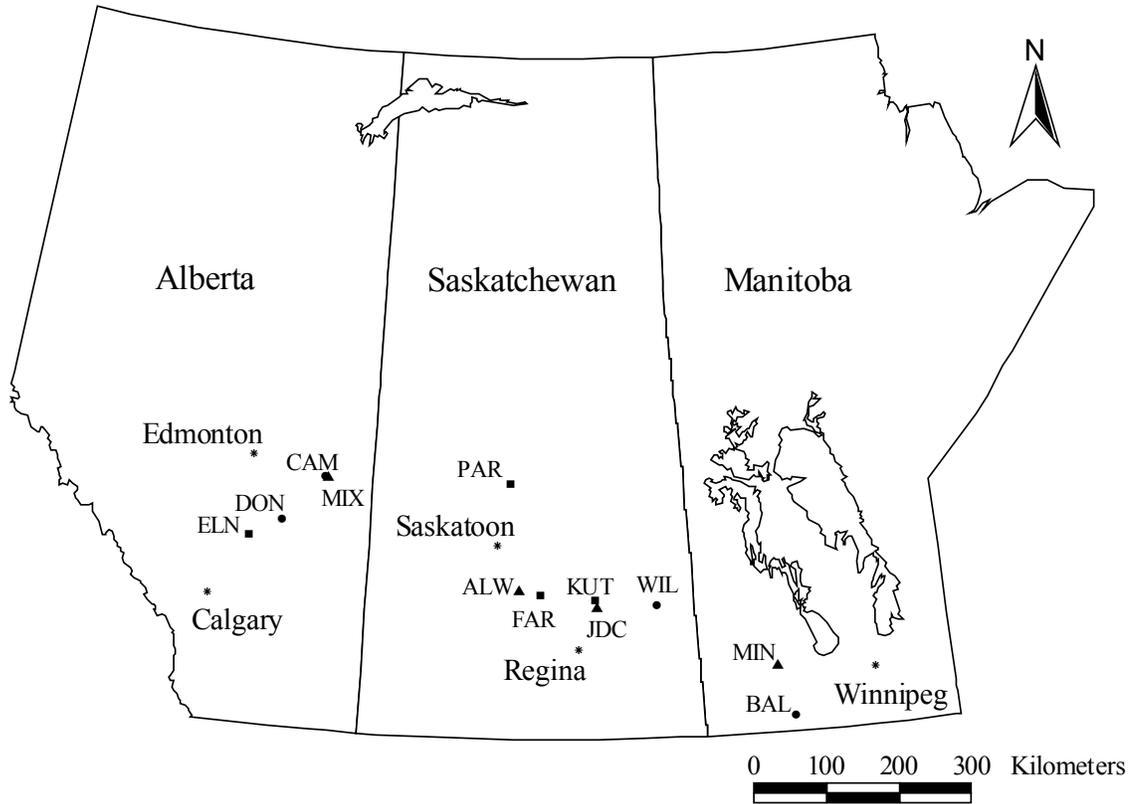
Figure 2.1. Location of study areas (SARs) within the prairie parkland region of Canada, 1995 - 1998. Squares represent low treatment SARs, circles represent medium treatment SARs, and triangles represent high treatment SARs. See Table 2.1 for SAR and treatment details.

Table 2.1. List of study areas (study area abbreviation[a]), treatment category (% of SAR in treatment[b]), year studied, province, and geographical location. Study areas are listed alphabetically within treatment types.

SAR (Abbrev.)	Treatment (%)	Year	Province	Lat-Long
Elnora (ELN)	Low (1.0)	1997	AB	52°02'N, 113°15'W
Farrerdale (FAR)	Low (0.0)	1998	SK	51°31'N, 105°52'W
Kutawa (KUT)	Low (0.0)	1995	SK	51°25'N, 104°11'W
Parkside (PAR)	Low (0.0)	1996	SK	53°11'N, 106°33'W
Baldur (BAL)	Medium (9.4)	1996	MB	51°25'N, 104°11'W
Camp Lake (CAM)	Medium (7.9)	1995	AB	53°09'N, 111°32'W
Donalda (DON)	Medium (7.1)	1998	AB	52°33'N, 112°36'W
Willowbrook (WIL)	Medium (4.3)	1997	MB	51°13'N, 102°54'W
Allan Hills West (ALW)	High (21.6)	1997	SK	51°39'N, 106°05'W
Jumping Deer Creek (JDC)	High (20.1)	1998	SK	51°14'N, 104°08'W
Minnedosa (MIN)	High (12.3)	1998	MB	50°11'N, 99°52'W
Mixburn (MIX)	High (13.6)	1997	AB	53°08'N, 111°23'W

[a] Study area abbreviation used throughout text.

[b] Low treatment SARs had <3% of the total SAR enrolled in PHJV habitat programs, medium treatment SARs had between 4-11%, and high treatment SARs had >11%.

(*Typha* spp.), bulrush (*Scirpus* spp.), sedges (*Carex* spp.), whitetop (*Scolochloa festucacea*), reed grass (*Calamagrostis* spp.), and manna grass (*Glyceria* spp.). Willow (*Salix* spp.) and red-osier dogwood (*Cornus stolonifera*) dominated low-lying areas around wetlands, and grasses, wild rose (*Rosa woodsii*), snowberry (*Symphoricarpos albus*), chokecherry (*Prunus virginiana*), and silverberry (*Elaeagnus commutata*) typically dominated upland and low shrub communities (Emery et al. 1997, Joynt et al., 1999). Common waterfowl predators found on some or all study areas included: American crows (*Corvus brachyrhynchos*), black-billed magpies (*Pica pica*), coyotes (*Canis latrans*), Franklin's ground squirrels (*Spermophilus franklinii*), great-horned owls (*Bubo virginianus*), northern harriers (*Circus cyaneus*), red foxes (*Vulpes vulpes*), red-tailed hawks (*Buteo jamaicencis*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*).

2.2 General methods

2.2.1 Capture and marking

Pre-laying female mallards (135 per study area) were captured using decoy traps (Sharp and Lokemoen 1987), and banded with USFWS leg bands. Mass (nearest 10 g, measured with 1500g Pesola® spring scale), wing chord length (nearest 1 mm, measured with ruler), tarsus and head-bill lengths (nearest 0.1 mm, measured with dial calipers) were recorded for each captured female. A 22g-radio transmitter (Telonics model IMP/150, Mesa, Arizona, USA) was implanted into the abdominal cavity of each female using a general anesthetic (Olsen et al. 1992, Rotella et al. 1993) and released ≤ 1 hour after surgery was completed. This attachment method was expected to yield the least biased data (Korschgen et al. 1984, Pietz et al. 1993, Rotella et al. 1993 and Paquette et

al. 1997). The second greater secondary covert was removed to classify each female as either second-year (SY, entering first breeding season), after second-year (ASY, entering $\geq$ second breeding season), or after hatch-year (AHY - SY or ASY not determined) based on feather criteria (Krapu et al. 1979, R. G. Clark, CWS, unpublished data). I followed animal-welfare protocol (19920007) approved by the University Committee on Animal Care and Supply Protocol Review Committee, University of Saskatchewan.

2.2.2   Radio-tracking

Each study area was divided into 4 equal-sized focal quadrants (16-km^2) and one was randomly selected from each study area for intensive mallard tracking. Within each focal quadrant, 25 randomly selected females were initially included (n = 300). Tracking period for each female began 3 days after capture and release, and ceased at the end of nesting (i.e., when a female hatched a nest, was killed, or was seen flocked once with at least one other female). I attempted to locate each female at least twice daily (6 days/week) from 0600-1330 hours and also hourly during either one afternoon (1400-1800) or evening (1800-2200) session per week, trying also to locate a female at different times on successive days to reduce potential temporal location biases. Logistical constraints prevented tracking females in the entire study area and also obtaining more locations during afternoon and evening sessions.

All locations were estimated by triangulation procedures using either truck-mounted null array antenna systems or hand-held antennas (White and Garrott 1990). Triangulations from trucks were taken from grid roads (generally 1.6 km apart), and dirt-trails, which typically allowed for bearings to be recorded at, or as close as possible

to, 90° angles from a distance of ≤ 0.8 km. Hand-held triangulations were performed by circling around the female at close range (attempting not to flush her) and estimating her location. Females were located 26,895 of the 27,800 times they were searched for ($\bar{x}$ = 96.9% ± 2.3% SD). Locations were plotted on field maps and descriptions (which aided in transcribing locations) for each location were recorded. Each telemetry location was transcribed from field maps to digitized maps and assigned Universal Transverse-Mercater (UTM) coordinates. Bearings from truck-mounted systems had a mean error of 0.5^o (SD = 3.2) (Rotella et al. 1995). Bearing errors for hand-held systems were not calculated because observers either obtained visual observations or were close enough to the radio-marked female to reliably estimate her location within a few meters.

2.2.3   Selection of home range estimation technique

I used the Arcview 3.2 (ESRI, Redlands, California, USA) extension Animal Movement 2.0 (Hooge and Eichenlaub 1997) to estimate home range size. Fixed kernel estimation using least squares cross-validation (LSCV) (see Naef-Daenzer 1993, Worton 1995, Seaman and Powell 1996, Seaman et al. 1999) was used to calculate 95% probability contours of home range boundaries (i.e., total home range size) for all females that met stringent inclusion requirements (see below).

2.2.4   Mallard pair surveys

Pair surveys were conducted, using a protocol established by the Institute for Wetland and Waterfowl Research (IWWR) (IWWR 1999), on each study area to estimate mallard breeding pair densities. Pair densities were calculated (see Dzubin 1969b) for each study area using data collected on equal-sized, randomly selected

transects conducted on two consecutive mornings. Approximately half of each study area was covered during the two surveys, and each transect was surveyed only once.

2.2.5 Habitat composition

Each study area was photographed in July of the study year using 1:5000 black and white aerial photography. Photographs were ground-truthed against detailed land-use information and corrected for distortion, and habitats were delineated (see Ptashynski et al. 2001) and digitized in vector format (SPANS 1997, Tydec Research Inc., Ottawa, Ontario, Canada) with < 5 m accuracy. Habitats for each study area were initially classified into the following cover types: grassland (GR), hayland (HA), planted cover (PC), cropland (CR), woodland (WD), shrubland (SH), wetland basins (WE), farmstead (FA), and other habitats like rock-piles, stick nests, hay-bales, and unknown (OT1). Wetland habitat for each study area was further categorized (during July because of logistical constraints) into 6 different classes described by Stewart and Kantrud (1971) and linked to digitized polygons. Wetland information was included in my analyses only if water was present. Detailed descriptions of habitats are provided in Appendix 2.1. Type and amount of habitat within each female's home range was estimated (nearest 0.5 ha) using Arcview 3.2 (ESRI, Redlands, California, USA). Percentages of habitat composition at the study area, focal quadrant, and home range level were used in all analyses unless otherwise noted.

