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Factors Influencing Utilization of Artificial Nesting Cylinders by Mallards and Wood Ducks in Northwest Pennsylvania and Southern Ontario

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Factors Influencing Utilization of Artificial Nesting Cylinders by Mallards and Wood Ducks in Northwest Pennsylvania and Southern Ontario

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Abstract

Factors influencing utilization of elevated nesting structures by waterfowl were examined in southern Ontario and northwest Pennsylvania, 2006-2008. In the final-year, Mallard occupancy rates were 18 % in Pennsylvania and 16 % in Ontario. Mean nest success was 77 ± 20 % for combined sites (2006-2008). Final-year Wood Duck occupancy rates were 12 % in Pennsylvania and 2 % in Ontario; mean nest success was 70 ± 29 %. Mallards tended to select structures in areas with high wetland densities and adjacent to grasslands or hayfields. In Pennsylvania, Wood Ducks had similar preferences for structures as did Mallards. In Ontario, Wood Ducks were more likely to use structures with a high proportion of adjacent forest cover and a high abundance of invertebrates. Cost per duckling fledged was \$20.00 with a paid technician and \$5.24 if structures are maintained by volunteers. Relative to other management strategies, artificial nesting cylinders may be cost effective for increasing Mallard populations in Ontario and Pennsylvania.

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CHAPTER 1. INTRODUCTION

The Mallard (*Anas platyrhynchos*) is a grassland nesting duck species that is found throughout North America. North American Mallard populations are generally divided into Eastern, Midcontinent, and Western populations (U.S. Fish and Wildlife Service 2007). The Eastern population of North American Mallards breeds primarily in southeast Canada and the northeast United States (U.S. Fish and Wildlife Service 2007). Within the Eastern population, the number of breeding Mallards in Bird Conservation Region 13, the Lower Great Lakes/St. Lawrence River Plain, substantially increased between 1966 and 1995 according to Breeding Bird Surveys (Sauer et al. 2004). However, since the mid 1990's, there is some evidence of declining Mallard productivity and populations in portions of the Great Lakes Region (GLR) including Michigan, Ohio, New York, Pennsylvania, and Southern Ontario (Yerkes 2005).

The GLR is a particularly important breeding area for the Eastern and Midcontinent population of Mallards with an estimated 750,000 breeding pairs in 2007 (U.S. Fish and Wildlife Service 2007). Despite the importance of the GLR for breeding Mallards, until recently, few studies have focused on factors influencing vital rates, such as nest success, and how they influence population growth rates.

Extensive research and modeling of Midcontinent populations have been used to develop population and habitat management plans for Mallards in the Prairie Pothole Region (PPR) (Williams et al. 1999, Hoekman et al. 2004). Specifically, management strategies have been developed to increase important vital rates such as nest success and hen survival during breeding (Johnson et al. 1987, Hoekman et al. 2004, Coluccy et al. 2008). However, these models may not be directly applicable to the Eastern population of Mallards due to differences in demographics such as nest success rates, hen survival, and duckling survival between the two populations (Hoekman et al. 2006).

In the (PPR), nest success is a major factor influencing populations of upland nesting ducks (Eskowich et al. 1998) and contributes the most to annual variation in PPR Mallard populations (Hoekman et al. 2002). In the PPR, population models suggest that a nest success of 15-20 % is required to maintain stable Mallard populations (Cowardin et al. 1985). However, numerous studies have shown that nest success for upland nesting ducks in the PPR is well below this threshold as a result of mammalian and avian predation (Cowardin et al. 1985, Klett et al. 1988)

Nest success in the PPR is also influenced by the quantity of nesting habitat (Ball et al. 1995). Nest success is typically highest in dense and undisturbed grasslands and planted cover (Klett et al. 1988, Greenwood et al. 1995). However, the PPR has been subjected to intense agricultural practices leading to the loss and fragmentation of waterfowl breeding habitat (Cowardin et al. 1983, Greenwood et al. 1995). Fragmentation negatively impacts nest success by increasing predator foraging efficiency and can lead to higher nest predation (Ball et al. 1995, Reynolds et al. 2001, Philips et al. 2003).

As in the PPR, variation in nest success influences annual fluctuations in GLR Mallard populations (Hoekman et al. 2006, Coluccey et al. 2008). Recently, a Mallard study reported an average nest success of 0.13 among four study sites in southern Ontario (Hoekman et al. 2006). Of the unsuccessful nests, ~ 90 % were depredated (Hoekman et al. 2006). This suggests that management strategies aimed at increasing nest success may be effective at increasing Mallard populations in the GLR (Hoekman et al. 2006).