2.2.6 Data screening and selection

All telemetry locations used for home range estimation were recorded at least one hour apart. Although most locations were not statistically independent (Swihart and

Slade 1985), I believed they were biologically independent (Lair 1987, Ganey and Balda 1989) because a female could have traversed multiple home ranges within one hour. Also, only one nest location per nesting attempt (all of which were within home range boundaries) was included in analyses to reduce systematic bias of repeated locations from the same nest site (Squires et al. 1993, Mazur et al. 1998). I determined the minimum number of locations needed to reliably estimate home range size by determining the asymptotic relationship between home range size and number of locations. This relationship was calculated utilizing a bootstrap routine (Seaman et al. 1999), using 100 iterations for 5 to 8 different sample sizes (n = 25 – 100), within Animal Movement 2.0 (Hooge and Eichenlaub 1997) (see Appendix 2.2.).

Habitat information was available only within study area boundaries; therefore, locations off the study area were not linked to habitat information. However, given high spatial autocorrelation of habitat within study areas (D. W. Howerter, IWWR, unpublished data and Chapter 3); habitat information was extrapolated for the entire home range for individuals with ≥50% of locations on the study area. To summarize, I only included females in analyses if there was never a lapse of locating them for ≥5 consecutive days, and there were ≥50 locations available and ≥50% of these were on the study area. Although these criteria considerably reduced my sample size (300 to 131), I believe that these data provided the best possible estimates of home range size and composition.

CHAPTER 3: SIZE AND HABITAT COMPOSITION OF FEMALE MALLARD HOME RANGES IN THE PRAIRIE PARKLAND REGION OF CANADA

3.1 Introduction

Understanding factors that affect the spatial distributions of animals is a general problem faced by ecologists and is fundamental to conservation management decisions (Anderson and Titman 1992, Larkin and Halkin 1994, Badyaev et al. 1996a, Pöysä et al. 1998). Therefore, ecologists often attempt to determine which biological factors (e.g., landscape characteristics, female attributes) affect spacing patterns. Spacing patterns, in turn, are frequently evaluated by estimating individual home range sizes and overlap (McNab 1963, Schoener 1968, Blundell et al. 2001).

Conventional wisdom holds that the main determinant of female mallard (*Anas platyrhynchos*) home range size is wetland density (e.g., Titman 1973, Pospahala et al. 1974, Dwyer et al. 1979, Krapu et al. 1983, Kirby and Riechmann 1985, Johnson and Grier 1988). However, the moderate correlation (r = 0.543) between wetland abundance and mallard breeding density (Krapu et al. 1983) suggests that variation in home range size also may be affected by wetland area or class (see Stewart and Kantrud 1971), amount of perennial upland cover, spatial arrangement of upland or wetland habitats or some combination of these factors (Nudds and Ankney 1982, Krapu et al. 1997, Austin 2002).

Female attributes may also affect home range size since there is a positive correlation between home range size and body size across animal taxa (McNab 1963,

Schoener 1968, Harestad and Bunnel 1979), including waterfowl (McKinney 1965, Nudds and Ankney 1982). However, whether intraspecific differences in body size influence home range size has not been adequately evaluated. Home range size may also vary as a function of age class within a species (Thogmartin 2001). Younger individuals may be forced into less suitable habitat because older individuals exclude them from optimal areas (Dzubin 1969a, Lindstedt et al. 1986, Lokemoen et al. 1990) producing larger home ranges for younger females as they compensate for low quality habitat.

Although ideas concerning landscape characteristics and female attributes have been tested in some other animals (see Korpimäki 1990, Badyaev et al. 1996a, Forero et al. 1999, Selonen et al. 2001), there have been remarkably few tests of these hypotheses in waterfowl. No one has yet investigated correlates of mallard home range size using a large data set with spatial replication, measures of landscape characteristics, female morphometric measurements, or recognizable age classes. Furthermore, with the exception of few other studies (Dzubin 1955, Titman 1973, Thorpe 1997), research concerning female mallard home range size has been conducted outside the prairie parkland region of Canada (hereafter referred to as prairie parklands). Only Thorpe (1997) has investigated correlates of home range size variation of female mallards; however, he was not able to evaluate effects of upland habitat characteristics and female attributes. Therefore, my objectives were to 1) examine home range size variation and habitat composition of free-ranging female mallards, 2) test whether older or smaller female mallards had smaller home ranges than either younger or larger individuals, and 3) evaluate whether home range size was related to specific features of home ranges, wetland density or mallard pair density.

3.2   Methods

Data were collected from 12 study areas in the prairie-parklands, 1995 - 1998. Each study area (65-km^2) was examined for one year and categorized into one of three Prairie Habitat Joint Venture (PHJV) treatment levels. Detailed descriptions of study areas and field methods are provided in Chapter 2.

3.2.1   Data analysis

3.2.1.1   Home range size variation

To assess the extent and nature of individual home range size variation in my data, I first tested whether individual home range size varied among study areas and among treatment type, and study areas nested within treatments using analysis of variance (ANOVA), and nested ANOVA, respectively (PROC GLM, SAS Institute 1999). Multiple comparisons for each analysis were performed using Duncan's multiple range tests.

Generally, waterfowl pair densities are positively correlated with wetland area (Krapu et al. 1983, Johnson and Grier 1988, Krapu et al. 1997, Austin 2002). I also found this relationship ($r = 0.65$, $P = 0.02$) in my data (Figure 3.1) at the study area level. I used mallard pair densities enumerated during May surveys (see Chapter 2) and seasonal (class 3; Stewart and Kantrud 1971) and semi-permanent (class 4) wet wetland area determined in July to test this relationship. Wetland area was taken as the percentage area of each home range, focal quadrant, or study area occupied by class 3 and class 4 wetlands combined (hereafter 'percentage of C3-4 wetlands' or simply 'C3-4 wetland area'). Since home range size could be affected by both pair density and
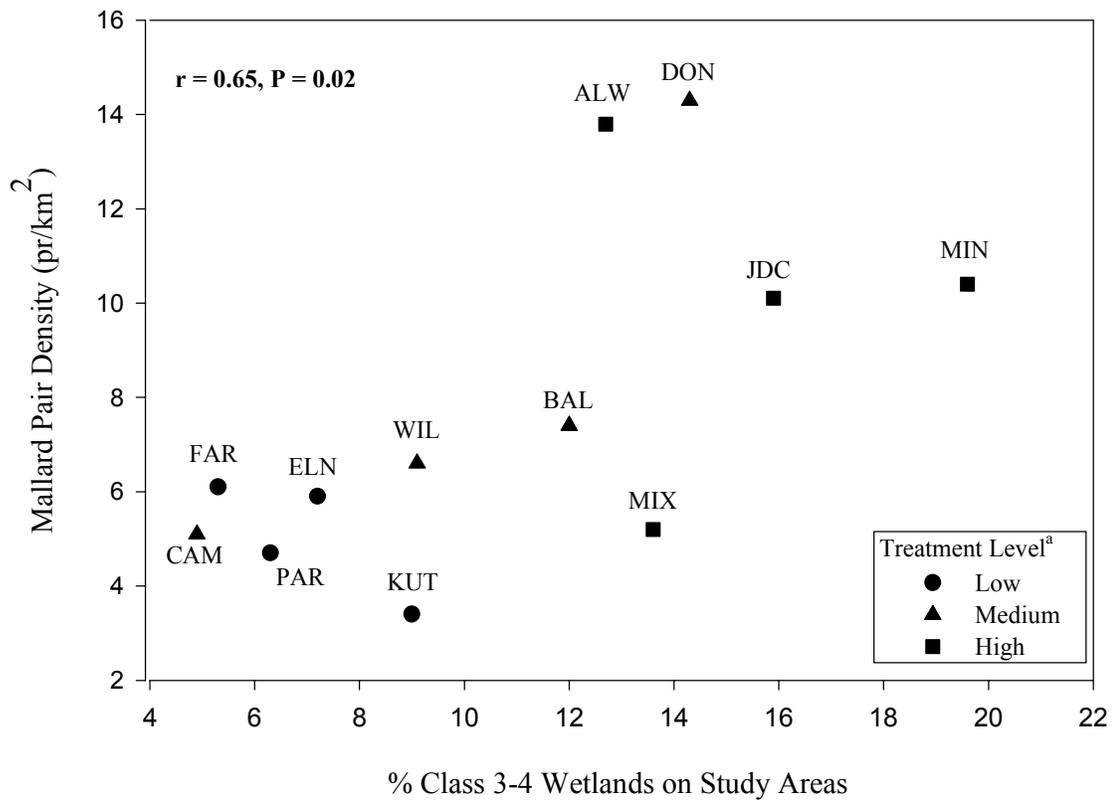
Figure 3.1. Mallard pair density vs. percent class 3-4 wetlands for 12 study areas (SARs)
in the prairie parkland region of Canada, 1995 - 1998. See Table 2.1 for SAR and
treatment[a] details.

wetland area; the strength of the correlation among variables could be confounded by their interactions (Cody and Smith 1997). Therefore, I used partial correlation (PROC CORR [SAS Institute 1999]) to test if variation in home range size, at the study area scale, was related to either mallard pair densities or percentage of seasonal and semi-permanent wetlands.

3.2.1.2 Female body size and age

Principal component analysis (PCA) (PROC PRINCOMP, SAS Institute 1999) was used to determine patterns of covariation among wing chord, head-bill length, and tarsus length. The first principal component (PRIN1) described positive covariation among the morphometric variables (coefficients: 0.56, 0.62, 0.55 corresponding to wing, head-bill, and tarsus, respectively) and accounted for 60.1% of the total original variance. Therefore, I interpreted scores along PRIN1 as an index of structural size (Dufour et al. 1993). However prior to using body size as a predictor in home range size models, I determined if body size was related to study area, age or capture date (standardized for all study areas relative to study area-specific date that trapping began so days were comparable among all females). I determined if body size was related to these factors using 14 candidate models including all combinations of these factors including second-order interactions, and a null (intercept only) model. For this and subsequent analyses, I used Akaike's Information Criterion corrected for small sample size (AIC_c), and corresponding Akaike weights as the principal basis for selecting among competing models (Burnham and Anderson 1998).

3.2.1.3 Habitat composition

I tested habitat variables for normality using Shapiro-Wilk's test statistic (SAS Institute 1999) and transformed them if necessary. All variables were best transformed using $\log_e$. Back-transformed values (mean ± SE) are presented in all tables and figures unless otherwise noted. Multivariate analysis of variance (MANOVA; PROC GLM, SAS Institute 1999) was used initially to test for variation in home range habitat composition among study areas. Transformed habitat variables were included simultaneously as dependant variables, study area was the main effect and home range size (95% probability contour) was the covariate. Very similar results were obtained with habitat area and home range size as the covariate so I used and reported percentage only.

3.2.1.4 Correlates of home range size

I developed a candidate set of models using nesting habitats and female attributes that are believed to be important to breeding mallards (see Cowardin et al. 1985, Greenwood et al. 1987, 1995, Clark and Shutler 1999). I combined woodland and shrubland habitat into wood-shrub (WDSH) because mallards frequently nest in these habitats, these variables were correlated ($r = 0.56$, $P < 0.0001$), and difficulties existed in delineating between tall shrubs and small trees. I predicted home range size would decrease as percent WDSH increased. I also included C3-4 wetland area because these two wetland classes (Stewart and Kantrud 1971) appear to be equally important for breeding waterfowl (see Johnson and Grier 1988, Krapu et al. 1997, Austin 2002). I predicted home range size would decrease as the percent of C3-4 wetlands increased. Planted nesting cover (PC) was included as a potential covariate in my models because

this is a preferred nesting habitat (IWWR, unpublished data); thus, I predicted that home range size would decrease as the percent of PC increased. Female age, body size, and standardized capture date were also included in the global model. I predicted that ASY and smaller females would have smaller home range sizes, and females captured earlier would have smaller home ranges than those captured later.

I used general linear models (PROC GLM; SAS 1999) to evaluate correlates of home range size using the above variables and second order interactions (following Burnham and Anderson 1998) in models that included any combination of C3-4 wetland area, age, body size, or capture date, resulting in a total of 65 candidate models. I excluded grassland, hayland, and other wetland classes because grassland and hayland were not used as primary nesting cover by mallards (Howerter 2003), grazed grassland areas were indistinguishable from non-grazed grasslands, and other wetland classes consisted of < 11% of all wetland basin area.

3.3   Results

Overall, 131 females (range = 5-15 per study area; median = 10) met all criteria needed for inclusion in my analyses (see Chapter 2). Number of locations used to estimate home range size for individual females averaged 114 ± 38 SD (range = 53 - 252) and home range size (95% fixed-kernel) ranged from $3.9 - 1281.8$ ha ($\bar{x} = 163.8$ ha ± 16.7 SE). As expected, home range size was not correlated with number of locations used to estimate home range size (r = 0.07, P = 0.38). Females in each age group were well represented in the sample (61 SY females and 65 ASY females); ages of 5 females could not be determined and were excluded from age-related analyses (Table 3.1).

Table 3.1. Number of female mallards that met criteria for inclusion in analyses. Study areas (SARs) are grouped by treatment level (TRT) (see Table 2.1 for SAR and TRT information).

TRT	SAR	N[a]	NST[b]	HAT[c]	DEAD[d]	SY[e]	ASY[f]	UNK[g]
Low	ELN	8	8	4	2	3	5	0
	FAR	15	13	1	3	3	11	1
	KUT	11	7	0	0	8	2	1
	PAR	15	14	0	2	9	5	1
Subtotal		*49*	*42*	*5*	*8*	*23*	*23*	*3*
Medium	BAL	15	15	3	2	6	9	0
	CAM	5	5	0	1	1	4	0
	DON	15	11	2	1	11	4	0
	WIL	9	8	2	0	4	5	0
Subtotal		*44*	*39*	*7*	*4*	*22*	*22*	*0*
High	ALW	15	15	4	4	7	7	1
	JDC	9	9	3	0	4	5	0
	MIN	9	9	1	2	2	6	1
	MIX	5	5	3	2	3	2	0
Subtotal		*38*	*38*	*11*	*8*	*16*	*20*	*2*
TOTAL		**131**	**119**	**23**	**19**	**61**	**65**	**5**

continued

Table 3.1 continued.

[a] Females with at least 50 locations and 50% of total locations on the study area.

[b] Females that nested at least once.

[c] Females that hatched at least one egg.

[d] Females known killed during breeding season.

[e] Second Year females.

[f] After Second Year females.

[g] Unknown aged females – eliminated from age-related analyses.

3.3.1 Home range size variation

Home range size differed among study areas (F = 2.91, df = 11,119, P = 0.002). Females from KUT had larger home ranges than those from JDC, MIN, ELN, ALW and DON, and females at KUT, CAM and FAR had larger home ranges than those at MIN, ELN, ALW and DON (Figure 3.2).

Home range size varied among treatments (F = 4.41, df = 2,119, P = 0.01) and among study areas nested within treatments (F = 2.02, df = 9,119, P = 0.04). Home ranges (mean ± SE) of females on low treatment study areas (211.5 ± 31.9, n = 49) were larger than those of females on medium (153.1 ± 27.3, n = 44) or high (114.6 ± 23.2 SE, n = 38) treatment study areas; home ranges of females on medium or high treatment study areas did not differ (Appendix 3.1). Mean home range size at the study area scale (n = 12) was not correlated (r = -0.26, P = 0.43) with the percentage of C3-4 wetlands when statistically controlling for mallard pair density. However, a moderate negative correlation (r = -0.56, P = 0.07) existed between home range size and mallard pair density when percentage of C3-4 wetlands was statistically controlled (Figure 3.3).

3.3.2 Habitat composition

A wide range of habitat composition existed both inside and outside the focal quadrant level (see Chapter 2) (Table 3.2). The following list provides the range of habitat at the focal quadrant level across all study areas; grassland, 5.2% - 43.8%, median 11.8%; planted cover, 0% - 14.0%, median 3.0%; cropland, 9.9% - 66.2%, median 57.4%; woodland, 0.8% - 24.8%, median 5.7%; shrubland, 0.7% - 5.7%, median
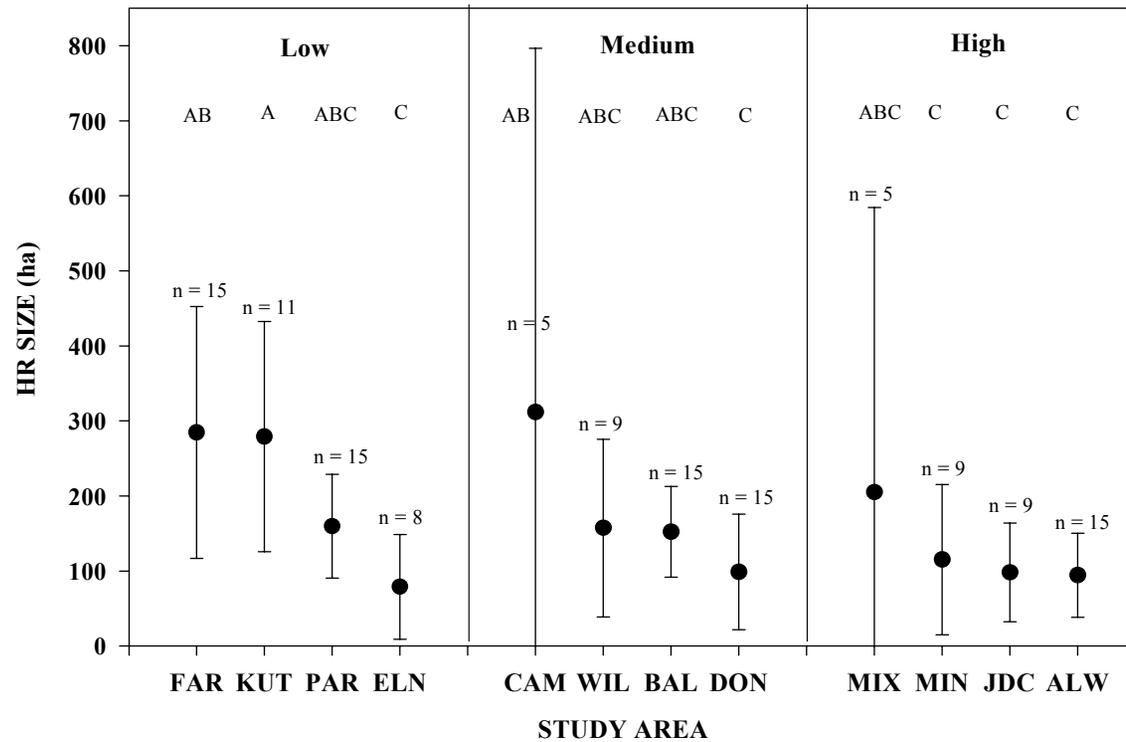
Figure 3.2. Site-specific variation in female mallard home range (HR) size (mean and 95% CI). Study areas (SARs) are grouped by treatment level (see Table 2.1 for SAR and treatment details). Sample sizes for each SAR are given along with results from Duncan's multiple range test (SARs sharing the same letter [A, B, C] are not significantly different).
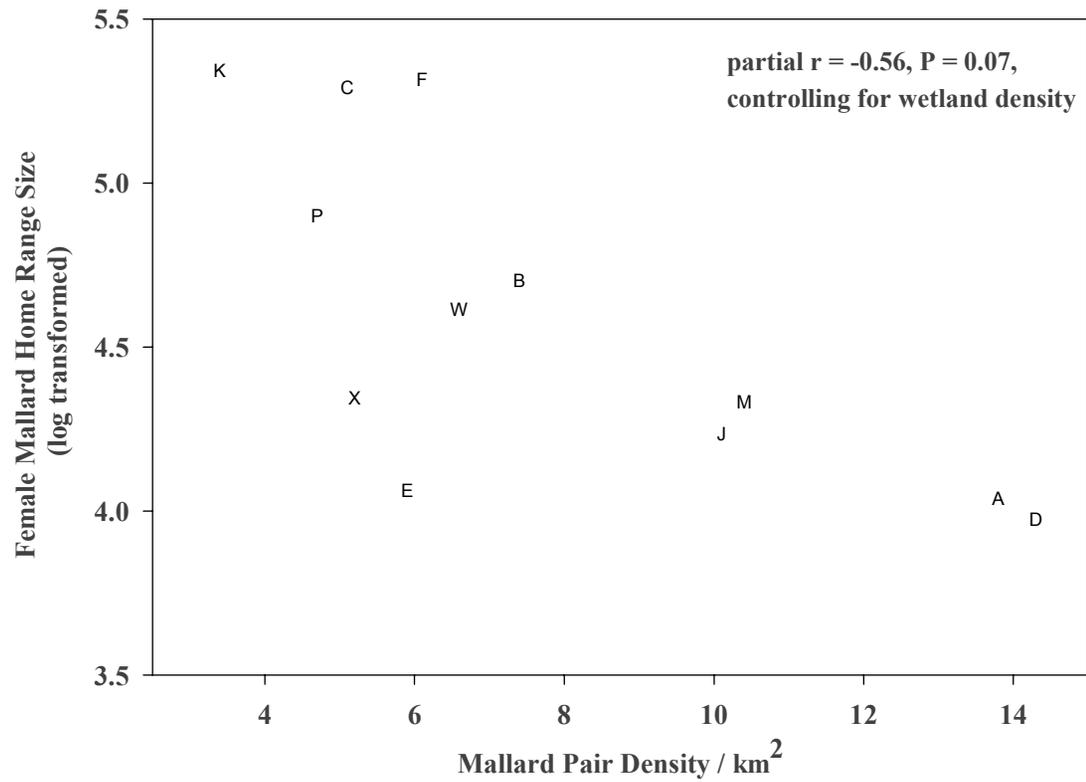
Figure 3.3. Female mallard home range size vs. mallard pair density when controlling for wetland density for 12 study areas (SARs) in the prairie parkland region of Canada, 1995 - 1998. Symbols represent the first letter of each SAR, except 'X', which is the last letter for Mixburn. See Table 2.1 for SAR and treatment information.