However, due to low nesting densities in the GLR, the restoration of upland nesting habitat would likely yield few demographic benefits, especially since nest survival varies little among habitat types (Hoekman et al. 2006).

Since nest success of Mallards is below the threshold necessary to maintain Mallard populations in the PPR, numerous management strategies have been developed to increase nest success in that region. Specifically, programs such as predator control, upland habitat restoration, fencing of nesting habitat, and construction of nesting islands have been used with varying success to reduce predation. While rarely utilized, management strategies aimed at increasing vital rates such as nest success, duckling and hen survival may also provide viable solutions to increase Mallard populations in the GLR (Hoekman et al. 2006, Coluccy et al. 2008). Although these management strategies can be cost effective in the PPR because of high densities of breeding Mallards (Lokemoen 1984) they would likely be much less cost effective in the GLR because breeding densities are substantially lower (Klett et al. 1988, Hoekman et al. 2006).

Some conservation organizations concentrate their conservation initiatives on extensive management techniques such as habitat protection, enhancement, and restoration. However numerous intensive management techniques (e.g., predator control and artificial nesting structures) have also been developed to increase nest success, brood survival, and hen survival of waterfowl. For example, artificial nesting structures have proven to be a useful and cost effective management technique for several waterfowl species, including Wood Ducks (*Aix sponsa*), Hooded Mergansers (*Lophodytes cucullatus*), Giant Canada Geese (*Branta canadensis maxima*), and Mallards (Bishop and Barratt 1970, Doty et al. 1975, Johnson et al. 1992, Ray and Higgins 1993). More recently, Delta Waterfowl (2006) helped develop and promote the Mallard Hen House (HH) in response to declining nest success and Mallard populations in the PPR.

Artificial nesting structures for Mallards have evolved substantially during the past 30 years. Earlier designs consisted of open baskets, hay bales, cone shaped structures, and nesting culverts (Bishop and Barratt 1970, Doty et al. 1975, Ray and Higgins 1993). Nesting structures eventually developed from these relatively open structures into a covered cylinder design called a "Hen House". This design proved to have higher occupancy rates, nest success and hen survival. Cylinders effectively protected nests and nesting hens from avian predators which is a major source of hen mortality during the breeding season (Bishop and Barratt 1970, Sargeant and Raveling 1992, Haworth and Higgins 1993, Eskowich et al. 1998). As with the other designs previously mentioned, HHs are also elevated above the water and typically contain a predator guard to deter mammalian predators such as raccoons (*Procyon lotor*), mink (*Mustela vision*), skunk (*Mephitis mephitis*), and small rodents. HHs used in the PPR have nest success rates exceeding 70 %, which is well above success rates for ground nesting Mallards (Eskowich et al. 1998, Mammenga et al. 2007). Previous studies have also shown that occupancy rates increase over time likely due to hen and offspring philopatry (hens and female offspring returning) (Doty and Lee 1974, Bishop et al. 1978, Lokemoen et al. 1990, Majewski and Beszterda 1990, Yerkes 1999). However, few studies have confirmed this.

Furthermore, ducklings hatched from HHs erected in large wetlands with high interspersion of emergent cover can have high survival (Stafford et al. 2002). Duckling mortality is typically highest shortly after hatching because at this time they are most susceptible to predation, particularly during overland brood movements between upland nesting sites and brood rearing habitats (Rotella and Ratti 1992, Hoekman et al. 2004). HHs erected in adequate brood rearing habitat could reduce or eliminate long overland travel from nesting sites to brood rearing habitat (Stafford et al. 2002).

To increase effectiveness of HH programs, it would be beneficial to know what factors such as habitat composition, food availability, wetland size, and wetland density influence hen Mallard utilization rates. Currently, most studies of artificial nesting cylinders have been conducted in the PPR of the United States and Canada (Higgins and Ray 1993, Eskowich et al. 1998, Artmann et al. 2001, Stafford et al. 2002, Chouinard 2003). The PPR is considerably different in a variety of aspects, such as high wetland density and large tracks of native grasslands which contains high densities of breeding Mallards. These studies have reported high utilization rates (>70%) (Eskowich et al. 1998, Chouinard 2003). Outside the PPR, HH utilization rates are highly variable and few studies have looked at variables influencing occupancy rates of Mallards or Wood Ducks (Knowlton and Zolnowski 2000, Zimmerling et al. 2006).