Table 3.2. Percent habitat composition of areas located outside (OUT) and inside (IN) the focal quadrant from which females were intensively tracked for each study area (SAR) in the prairie parkland region of Canada, 1995 - 1998. Study areas are arranged in alphabetical order by treatment level. See Table 2.1 for SAR information.

	Habitat Type																			
SAR	Grassland		Hayland		PC[a]		Cropland		Woodland		Shrubland		Wetland[b]		C34Wet[c]		Farm		Other[d]	
	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN
ELN	43.3	43.8	7.0	5.8	0.0	0.0	9.2	9.9	17.8	24.8	7.6	5.7	11.8	7.5	7.3	6.5	2.0	1.2	0.1	0.0
FAR	27.1	18.5	2.1	1.5	0.0	0.0	56.2	66.2	1.0	0.8	4.6	2.6	4.8	6.2	4.3	5.9	1.3	1.3	0.0	0.0
KUT	19.0	10.7	3.5	2.3	0.0	0.0	51.5	60.9	6.6	6.2	2.5	3.1	13.3	13.8	9.3	8.2	0.9	1.3	0.4	0.4
PAR	14.1	10.8	10.4	4.9	0.0	1.4	56.0	63.6	8.1	5.6	1.0	0.7	5.9	11.4	4.4	10.4	3.4	0.7	0.1	0.1
BAL	18.9	14.1	5.6	4.1	3.7	10.6	31.2	28.7	14.2	19.5	2.4	3.0	21.9	17.3	14.1	8.3	0.5	1.0	0.0	0.8
CAM	37.2	10.0	0.5	3.7	4.8	8.4	30.2	56.0	7.1	6.2	7.4	4.5	8.0	6.8	4.9	4.6	0.8	0.7	0.8	0.9
DON	14.2	5.2	8.1	5.1	6.5	0.0	44.4	65.7	6.1	3.3	2.3	1.6	13.9	15.2	13.6	15.0	2.0	0.9	0.0	0.0
WIL	12.5	11.3	5.1	6.0	2.7	0.6	51.1	60.4	9.4	5.7	6.2	3.9	9.4	8.0	9.1	7.7	1.4	1.7	0.1	0.1

continued

Table 3.2. continued

	Habitat Type																			
SAR	Grassland		Hayland		PC[a]		Cropland		Woodland		Shrubland		Wetland[b]		C34Wet[c]		Farm		Other[d]	
	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN
ALW	8.6	13.2	2.0	0.0	23.6	7.3	46.4	58.6	1.4	1.6	2.9	4.1	12.9	12.1	12.9	12.1	0.8	1.4	0.1	0.1
JDC	18.2	14.8	5.1	1.8	13.1	14.0	19.7	36.0	13.6	10.2	11.6	5.6	16.8	15.8	15.8	15.3	0.8	1.1	0.1	0.0
MIN	11.9	12.2	4.6	0.3	8.6	7.0	46.9	48.8	3.4	2.1	2.3	2.4	18.5	22.0	18.1	21.4	1.7	2.9	0.1	0.1
MIX	19.0	10.0	4.5	6.9	7.0	4.5	40.1	56.2	4.2	2.4	7.7	4.5	15.1	13.5	13.6	13.0	0.7	0.4	0.1	0.1

[a] Planted cover

[b] Total wetland basins that contained water in July

[c] Class 3 and 4 wetland basins that contained water in July

[d] Other habitat includes rockpiles, brushpiles, farm machinery, stick nests, and unknown habitats.

3.5%; C3-4 wetland area, 4.6% - 21.4%, median 9.4% (Table 3.2). Similar ranges

existed outside the focal quadrant level (Table 3.2).

Percent habitat composition of home ranges (within 95% probability contour)

varied across study areas (Wilk's lambda = 0.01, F = 7.33, df = 99, 794, P < 0.0001).

Home ranges at BAL had the most planted cover while DON, MIX, WIL and all 4 low

treatment study areas had none (Table 3.3). Cropland exceeded 35% of home ranges on

all study areas except BAL and ELN. Home ranges on BAL, ELN and JDC had >10%

woodland (Table 3.3). Shrubland occurred most often in home ranges of females at

CAM, ELN and JDC whereas it was <5% of home ranges on all other study areas (Table

3.3). Wetlands (basins with water present in July) comprised > 18 % of home ranges on

BAL, DON, MIN, MIX, and PAR and < 16% on all other study areas (Table 3.3).

3.3.3   Female age and body size

The null model (without age, capture date, or study area effects) had the most

support, suggesting that body size for ASY females ($\bar{x}$ = 0.197 ± 1.31 SD, n = 65) and

SY females ($\bar{x}$ = -0.210 ± 1.35 SD, n = 61) was not related to capture date, or study area

(Table 3.4); however, there was some support for an age difference (Table 3.4).

3.3.4   Correlates of home range size variation

Class 3-4 wetlands were present in the top five models and WDSH was present in

four of the top five models (Table 3.5). These five models received 65% of total support

among models considered (summed AIC_c weights = 0.65). The top model (C3-4 wetland

area, WDSH) had approximately 3 times more support (AIC_c weight) than other top

models, providing strong plausibility for effects of C3-4 wetland area and WDSH on

Table 3.3. Size (ha) and percent habitat composition of female mallard 95% fixed kernel home range (HR) sizes on study areas (SARs) located across the prairie parkland region of Canada, 1995 – 1998. Study areas are arranged in alphabetical order by treatment level. See Table 2.1 and 3.1 for SAR and sample size information, respectively. Shown are mean ± SE

SAR (n)[b]	HR size	Habitat Type[a]							
		Grassland	Hayland	PC[c]	Cropland	Woodland	Shrubland	Wetland[d]	C3-4 Wet[e]
ELN (8)	78.9 ± 29.5	38.9 ± 2.2	7.1 ± 3.0	0.0 ± 0.0	11.1 ± 5.3	23.7 ± 3.7	6.4 ± 1.1	9.9 ± 1.2	7.9 ± 1.3
FAR (15)	284.6 ± 78.3	18.8 ± 3.2	2.0 ± 1.0	0.0 ± 0.0	64.5 ± 2.6	0.7 ± 0.9	2.3 ± 0.3	8.6 ± 0.8	7.7 ± 0.8
KUT (11)	279.1 ± 68.9	8.7 ± 0.9	2.0 ± 0.9	0.0 ± 0.0	64.6 ± 2.1	4.2 ± 0.6	3.6 ± 0.4	13.7 ± 1.0	10.8 ± 0.8
PAR (15)	159.5 ± 32.3	12.9 ± 1.4	4.8 ± 1.7	0.0 ± 0.0	52.1 ± 3.9	5.6 ± 0.7	0.8 ± 0.1	22.1 ± 3.3	18.6 ± 3.7
BAL (15)	152.1 ± 28.2	16.4 ± 2.0	0.6 ± 0.4	16.2 ± 4.2	28.6 ± 2.6	11.8 ± 2.4	2.6 ± 0.5	21.0 ± 3.0	12.5 ± 2.1
CAM (5)	311.4 ± 174.8	10.1 ± 1.0	1.0 ± 1.0	11.7 ± 2.6	45.0 ± 4.6	8.3 ± 2.6	8.9 ± 2.6	11.6 ± 1.8	10.0 ± 1.7
DON (15)	98.8 ± 35.9	5.4 ± 0.6	3.6 ± 1.6	0.0 ± 0.0	60.2 ± 3.8	4.8 ± 0.8	2.3 ± 0.5	20.8 ± 2.0	19.9 ± 2.0
WIL (9)	157.2 ± 51.3	15.9 ± 2.3	4.0 ± 1.4	0.0 ± 0.0	52.5 ± 5.4	6.1 ± 0.9	4.2 ± 0.7	13.0 ± 3.6	12.2 ± 3.8
ALW (15)	94.2 ± 26.0	13.9 ± 1.6	0.0 ± 0.0	14.2 ± 5.7	44.8 ± 5.7	1.5 ± 0.3	4.7 ± 0.5	16.3 ± 2.6	16.0 ± 2.6

Continued

Table 3.3 continued.

SAR (n)[b]	HR size	Habitat Type[a]							
		Grassland	Hayland	PC[c]	Cropland	Woodland	Shrubland	Wetland[d]	C3-4 Wet[e]
JDC (9)	98.0 ± 28.6	8.3 ± 2.4	0.0 ± 0.0	11.9 ± 4.3	39.6 ± 6.7	15.3 ± 4.2	6.5 ± 1.2	17.2 ± 0.9	15.4 ± 0.6
MIN (9)	115.0 ± 43.4	11.9 ± 1.3	0.1 ± 0.1	5.6 ± 2.9	47.1 ± 3.3	2.3 ± 0.7	2.5 ± 0.5	22.2 ± 2.6	20.0 ± 2.7
MIX (5)	205.0 ± 136.6	12.3 ± 3.8	1.5 ± 1.4	0.0 ± 0.0	56.6 ± 9.9	3.9 ± 2.2	4.8 ± 1.5	19.1 ± 3.2	17.5 ± 3.4

Note: Study areas are arranged in alphabetical order by treatment level (See Table 2.1).

[a] Farmstead and other habitats (e.g., rockpiles, brushpiles, unknown) within HRs averaged 1.7% ± 0.5 SE (range = 0.5% - 5.3) for all SARs, and are not shown separately.

[b] Number of radio-marked females used to calculate HR size for each SAR

[c] Planted cover.

[d] Total wetland basins that contained water in July

[e] Seasonal and semi-permanent wetlands that contained water in July

Table 3.4 Akaike Information Criterion values, adjusted for small sample size (AIC_c),

for top five models evaluating effects of age, study area, and capture date on body size

variation for 126 female mallards from 12 study areas in the prairie parkland region of

Canada, 1995 - 1998.

Model	NP^a	AIC_c	ΔAIC_c^b	AIC_c weight
Null[c]	2	35.74	0.00	0.43
Age	3	36.54	0.81	0.28
Capture date	3	37.83	2.09	0.15
Age, capture date	4	38.68	2.94	0.10
Age, capture date, age*capture date	5	40.71	4.97	0.04

[a] Number of estimable parameters in analysis of covariance model.

[b] Difference between AIC_c of the current model and the minimum observed value.

[c] Intercept-only model.

Table 3.5. Akaike Information Criterion values, adjusted for small sample size (AICc), for representative models of correlates of female mallard home range size in the prairie parkland region of Canada, 1995 - 1998. Top 5 models are presented along with body size, age and capture date only models.

Model	NP[a]	AIC_c	ΔAIC_c[b]	AIC_c weight
Class 3-4 wetlands[c], Wood-shrub[d]	4	2.55	0.00	0.27
Class 3-4 wetlands	3	4.42	1.87	0.11
Class 3-4 wetlands, Wood-Shrub, Age	5	4.66	2.11	0.09
Class 3-4 wetlands, Wood-shrub, PC[e]	5	4.68	2.13	0.09
Class 3-4 wetlands, Wood-Shrub, Body Size	5	4.70	2.16	0.09
Capture date	3	13.67	11.13	0.00
Body Size	3	14.51	11.96	0.00
Age	3	14.76	12.22	0.00

[a] Number of estimable parameters in model.

[b] Difference between AIC_c of the current model and the minimum observed value.

[c] Percentage of class 3 and 4 wetlands within total home range.

[d] Percentage of woodland and shrubland within total home range.

[e] Percentage of planted cover within total home range.

home range size variation (Table 3.5) Partial regression coefficients indicated that home range size was negatively related to the percentages of C3-4 wetlands or WDSH, $\beta = -0.06 \pm 0.01$ SE, $\beta = -0.03 \pm 0.01$ SE, respectively. Model-averaged estimates based on re-normalized model weights (see Burnham and Anderson 1998:148) were similar (nearest 0.01) to original estimates, so model-averaging was not used. Although age ($\beta = 0.41 \pm 0.24$ SE), body size ($\beta = -0.01 \pm 0.07$ SE), and PC ($\beta = 0.002 \pm 0.007$ SE) were each present in one of the top five models, these models were not well supported (AIC_c weight < 12%; Table 3.5). Models including only age, body size, or standardized capture date received no support (Table 3.5).

When I further checked relationships among variables it was evident that females from ELN could drive the association between home range size and WDSH. When females from ELN were excluded, rankings of the top two models (C3-4 wetland area, and C3-4 wetland area, WDSH) were reversed (Table 3.6). Home range size was negatively related to C3-4 wetland area ($\beta = -0.06 \pm 0.01$ SE); however, the negative relationship between home range size and WDSH was weak ($\beta = -0.02 \pm 0.01$ SE). The remaining top models (Table 3.6) were the same as when ELN was included.

3.4   Discussion

I evaluated four hypotheses about why home range size of breeding female mallards could vary and obtained strong support for one. Female home range size was inversely related to percentage of C3-4 wetlands, likely because intraspecific competition for breeding space is reduced when more C3-4 wetland area is present, as reported in other studies of breeding mallards (Titman 1973; Krapu et al. 1997). To my

Table 3.6. Akaike Information Criterion values, adjusted for small sample size (AICc) for representative models of correlates of female mallard home range size in the prairie parkland region of Canada, 1995 – 1998, with females from Elnora excluded. Top 5 models shown along with the body size and age models.

Model	NP[a]	AIC_c	ΔAIC_c	AIC_c weight
Class 3-4 wetlands[b]	3	3.10	0.00	0.39
Class 3-4 wetlands, Wood-Shrub[c]	4	4.29	1.19	0.22
Class 3-4 wetlands, Wood-Shrub, Body Size	5	6.42	3.32	0.07
Class 3-4 wetlands, Wood-Shrub, Age	5	6.43	3.33	0.07
Class 3-4 wetlands, Wood-Shrub, PC[d]	5	6.47	3.37	0.07
Capture date	3	14.00	10.89	0.0
Body Size	3	17.35	14.25	0.0
Age	3	17.60	14.49	0.0

[a] Number of estimatable parameters in model.

[b] Percentage of class 3 and 4 wetlands within total home range size.

[c] Percentage of woodland and shrubland within total home range size.

[d] Percentage of planted cover within total home range size.

knowledge, this study was the first to simultaneously test whether combinations of wetland classes, specific upland habitat components, and female attributes could be used to predict breeding female mallard home range size. Modest support was obtained for my prediction that home range size would decrease as the percent of WDSH increased (Table 3.5). The presence of WDSH in four of the top five models (Table 3.5) suggests that, at the home range level, breeding female mallards space themselves, in part, according to local availability of this preferred upland nesting habitat (Cowardin et al. 1985; IWWR unpubl. data). Wood-shrub habitat may also reduce visual contact among mallard pairs, possibly reducing intraspecific interactions and resulting in smaller home ranges. Although there was some evidence for a WDSH effect, my prediction that home range size would be negatively correlated to PC was not well supported (Table 3.5) and PC was a preferred nesting habitat on PHJV Assessment sites (Howerter 2003). However, since PC is often established in areas with high wetland densities, its importance in predicting home range size may be masked. Alternatively, I may have lacked sufficient data (i.e., PC was only present in home ranges of 36 females) to detect a difference.

There was only weak evidence that female characteristics were associated with home range size when considered in combination with C3-4 wetland area and WDSH (Table 3.5). However, contrary to my predictions, female mallard home range size was not associated with body size variation or age when considered separately (Table 3.5). One possible reason why we did not detect an intraspecific body size difference is that other female attributes, that we were unable to determine (e.g., body condition), played a more important role in determining home range size. Weak evidence for an age effect in

our study could be partly explained because most yearling female mallards are able to breed. Perhaps home range size is more strongly related to breeding experience, female quality, or male quality. We were only able to adequately determine female age, but these other ideas warrant further attention.

Although *a priori* associations between home range size and specific upland habitat components were evident, I realize that this does not distinguish cause from effect. Additionally, I was unable to account for effects of food availability (McKinney 1965; Nudds and Ankney 1982), social interactions (Dzubin 1955; McKinney 1965), changes in space use during different reproductive periods (Kirby et al. 1985; Thorpe 1997), and habitat quality. Therefore, these factors and those considered in this study should be evaluated in future studies at varying scales (e.g., home range size, territory size, and local and regional levels).

Home range size of female mallards in the prairie parklands is at least partly related to local availability of C3-4 wetland area and, to a lesser extent, WDSH habitat. The importance of wetlands is not surprising; however, until this study, potential effects of upland habitat or female characteristics on home range size had not been explored simultaneously. Habitat managers typically establish upland conservation projects (e.g., planted cover) in areas of high wetland densities to provide nesting habitat for as many pairs as possible, based on the premise that female mallards use approximately 6.4 km^2 during the nesting season. Home range sizes that I estimated were smaller and negatively associated with WDSH, so fewer pairs than originally thought may be exposed to habitat programs (also see Thorpe 1997, McKinnon and Duncan 1999). Thus, information about within and between-year breeding dispersal among nesting

habitats by female mallards is urgently needed. Likewise, quantifying the impact of WDSH habitat on use of planted cover by nesting females has clear implications for successful habitat management. For instance, benefits of increased nest success associated with planting cover in areas with widespread perennial cover must be balanced against costs of low use of planted cover if females show high affinity and preference for WDSH or other natural habitats (e.g., Cowardin et al. 1995). This trade-off deserves further investigation.

Average home range sizes varied across parkland sites and between prairie and parkland ecoregions, so it may be unwise to directly extrapolate findings from one study to other areas. Thus, interactions between birds, habitats and other environmental factors must be evaluated at multiple, widely-separated sites to better inform management; these spatial issues must be given serious consideration in regions like the prairies where breeding habitat is highly variable and fragmented (Plissner et al. 2000:427).

CHAPTER 4: HOME RANGE CHARACTERISTICS, AGE, BODY SIZE AND BREEDING PERFORMANCE OF FEMALE MALLARDS IN THE PRAIRIE PARKLAND REGION OF CANADA

4.1   Introduction

A species' evolutionary biology can be better understood with knowledge of how breeding success and survival are affected by space use (Cody 1985). Therefore, ecologists are often interested in evaluating whether variation in breeding success or survival is related to home range (Greenwood et al. 1987, Rotella and Ratti 1992, Petit et al. 1995) or female (Schoener 1968, Harestad and Bunnel 1979) characteristics. Such knowledge also has important conservation ramifications because wildlife managers commonly attempt to improve these vital rates via habitat manipulations (Johnson et al. 1992, Cowardin et al. 1995, Ball 1996, Reynolds et al. 1996).

Generally, mallard nest success improves as the percentage of perennial upland cover increases in an area (Greenwood et al. 1995, Reynolds et al. 1996, Institute for Wetland and Waterfowl Research [IWWR], unpubl. data), and female mallards may choose home ranges based on a combination of wetland and upland habitat cues (see Chapter 3). Older females may be more experienced in obtaining necessary requirements to successfully reproduce, and therefore should be more successful than younger, less experienced individuals (Dzubin 1969a). Additionally, reproductive success may increase when home range sizes are smaller because individuals can devote more energy to reproduction and less energy to foraging or defending a larger home range (see McNab 1963, Schoener 1968).

Female ducks are believed to experience higher mortality while nesting because of increased susceptibility to predators (Sargeant et al. 1984), and in turn adult females are thought to experience higher mortality than SY females because of greater reproductive investment (Cowardin et al. 1985, Dufour and Clark 2002, Hoekman et al. 2002). Devries et al. (*in press*) examined nesting season survival of female mallards on a regional scale (i.e., throughout the prairie parkland region) and found that survival was positively related to percentage of wetland habitat, longitude and age. However, these studies did not consider how a combination of habitat composition within the home range, and female body size and age may influence nesting season survival. Because survival may be affected differently at different spatial scales (e.g., study area vs. home range levels), as in the case with space use (see Chapter 3), investigating survival at smaller and larger scales could be informative.