In addition, few studies have seen or reported on the use of HH by other duck species. During my pilot study in 2006, however, I found several Wood Duck using HH. This is interesting considering that Mallards and Wood Ducks have different preferences for nesting sites. At the turn of the century, Wood Ducks were nearly reduced to extinction from deforestation and market hunting (Bellrose and Holm 1994). However, with the elimination of market hunting during 1914 -1950 and the subsequent large scale implementation of Wood Duck box programs, Wood Duck populations substantially increased (Bellrose and Holm 1994). Wood Ducks nest almost exclusively in preexisting and man made cavities and share similar distribution patterns throughout the eastern flyway as Mallards (Richardson and Knapton 1993). Although both Mallards and Wood Ducks exhibit different preference for nesting sites (ground nesting vs. cavity), they may compete for HH. Thus, it is unknown what habitat variables may influence HH site selection among the two species for HH.

Hen House acceptance, utilization and success rates are not known at the landscape level in the GLR. Information is needed on the utilization and success rates of HHs in the GLR to assist with waterfowl conservation and population efforts in this region. Variables affecting HH occupancy by Mallards and Wood Ducks such as wetland size, habitat type, food abundance and interspecific / intraspecific competition should be investigated to maximize the efficiency of conservation efforts.

1.2 Objectives and Hypotheses

The three objectives of my study are as follows:

Objective 1: Determine upland and wetland habitat characteristics (wetland size, food abundance, land use) that influence HH utilization rates of Mallards and Wood Ducks in Ontario and Pennsylvania.

Hypothesis 1: Hen House utilization rates will be higher in areas surrounded by grassland nesting habitat for Mallards and forested areas for Wood Ducks because female hens select suitable habitat/ponds rather than HHs, especially in areas where HH have never been used. I also predict that there will be a positive correlation between macro-invertebrate availability and HH utilization rates for both Mallards and Wood Ducks because ovulating hens and broods require protein-rich invertebrates.

Objective 2: Determine occupancy, nest success, and a cost analysis for a HH program in the GLR.

Hypothesis 2: Occupancy rates in the GLR will be lower than the PPR because densities of breeding mallards are substantially lower. However, nest success of hens using HHs will be comparable. Finally, the cost per fledged duckling will be higher in the GLR compared to the PPR, however they will likely be more cost effective than other management techniques in the GLR.

Objective 3: Calculate philopatry of Mallard hens and female offspring to HHs in the GLR.

Hypothesis 3: Successful hens will return to the HH in subsequent years and new hens using the structures will be predominantly first year nesters and female offspring from the previous year.

CHAPTER 2: STUDY DESIGN AND METHODOLOGY

2.1 Study Areas

This study was conducted in permanent and semi permanent wetlands located in two research areas, one in northwest Pennsylvania (PA) and the other in southern Ontario (ON). The study site in northwest PA consisted of approximately 50,265 acres of state game lands owned and managed by the PA Game Commission in Butler, Crawford, Erie, Lawrence, and Mercer Counties (Figure 2.1). Land use was determined by creating a 300 meter buffer around each structure using Geographical Information System (GIS) software. Across my PA study site, land uses within 300 meters of HHs consisted of approximately 35% forest, 22% shrubby vegetation, 12% fallow fields, 11% cultivated fields, 9% hay (land cut annually for forage production), 9% wetlands 3% mowed, 1% other (i.e. roads, houses, etc.) and 1% grassland (areas dominated by grassland <30% shrub coverage). The study site in southern ON was on public and private land located near Long Point, Aylmer, and Delhi in Norfolk, Middlesex, and Oxford counties (Figure 2.2). Land use within this study site consisted of 27% cultivated fields, 25% forest, 10% shrubby vegetation, 10% grassland, 10% mowed, 6% wetlands, 5% pasture, 3% other, and 2% hay. Since HH utilization rates are highly variable outside the PPR, I conducted my study on two sites (PA and ON) to get a better representation of HH utilization in the GLR.