While several studies have described home range size variation of female mallards (*Anas platyrhynchos*) (e.g., Dwyer et al. 1979, Kirby 1985, Krapu 1997, Thorpe 1997), to my knowledge no one has investigated potential consequences of this variation using a large data set with spatial replication, measures of landscape characteristics, female morphometric measurements, and recognizable age classes. Therefore, I examined whether specific habitat features of home ranges and/or female attributes were associated with greater breeding success (as measured by nesting success) or nesting season survival of female mallards in the Canadian parklands, 1995-1998. More specifically, I hypothesized that females with smaller home ranges, a higher percentage of seasonal and semi-permanent wetlands (C3-4 wetlands, see Stewart and Kantrud 1971) and perennial upland cover within their home ranges, and older females would

have higher reproductive success than yearling females or females with relatively large home ranges and lower percentage of perennial upland cover. I also hypothesized that nesting season survival would be higher for younger females and for all females with higher percentage of C3-4 wetlands, and perennial upland cover within their home range.

4.2   Methods

During 1995-1998, I collected data from 12 study areas in the prairie-parklands. Each study area (65-km^2) was examined for one year and categorized by one of three Prairie Habitat Joint Venture (PHJV) treatment levels. Detailed descriptions of study areas and field methods are provided in Chapter 2.

4.2.1   Data analysis

I included age and body size characteristics, home range size, two home range level habitat variables (percentage of C3-4 wetlands and WDSH), and three study area level habitat variables (percentage of C3-4 wetlands, WDSH, and treatment) (see Chapter 3) in all analyses. Planted nesting cover was also included initially as a binary variable (present, absent) because of its non-normal distribution. I log transformed home range size to improve normality while normality for all other variables could not be improved through transformation; therefore, original variables were used in all analyses.

I first used principal components analysis to test for multicollinearity among all nine variables. The first principal component explained 28% of variation, lower than by chance alone (34%) (broken stick model; Jackson 1993); therefore, I used the nine original variables in discriminant function analyses (DFA, PROC DISCRIM; SAS

Institute 1999) and subsequently excluded planted cover because its inclusion (binary or continuous) greatly reduced classification success. I used DFA to determine whether it was possible to distinguish among three reproductive and between two survival categories. Reproductive status consisted of 126 females that (1) did not nest (n = 10) versus those that initiated at least one nest but either (2) failed (nest destroyed; n = 94) or (3) nested successfully ($\geq$ 1egg hatched; n = 22). Survival status consisted of 115 females, 96 survivors and 19 non-survivors (see Chapter 3 for distribution of females among study areas). Since reduced breeding effort is thought to bias survival high (Devries et al. *in press*), I excluded non-nesting females from the survival analysis.

Differences between within-group covariance matrices was tested using a chi-square test of homogeneity and quadratic DFA was performed when group covariances were heterogeneous (PROC DISCRIM;SAS Institute 1999). Prior classification probabilities were set to equal group sample sizes (see Williams 1983). Classification success was chance-corrected following Titus et al. (1984).

4.3   Results

Quadratic DFA was used to distinguish females that did not nest from nesting females that failed or were successful (within-class covariance matrices were unequal, P < 0.09). The first discriminant function (Wilk's Lambda = 0.78, df = 16, P = 0.02) provided moderate segregation of all three groups and the second function (Wilk's Lambda = 0.90, df = 7, P = 0.10) further separated females that did not nest from those that failed (Table 4.1, Figure 4.1). Overall, correct classification rate was 78.6%, 53% better than chance alone (z = 5.46, P < 0.001). No non-nesting females were

Table 4.1. Structure coefficients (loadings) for canonical discriminant function (DF) analysis using three female mallard reproductive groups (did not nest, n = 10; nested but failed, n = 94; or nested successfully ($\geq$ 1egg hatched), n = 22) in the prairie parkland region of Canada, 1995 - 1998.

Variable	DF1	DF2
Percent wood-shrub[a]	0.720	-0.044
SAR level wood-shrub[b]	0.673	-0.051
Percent treatment[c]	0.572	0.207
SAR level Class 3-4 wetlands[d]	0.310	-0.177
Home range size[e]	-0.308	0.011
Class 3-4 wetlands[f]	-0.112	-0.036
Age	-0.003	0.706
Body Size	-0.126	0.458
Significance of discrimination[g] (P)	0.022	0.102

[a] Percentage of woodland and shrubland within the home range.

[b] Percentage of woodland and shrubland within the study area

[c] Percentage of treatment on study area (see Table 1 for treatment levels).

[d] Percentage of class 3 and 4 wetlands within the study area.

[e] Estimated using 95% fixed kernel; log transformed.

[f] Percentage of class 3 and 4 wetlands within the home range.

[g] Determined by Wilk's Lamda.

Younger and smaller females

Older and larger females

DF 2

DF 1

Lower % of HR and study area wood-shrub, treatment, and study area class 3-4 wetlands; larger HR size and higher % of HR class 3-4 wetlands.

Higher % of HR and study area wood-shrub, treatment, and study area class 3-4 wetlands; smaller HR size and lower % of HR class 3-4 wetlands.
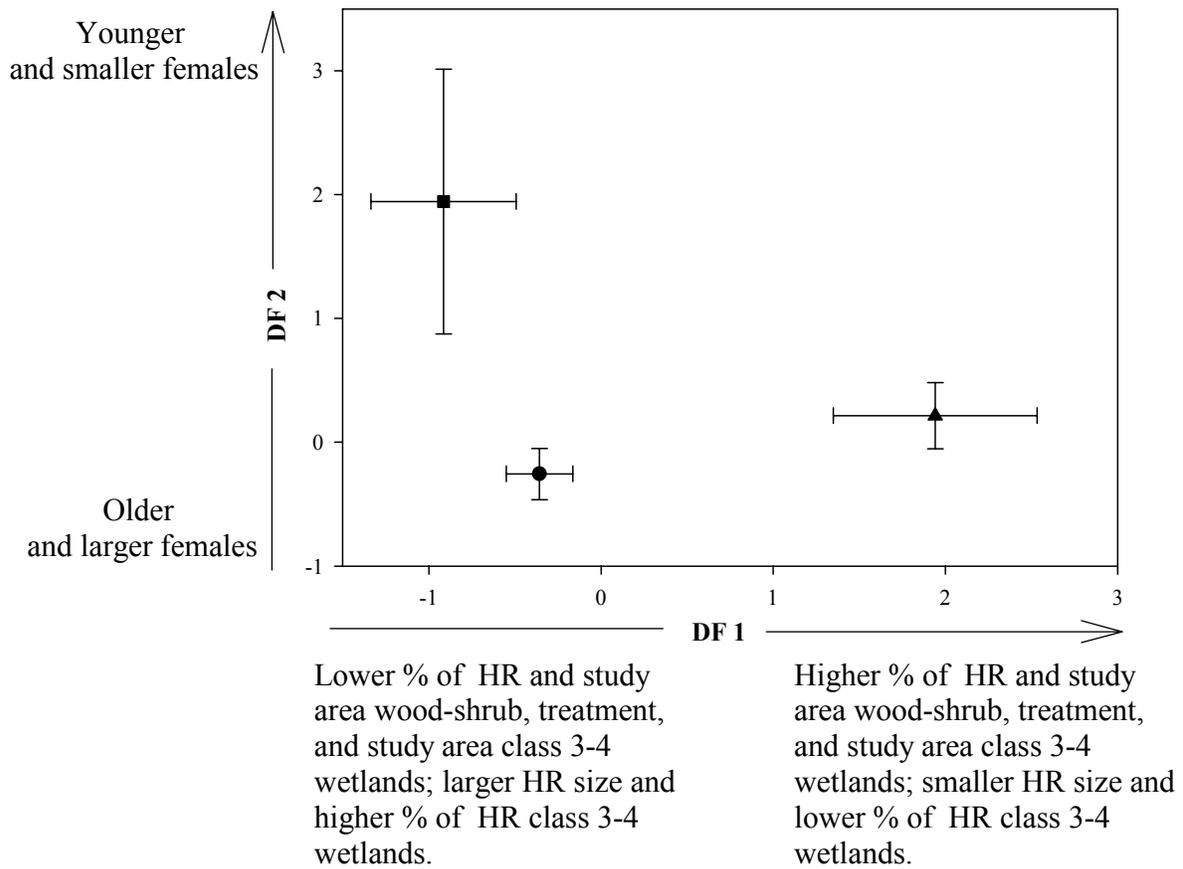
Figure 4.1. General relationships between mallard breeding effort and success versus characteristics of female and home ranges (HR) on 12 study areas in the prairie parkland region of Canada, 1995 - 1998. Shown are mean (symbols) and 95% confidence intervals (horizontal and vertical lines) for scores derived using quadratic discriminant function analysis. Reproductive categories were separated into females that did not nest (n = 10, square), nested but failed to hatch (n = 94, circle), or nested successfully (n = 22, triangle).

misclassified. Females that nested but failed were usually misclassified as being non-nesters (10 of 17), whereas 8 of 10 females with hatched nests were misclassified as failed nesters.

A linear DFA was used to segregate survivors from non-survivors (within-class covariance matrices were equal, $P > 0.85$). However, it was not possible to distinguish these groups (Wilk's Lambda = 0.96, df = 8, $P = 0.87$; Figure 4.2).

4.4 Discussion

Although several studies have investigated mallard home range size variation (e.g., Dwyer et al. 1979, Krapu 1997, Thorpe 1997), to my knowledge, my study was the first to test simultaneously whether home range composition and female attributes could predict reproductive and survival consequences for breeding female mallards. I also evaluated whether reproductive success or nesting season survival was related more to landscape characteristics at the study area versus home range levels. Significant separation existed among reproductive categories (Figure 4.1), but not between survival categories (Figure 4.2).