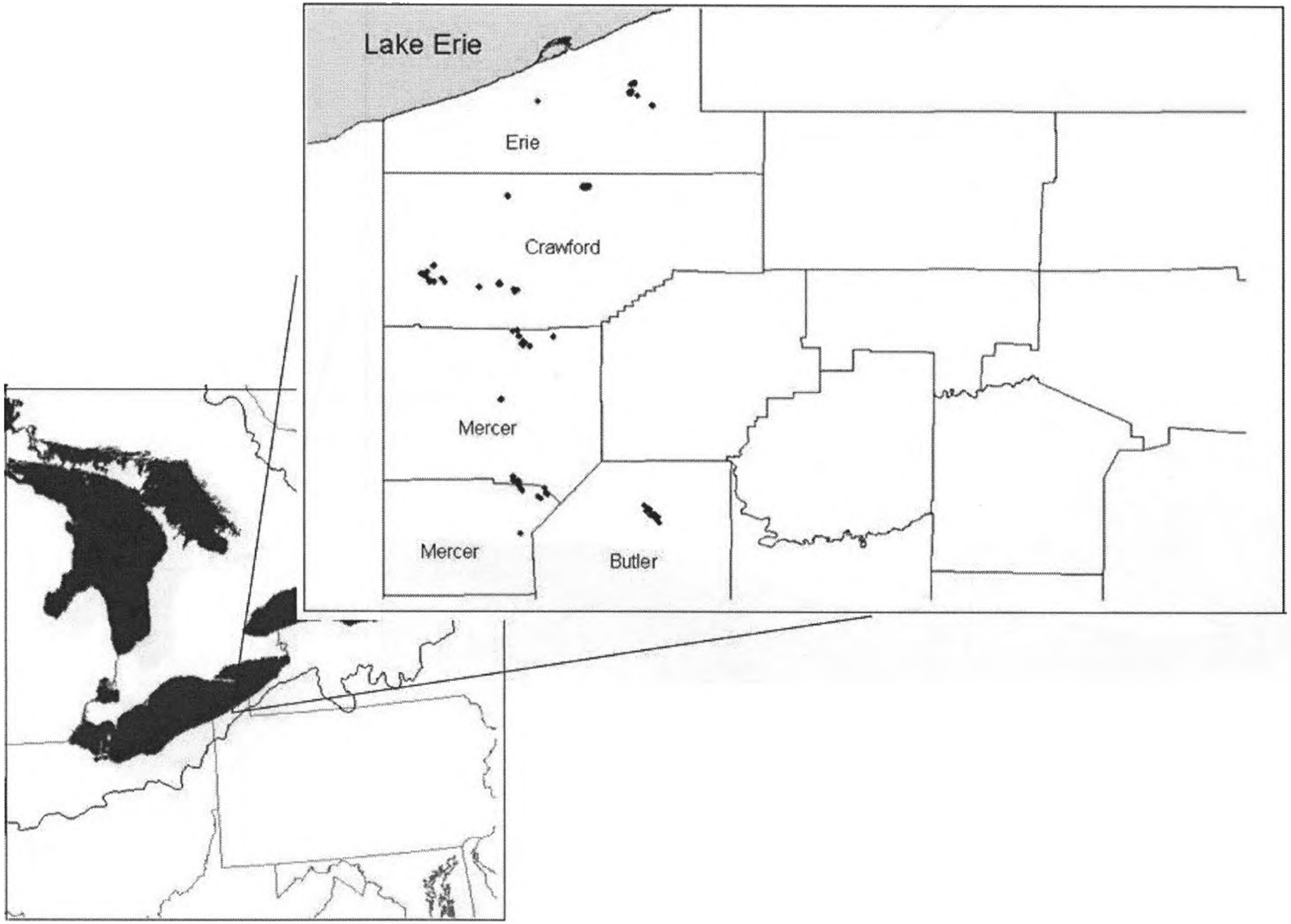

Figure 2.1: Study Site and HH locations in northwest Pennsylvania including Erie, Crawford, Mercer, Lawrence, and Butler counties

Figure 2.2: The study site and HH locations in southern Ontario including Elgin, Norfolk, Oxford, Middlesex, and Brant counties.