My results only partially supported my *a priori* hypothesis regarding reproductive consequences. Successful females had smaller home ranges and had relatively higher percentage of home range and study area level WDSH, study area level C3-4 wetlands and treatment within their home range (Figure 4.1). Contrary to my prediction, successful females had relatively lower percentage of home range level C3-4 wetlands within their home range. Successful females did not necessarily nest in WDSH habitat. However, the higher percentage of WDSH habitat within home ranges of successful

Higher % of SAR and HR wood-shrub, *Larger* HR size; *Smaller* females, *Lower* % of HR class 3-4 wetlands and treatment

Lower % of SAR and HR wood-shrub, *Smaller* HR size; *Larger* females, *Higher* % of HR class 3-4 wetlands and treatment
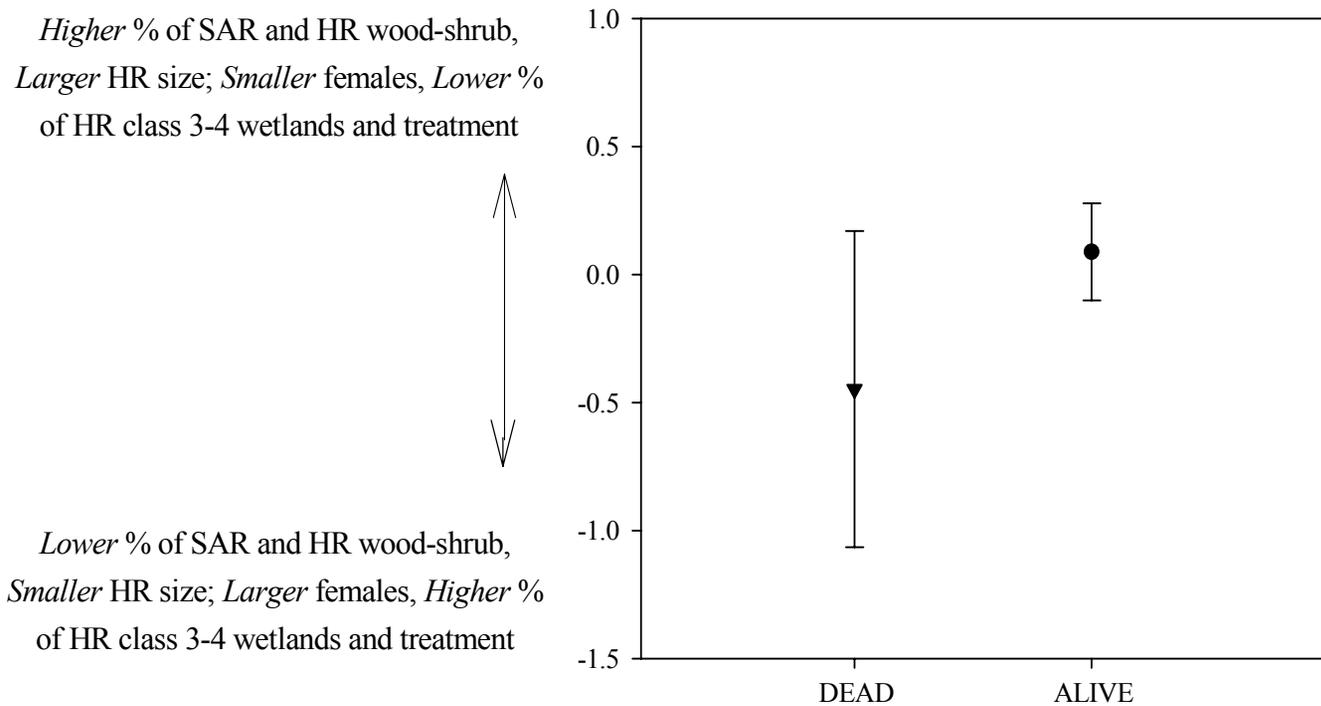
Figure 4.2. General relationships between mallard nesting season survival versus female and home range (HR) characteristics on 12 study areas in the prairie parkland region of Canada, 1995 - 1998. Shown are mean and 95% confidence intervals for scores derived using linear discriminant function analysis. Survival categories were separated into dead (n = 19) and alive (n = 96).

females could have affected abundance or interactions among predators and prey producing higher nest success. This hypothesis and related ones warrant further evaluation.

My results indicated that successful females had relatively smaller home ranges than females from either of the other two groups, which supports the hypothesis that animals tend to have higher reproductive success if they can acquire the necessary resources to reproduce in smaller areas (McNab1963, Schoener 1968, this study). Additionally, the fact that successful females had relatively more WDSH at both levels than either of the other two groups adds further support to the evidence that nest success is higher when more perennial upland cover exists (Greenwood et al. 1995, IWWR unpubl. data).

Successful females had a relatively higher percentage of study area level C3-4 wetlands but a lower percentage of home range level C3-4 wetlands present within their home ranges. Although this was contrary to my prediction, it does support the suggestion that behavioral decisions occur at different spatial levels (Orians and Wittenberger 1991, Morrison et al. 1998, Clark and Shutler 1999). One possible explanation for the difference in the percentage of C3-4 wetlands between levels is that females may require different amounts of wetland habitat during different stages of the breeding season (Krapu et al. 1997). For example, if nest predators are associated with wetlands, females may establish a nesting season home range with less wetland area to reduce predator encounters, while at the same time recognizing the need to settle in areas of high wetland density (Johnson and Grier 1988, Austin 2002) to provide adequate brood rearing habitat. Because I did not test whether the composition of brood

rearing home ranges was different than it was at the study area level, I can only speculate that this might be a reason for the difference in C3-4 wetland area at the two spatial levels. However, 17 of the 22 successful females actually fledged at least one duckling. Thus, the trade-off between choosing areas that will provide resources to successfully hatch a nest and fledge offspring must be balanced; presumably, selection should favor females that are able to make this distinction.

Female attributes contributed to the separation between all 3 reproductive categories on discriminant function 2, which supports the hypothesis that older and larger females likely have higher breeding propensity and reproductive success (Figure 4.1). However, the contribution of female attributes to the separation along the first axis is weak. This may be partly explained because of breeding-area philopatry; yearlings or successful females from the previous year often return to the same area regardless of habitat conditions (Krapu 1983 and references within); thus, potentially eliminating any effects of female attributes. However, I had no long-term information that would be needed to test this. Another possible explanation for the lack of contribution of female characteristics to the separation along DF1 is that smaller and younger females usually start nesting later than their larger and older conspecifics (Krapu and Doty 1979); therefore, they may be able to utilize a portion of a nesting (incubating) female's home range, possibly resulting in higher nesting success.

I did not detect a difference of habitat composition of home ranges or female attributes between survivors and non-survivors; however, the variation indicates there could be a difference if sample sizes were more equal (Figure 4.2). For example, the weak indication that non-surviving females were likely larger and had a higher

percentage of home range level C3-4 wetlands and treatment within their home range (Figure 4.2) supports the idea (noted above) that nesting mallards may be more susceptible to predation when nesting in areas with a relatively high percentage of wetlands; however, this needs to be investigated further.

Using DFA does not allow me to distinguish cause from effect (Klecka 1980); rather, it identifies "correlates" (variables) that could be important. I also recognize there are factors I was unable to include or measure that could also be important and these should be considered in future studies. For example, changes in home range size and composition with each reproductive period (e.g., pre-laying, laying, incubating, brood rearing) (Kirby et al. 1985, Thorpe 1997) and successive nesting attempt (R. Brua, Environment Canada, unpubl. data), as well as temporal (year-to-year) variation. Additionally, there is strong evidence that predator composition and abundance affects nesting success (Sargeant et al. 1985, Sargeant and Raveling 1992, Greenwood et al. 1995), but it is not known if female mallards are able to assess predator communities and abundance when deciding where to establish a home range. Although I could not determine cause and effect, my results provide for an excellent foundation for future experimental manipulations of resources or duck density and for understanding the consequences of home range size variation for breeding female mallards in the prairie parklands of Canada.

CHAPTER 5: SYNTHESIS

5.1   Home range characteristics

Knowledge of space use is critical for understanding the biology and management needs of waterfowl (Johnson and Grier 1988, Anderson and Titman 1992). Despite an unprecedented research effort conducted on waterfowl, on mallards in particular, over the last 30 years (see Ratti et al. 1982, Batt et al. 1992, Drilling et al. 2002) for a comprehensive literature review) few studies have examined mallard use of space (Titman 1973, Dwyer et al. 1979, Krapu et al. 1983, Thorpe 1997), likely because of logistical and technical challenges. Furthermore, to my knowledge only two studies (see Titman 1973, Thorpe 1997) were conducted in the prairie parkland region of Canada, an area that is critical for breeding mallards (CWS and USFWS 1986). The PHJV Assessment Study (Sankowski et al. 1991, 1995) provided an unprecedented opportunity to investigate correlates of home range size and, more importantly, potential consequences of this variation. Large numbers of female mallards were radio-marked prior to breeding on a large number of sites in widely separated, contrasting landscapes, creating an ideal template for evaluating mallard space use patterns.

The wide range of individual female home range sizes I reported is similar to earlier studies (see Titman 1973, Dwyer et al. 1979, Krapu et al. 1983, Thorpe 1997) and is consistent with the observation that female mallard home range sizes vary substantially within and among geographic landscapes. Although I used a different home range size estimation technique from that of previous studies, an approach that

should be superior to other estimation methods (Seaman and Powell 1996, Worton 1989), the range of home range sizes should still be comparable. However, for this methodological reason, some caution should be exercised when comparing mean female mallard home range sizes. Given this caveat, mean home range sizes in my study were at least 3 times smaller than that (6.4 km^2) typically regarded as the average area used by a female mallard during the nesting season. This general finding has a strong bearing on habitat program delivery (see below).

At the study area level, pair density was a better correlate of home range size than was wetland density, suggesting that social interactions were affecting home range size variation at this scale. At the home range level, my results demonstrated that percentage of WDSH habitat was associated with home range size, probably because of its importance for nesting females (see Greenwood et al. 1995. Clark and Shutler 1999, IWWR, unpubl. data). Although this is a preferred nesting habitat, nest success tends to be low (Howerter 2003). On the other hand, nest success is apparently higher in this habitat and in planted cover early in the nesting season (IWWR, unpubl. data) when compared with other habitat types; thus, WDSH habitat could make a greater contribution to local production than previously recognized owing to higher survival and recruitment probability of earlier hatched ducklings (Rotella and Ratti 1992, Dzus and Clark 1998, Krapu et al. 2000).

Contrary to my initial predictions, female age and body size did not contribute to variation in home range size or composition. Therefore, these female characteristics may not need to be considered in future mallard home range studies, at least in the prairie parkland region.

Previous research concerning mallard home ranges focused primarily on size variation but neglected breeding or survival consequences of variation in size or other features. My study was the first attempt to determine consequences of home range size variation for female mallards. One clear pattern was that the high proportion of non-breeders were yearling females. Admittedly, single breeding attempts could have been missed but these females certainly exhibited low breeding propensity. Non-breeding is believed to be uncommon in mallards (e.g., Rohwer 1992) but younger females may have lower breeding probability than older birds (e.g., Batt and Prince 1978, Dufour and Clark 2002).