2.2 Hen House Placement and Design

The single pole Delta Waterfowl mount and the tripod mount developed by Knowlton and Zolnowski (1998) were used in the study. The tripod design is constructed from three sections of 3.05 meter, 1.2 centimeter diameter electrical conduit pipes (Figure 2.3). The three sections of electrical conduit are bolted together and a HH is suspended between the tripod. The thin diameter of the conduit coupled with placement in deep water helps to deter mammalian depredation as it is difficult for mammals to climb the poles. The Delta Waterfowl design consists of a 2.4 meter section of 1.38 centimeter square iron pipe, a welded cradle and tube inserted into the iron pipe and a steel predator guard (Figure 2.4). These two designs were chosen based on cost, maintenance, installation and success of other HH programs. In January, February, and early March of 2006, 180 HHs were placed in northwest PA and 170 were placed in southern ON. HH were distributed in palustrine and lacustrine habitats consisting of marsh, swamp and open water wetlands of various sizes. HHs were placed in approximately 0.5 to 1 meter of water in each wetland. However, it was difficult to determine water depth in many wetlands because a large proportion of the HHs were placed when the wetlands were frozen. In addition, water levels in many of my study wetlands varied seasonally. HHs were placed in areas with open water and little emergent vegetation directly around the nesting structure to maximize visibility to nesting hens. In addition, they were oriented with the opening facing open water to maximize visibility and perpendicular to the prevailing wind when located in vulnerable wetlands, such as those located next to open fields or in large wetlands. Coordinates for each HH were collected using a Global Positioning System (GPS) unit and assigned a code based on mounting design

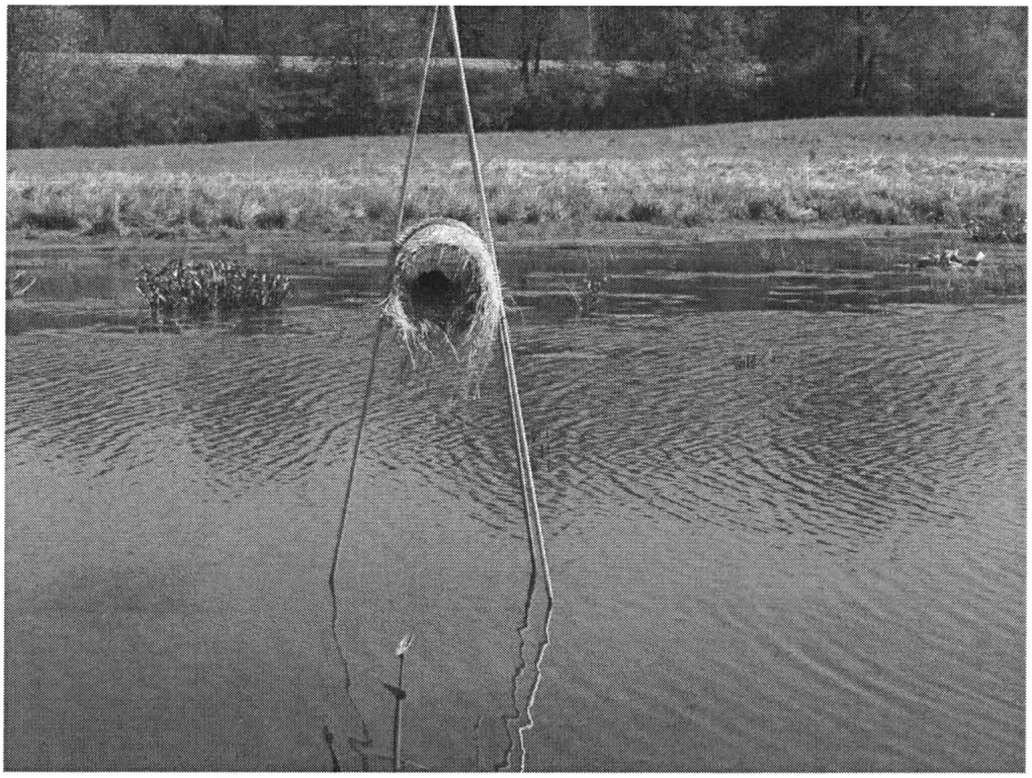

Figure 2.3: The tripod design developed by Sonny Knowlton.

Figure 2.4: The single pole Delta Waterfowl design.

(HHT, hen house tripod or HHP, hen house pole) followed by a number for identification purposes. Coordinates were then loaded into Garmin Map Source software for easy identification, mapping and reference. Ponds that went dry during the nesting season due to water level fluctuations were omitted from the study. Structures were maintained annually in January and February when the ice on ponds was safe enough to walk on; damaged poles or cylinders were replaced and new nesting material was added. Initially, nesting material consisted of Bermuda grass (*Cynodon spp*) as supplied with each HH during its construction in South Carolina. In subsequent years, nesting material consisted of little blue stem (*Schizachyryrium scoparium*) and timothy (*Phleum pretense*), which was acquired locally at each study site.

2.3 Hen House Monitoring

Starting in mid-April, the HHs were checked every 20 days for the presence of a hen or eggs. A HH was considered occupied when the nest contained one or more eggs or a down-lined nest bowl. Nesting structures occupied by Mallard and Wood Duck hens were checked every 7-10 days to detect depredation, abandonment, or a successful nest and checked every other day when hatching date approached. This schedule allowed us to collect nesting data and reduce nest abandonment from disturbance to the nest (Doty and Lee 1979). Nest-check data cards with the date, nest stage, eggs remaining, incubation period, and comments pertaining to the nesting structure were filled out for each visit to an occupied nesting structure. Eggs were also candled at each visit to the nest to determine the incubation period and estimate the date of hatch. Nest initiation was determined by establishing incubation period and backdating one day for each egg present (Eskowich et al. 1998). Incubation period was established by using a guide developed by Weller (1956) to estimate hatching time for Mallards when candling.

2.4 Utilization, Nesting success, and Hatchability rates

Using the data collected from the HHs, utilization rates, nesting success, and hatchability rates were calculated. Utilization rates were calculated by dividing the number of occupied HHs by the total number of available HHs in the region (i.e. Pennsylvania and Ontario). Hatchability was determined by dividing the number of eggs hatched divided by the total number of eggs per a successful nest. Production per HH was calculated by dividing the total number of ducklings hatched by the number of total HHs in the region. This information was used with the total cost (cash and staff time) for construction, placement, and maintenance to determine the cost effectiveness of a HH program in the GLR. Nesting success was calculated by dividing the total number of successful nests by the total number of nests found and multiplied by 100. Since all nests were detectable, it is not necessary to use the Mayfield method of calculating nesting success (Ray and Higgins 1993). Calculations for Pennsylvania and Ontario were separated to compare possible differences in utilization and success rates between the two geographic areas. I also measured water depth (cm) at each HH, height of the HH above the water (cm), distance from shore (m), and water depth at one meter from shore (cm). Measurements in Pa were taken during the first round of nest checks in mid-late April and early May in ON. Water depth, height above water, and water depth at one meter from shore were measured with a meter stick. Distance from shore was determined using a range finder. In addition, I visually estimated the proportion of open water, emergent vegetation, non persistent vegetation, forested habitat, and shrubby habitat within 15 meters of the HH and the total pond in mid May. These data were used as predictor variables in a discriminant function analysis.

2.5 Homing and Philopatry

Mallard hens were trapped and banded with standard USFWS aluminum leg bands after day 15 of incubation to reduce nest abandonment. Hens were trapped by: 1) sneaking perpendicular to the HH and then covering both openings with a dip net or 2) using nest cylinder traps similar to those documented by Yerkes (1997). To reduce nest abandonment, I used immobilization methods described by Doty et al. (1974). This technique is performed by placing the Mallard's head under the wing and rocking it back and forth until it is relaxed and then placing the hen back into the HH. A greater secondary covert feather was collected for aging females as second year (SY, 1 year old) or after second year (ASY, ≥ 2 years old) (Hoekman et al. 2006). Banding Mallard hens allowed us to detect if adult hens were returning to the HH in subsequent years. Ducklings were also web tagged to investigate offspring philopatry. All banding and web tagging were conducted under U.S Fish and Wildlife Service / Canadian Wildlife Service banding permits. Ducklings were trapped by checking the nesting structure daily at estimated hatch date. Ducklings were web tagged predominantly in the egg to reduce the likelihood of hatched ducklings prematurely exiting the HH and scattering.

2.6 Land Use Evaluation

The quality of nesting habitat surrounding HHs may influence their occupancy rates by Mallards and Wood Ducks. A Mallard management model predicts occupancy will be highest in areas with poor quality nesting habitat because HH would be the most attractive nest site (Zicus et al. 2005); however this is largely untested. Therefore, I quantified land use adjacent to all HH to determine the relationship between suitable land use and HH occupancy. Land use characteristics were examined in Arc*GIS* (9.2 using USGS aerial photos of wetland study sites that were taken during 2004-2006. Since, Mallards typically nest in uplands < 100 meters from water (Bellrose 1980), I quantified land use/habitat within a 100, 200, and 300 meter buffer around each HH. A land use shape file was then created by interpreting the aerial photos in the field and polygons were drawn around each land use / habitat type. Land use/ habitat types were categorized similar to Hoekman et al. (2006). Land use / habitat types included, grassland (areas dominated by grassland <30% shrub coverage), pasture (grasslands with livestock), hay (land cut annually for forage production), cropland (annually tilled), shrubland (>30% shrub coverage), woodland (> 30 % coverage of woody debris), wetland (all non-riverine wetlands), fallow fields (idle land), and other (urban areas, roads, railroads, and river). Each buffer was then intersected with the land use layer and the area of each land use category was summed using Hawth's tools, in Arc*GIS*. In addition, a polygon was created around each wetland and the area was calculated using Hawth's tools.