My results also indicated that successful females had smaller home ranges, a higher percentage of WDSH upland cover and, to a lesser extent, less C3-4 wetland area. Smaller home ranges and more WDSH upland cover are consistent with hypotheses that (1) it is beneficial for individuals to acquire concentrated, necessary resources (McNab 1963, Schoener 1968) and (2) nest success is higher when more perennial cover is present (Greenwood et al 1987, 1995, Reynolds 1994). However, lower amounts of C3-4 wetland area within successful female home ranges is suggestive of a trade-off in which benefits of wetlands for pair settling (Johnson and Grier 1988) and brood-rearing could be balanced against costs of being near preferred predator foraging areas around wetlands. I did not find unequivocal evidence for this trade-off but obtained sufficient support to encourage further testing of this idea.

Finally, I did not detect any difference in home range composition between females that survived and those that did not, indicating that uncontrolled environmental factors (e.g., weather, prey base) and chance events could be more important

determinants of nesting season survival than female or local habitat characteristics. This issue requires further investigation.

5.2   Implications for management and conservation of mallard nesting habitat in the prairie parkland region of Canada

Protecting and restoring habitat is a central objective of most wildlife conservation agencies including those involved in the NAWMP. The PHJV has focused on increasing waterfowl production by converting cultivated land to planted nesting cover or protecting idle native cover since these natural habitats typically have higher nest success (Reynolds et al. 1994, 1996). Previous work showed that it would be difficult to attract many breeding female mallards to managed cover within the PHJV target areas unless *much* larger areas were planted (Thorpe 1997, McKinnon and Duncan 1999); my home range size estimates are consistent with this view because they suggest that females use much smaller areas than previously believed. Unfortunately, the socioeconomic costs associated with planting large areas to managed cover make this scenario impossible for wildlife agencies in the absence of either agricultural green-cover programs or market shifts that could trigger increased forage production. Therefore, other management scenarios must and are being considered to attain PHJV habitat and population goals.

My results suggest that land managers should continue to focus on conserving and restoring wood and shrublands, and seasonal and semi-permanent wetlands. The importance of wetlands is obvious for pairs and broods. My results, however, also showed that females were more successful when their home ranges consisted of a relatively lower percentage of C3-4 wetlands but higher percentage of WDSH. These

findings suggest a new management regime that could be tested, possibly with existing field data. It could be more cost-effective to protect or acquire upland habitat adjacent to these wetlands. Likewise, restoring wetlands within existing or planned upland habitat projects could be detrimental. Because most brood-rearing female ducks are highly mobile (Talent et al. 1982, Rotella and Ratti 1992), with virtually no evidence of a direct survival cost associated with brood movement, this approach probably would not reduce productivity.

Converting cultivated land to perennial cover by traditional methods (e.g., leasing and purchasing land) is costly and often socially unacceptable when farmland is removed from production (McKinnon and Duncan 1999). Therefore, habitat managers have begun to develop alternate methods of securing perennial upland habitat (e.g., easements on native habitat, converting cropland to pasture). Although having more of the landscape in pasture than cropland has been recommended (e.g., Greenwood et al. 1995), I caution that if pastures are poorly managed (i.e., overgrazed) the benefit of having more perennial cover may be lost. Thus, I suggest managers attempt to conserve and restore existing patches of wood and shrub habitat, especially in areas where my study was conducted. Since space requirements for mallards are highly variable from region to region, management recommendations for regions other than the prairie parklands should be based on information obtained from the region of interest. Finally, management efforts in the Canadian prairie parklands should focus on changing agriculture policy to one similar to that of the Conservation Reserve Program in the United States, which may have longer lasting effects not only for mallards but other species as well.

5.3   Recommendations for future research

Results from this study provide much needed insight (see Anderson and Titman 1992) into correlates of female mallard home range size variation and the consequences for breeding females in the prairie parkland region of Canada; however, unresolved questions remain. First, my results could be tested by using data from remaining PHJV Assessment sites to further test hypotheses and models developed in this study. Also, since my study only examined spatial aspects of home range size variation, there is still a need to understand how females adapt their spacing strategies from year to year and within season (e.g., pre-laying, laying, incubation, brood rearing) depending on past breeding success. This could be accomplished by using long-term studies that encompass a wide array of habitat conditions.

My results and those of other recent studies (Krapu et al. 1997, Thorpe 1997) are based on movements of breeding female mallards and do not consider possible impacts of intra- or interspecific social interactions. Because of dramatic changes in habitat conditions over the past 30 years and the spatial variability in home range composition found in this study, I believe studying social interactions could provide valuable insight into changes in mallard spacing behavior, especially because this was last examined by Titman (1973). Additionally, since males play an important role in social interactions, mate and home range defense (McKinney 1965), investigating how mate quality influences spacing behavior could also improve our understanding of the dynamics of mallard social interactions during the breeding season. Furthermore, other waterfowl species should be examined to provide clues about the role of interspecific interactions.

Food abundance and availability are recognized as proximate factors that determine individual space use (Christman 2001, Jonsson et al. 2002) but measuring food resources in waterfowl spacing studies is logistically difficult (e.g., spatio-temporal changes in food resources, expense); therefore it has not been attempted. However, such information would greatly increase our understanding of female mallard spacing behavior.

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APPENDICES

Appendix 2.1. This section contains detailed habitat class descriptions, taken directly from the Ducks Unlimited, Institute for Wetland and Waterfowl Research Nest Card Manual (IWWR 2000).

Grassland (GR) – Areas vegetated with mixtures of grasses, forbs, and often short (<0.5m) woody species such a buckbrush (*Symphoricarpos occidentalis*), silverberry (*Eleagnus argentea*), or Wood's rose (*Rosa woodsii*). Introduced species such as Kentucky bluegrass (*Poa pratensis*) and brome (*Bromus spp.*) may also be present. Most areas in this class have never been tilled; however, some areas may have been tilled and reverted to native species, frequently mixed with introduced species such as quackgrass (*Agropyron repens*), or they may be planted to introduced grasses. This situation is in contrast to the hayland and planted cover classes, where the area has been tilled and planted to grasses or legumes in order to establish grass/legume forage. Land use on grassland is predominantly pasture, but some non-use areas may occur. In much of the Prairie Pothole Region, grasslands are confined to areas with sufficient relief to prevent farming. Grasses are typically warm season species and will show little growth in May.

Hayland (HA)– Areas that have been tilled and seeded to mixtures of grasses and legumes for forage production and that are hayed annually. This class is typically represented by alfalfa (*Medicago sativa*) on private land.

Planted Cover (PC)– Planted cover includes mixtures of grasses and legumes planted for wildlife cover or soil conservation. Species include introduced cool season grasses such as wheatgrasses (*Agropyron spp.*) and bromegrass, legumes such as alfalfa and sweet clover (*Melilotus spp.*), and various mixes of native cool season grasses such as tall wheatgrass (*Agropyron caninum*) and green needlegrass (*Stipa viridula*).

Cropland (CR) – Areas that are typically tilled and planted to cereal or oil-seed crops, or that are tilled and left fallow, or contain crop residue.

Woodland (WD) – Areas with woody plants (trees or tall shrubs) ≥ 6 m (20 ft.) in height having an areal cover of ≥ 30%.

Shrubland (SH) – Areas of shrubs 0.5 to 6 m (1.5 to 19 ft.) tall having an areal cover of ≥ 30%. If areal shrub cover is < 30%, the habitat is considered to be grassland.

Wetland (WE) **–** All areas, regardless of size, mapped as wetland according to definitions in (Stewart and Kantrud 1971). Only islands covered with emergent hydrophytes are classified as wetland habitat; islands bearing upland vegetation are placed in the appropriate upland class. Nests in nest baskets, nest culverts, artificial floating structures, hay bales, brushpiles, etc., in wetlands are classified as wetland nests.

Other (OT1) – Includes all habitats that don't fit into any of the previously listed habitats (e.g., rock-piles, brush-piles, stick nests hay-bales, unknown).

Appendix 2.2. Fixed Kernel (95%) home range sizes as a function of the number of

locations for 3 female mallards from Baldur, 1996. Mean ± 95% CI are based on 100

bootstrap estimates for each sample size listed. The minimum number of locations for

each radio-marked female mallard used in this study was 50 (as indicated).
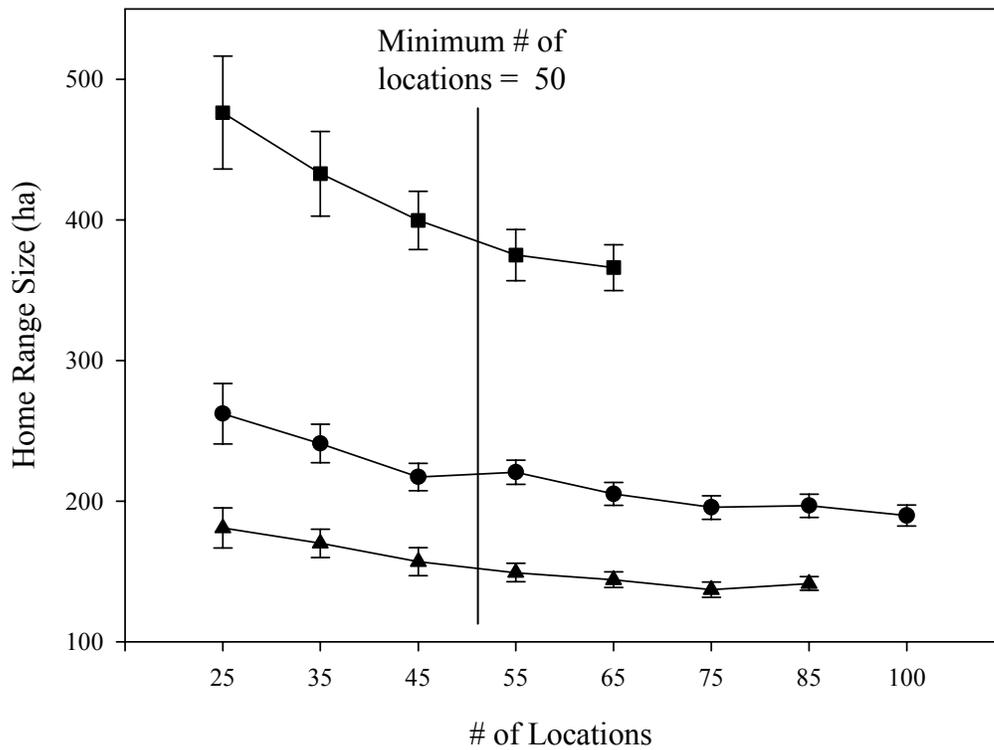
Appendix 3.1. Treatment-specific variation in female mallard home range size (mean and 95% CI) in the prairie parkland region of Canada, 1995 - 1998. Four study areas (number of radio-tracked females) are nested within each treatment level (see Table 2.1 for definitions of treatment levels). Home range sizes on medium and high treatments did not differ (Duncan's multiple range test).