2.7 Invertebrate sampling

For each wetland, invertebrates were collected using a 500μm D frame net with a standardized three second jab and sweep method (Marcus 2006). Invertebrates were collected mid May from six locations within each wetland containing a HH and combined into a single sample. Samples were stored in 95% ethanol solution to preserve specimens (Marcus 2006). Samples were sieved and debris were removed prior to processing. Samples were then spread onto a grid and sub-sampled by randomly selecting grid numbers and counting invertebrates under a dissecting scope. This process was continued until 150 macroinvertebrates were counted or the entire sample was completed to get a relative density. Once 150 invertebrates were found, the sub-sample was completed, and the total number of macroinvertebrates was estimated using the average count per sub sample. Cox et al. (1998) found that differences in biomass were typically caused by large gastropods, therefore I categorized the invertebrates into 1) gastropods, 2) clams, and 3) other, to take into account shell weight of both gastropods and clams. The relative density of each group and mass were entered as predictor variables into the discriminant function analysis.

2.8 Statistical analysis

I conducted an observational study on the nesting site selection preferences for Mallards and Wood Ducks using HHs. I used a discriminant function analysis (DFA) to predict group membership from a set of independent variables or predictors (Fidell and Tabachnick 1996). Prior to the analysis, data were tested to evaluate assumptions of multivariate analysis; DFA assumes multivariate normality, homogeneity of variancecovariance, and linearity (Fidell and Tabachnick 1996). If any of these data did not meet any of the assumptions, appropriate transformations were made. The statistical software SPSS checks for multicollinearity (high correlation between predictor variables) and variables with low tolerance (high multicollinearity) $X < 0.0001$ are omitted from the model (Fidell and Tabachnick 1996).

The results for each study site were separately analyzed in my thesis because of known regional variation in Mallard breeding density, wetland density, wetland types, and land use/habitat between Pennsylvania and southern Ontario. A DFA was performed using 40 quantitative variables to predict membership of three groups: 1) HHs used by "Mallards", 2) HHs used by "Wood Ducks" and 3) HHs not used by either species – "Structures not used". The group "Mallard" consisted of HHs that were occupied at least once, independent of year, by a Mallard during the two year study or the pilot year. The group "Wood Duck" consisted of HHs that were occupied at least once during the three years of study. The group "Structures not used" were unoccupied during all three years. Group predictors were based on HH design, pond characteristics, adjacent land use/habitat, and invertebrate samples collected from each pond. In addition, variables that had matrix loadings less than 0.15 were not interpreted in the results.

2.9 Pennsylvania analysis

Of the original 180 HHs placed in Pennsylvania, only 142 were used in the analysis. HHs that were not maintained, moved, or were in wetlands that were drained or went dry throughout the nesting season were not included in the analysis. In addition, nine HHs were used by both Mallards and Wood Ducks. Since the response variables in DFA can only be a member of one group (Fidell and Tabachnick 1996), data from these HHs were not incorporated in the analysis. Of the remaining 133 HHs, three ponds, containing six HHs, had missing invertebrate data and were thus assigned group means for the analysis. A DFA was conducted with group means added for missing values and with the appropriate cases deleted. Both methods resulted in similar statistical results, therefore group means were used and cases remained in the analysis.

Prior to the analysis, data were tested to evaluate assumptions of multivariate analysis. Originally, three buffer distances of 100, 200, and 300 meters inclusive were used to evaluate surrounding land use. The 200 meter buffer was omitted from the analysis due to a high level of correlation with the 100 and 300 meter buffers. In addition, the pasture and other land uses (roads, houses, etc.) at 300 meters were removed as a result of low tolerance $X < 0.001$. A constant of 1 was added to the invertebrate measurements and then the data were log transformed to meet assumption of normality. In addition, all land use data and visual pond estimates were recorded as proportions and Arcsin transformed prior to the analysis. However, the data did not meet assumptions of normality before or after data transformation. Although the data did not meet this assumption, DFA is typically robust against violations of normality when caused by skewed data rather than outliers (Fidell and Tabachnick 1996). Since the data did not meet all multivariate assumptions, statistical results should be interpreted with caution; however, these results were mainly used to explain trends in selection preference between the two species.

2.10 Ontario analysis

Of the original 170 HHs, only 137 structures were used in the analysis. HHs that were difficult to check because of land owner issues, or were in wetlands that were drained or went dry throughout the nesting season, were not included in the analysis. Of the 137 HHs, four ponds containing seven structures had missing invertebrate data and were assigned group means for the analysis. A DFA was conducted with group means added for missing values and with the appropriate cases deleted. Both methods resulted in similar statistical results, therefore group means were used and cases remained in the analysis.

Prior to the analysis, data were tested to evaluate assumptions of multivariate analysis. As in the PA data, the 200 meter buffer was omitted from the analysis due to a high level of correlation with the 100 and 300 meter buffers. In addition, pasture at the 300 meter buffer was removed due to low tolerance $X < 0.001$. All land use data and visual estimates were recorded as proportions to reduce variation between groups. However, the data did not meet assumptions of normality prior to or after transformation.

2.11 Cost Analysis

I estimated a total time required to build and erect one HH as 0.55 hours per tripod design and 0.9 hours per single pole design. Annual maintenance took approximately three weeks (15 days) or 120 hours in both PA and ON including driving and refurbishing nesting material in each HH. Since our study sites were widely dispersed, driving accounted for a relatively high proportion of the time. The initial cost of materials per HH was estimated at $16 per tripod and $50 per single pole mount design (including mount, basket, hay, and predator guard). Considering that the initial cost is relatively high compared to annual maintenance, HH programs should be considered long-term programs. Therefore, I calculated the cost of the program over a hypothetical 10 year period (Chouinard 2003). I included an hourly wage of $10.00 to estimate the total cost of a long-term HH program. The total cost of materials and installation per tripod mount and single pole mount design were estimated at $21.50 (material cost + 0.55 hours construction and installation) and $59.00 (material cost + 0.9 hours construction and installation), respectively. In addition, the tripods would likely have to be replaced once during the 10 year period adding an additional six dollars (tripod poles only) and an additional 0.15 hours for construction (tripod only) totaling $29.00 per tripod mount design. The installation of the replacement tripod would occur during annual maintenance.

I calculated the cost per duckling similar to Chouinard (2003) for comparative purposes. I also calculated the cost for a HH program including mileage to represent cost for a multi-county program such as the one in this study. The number of ducklings produced per year was estimated using the average nest success in HHs during the study period, multiplied by the number of nests found in PA and ON in 2008, multiplied by the average clutch size, multiplied by the average hatchability rate. To determine the total number of ducklings fledged during the hypothetical 10 year period, the total number of ducklings fledged was multiplied by 10. Calculations were based on 2008 occupancy rates rather than the average of the entire study (2006-2008) since previous studies have shown that occupancy rates increase over time (Artmann et al. 2001). The cost per fledged duckling was then determined by multiplying the total number of ducklings produced over the 10 year period by a recent estimate of duckling survival (0.50) in the GLR (Simpson et al. 2005). I also calculated the cost per duckling and fledged duckling if the HH program was implemented by volunteers; therefore neither labor nor mileage was included in the cost. This analysis assumes that HH utilization rates will not increase in the future.

CHAPTER 3 RESULTS

3.1 Pennsylvania Hen House Selection

In the DFA, two discriminate function axes accounted for 58.5 %, and 41.5 % of the between group variation. The group centroids significantly differed between groups (DF 1-2 Wilks $\lambda = 0.321$, $X^2 = 125.7$, Df 80, p =0.001). After removal of Discriminate Function 1 (DF1), Discriminant Function 2 (DF2) also significantly differed between groups (DF 2-3 Wilks $\lambda = 0.610$, $X^2 = 54.35$, Df 39, p = 0.049) (Figure 3.1). DF1 separated HHs used by Mallards and Wood Ducks from unoccupied structures while DF2 separated HHs used by Mallards from those used by Wood Ducks (Figure 3.1). The structure matrix (Table 3.1) shows that Mallards and Wood Ducks were more likely to nest in HHs located further from shore, in deeper water, and in wetlands that contained a greater proportion of open water within 15 meters of the HH.

In relation to unoccupied HHs, occupied structures used by both Wood Ducks and Mallards had a greater biomass of gastropods, higher density of wetlands within the 300 meter buffer and higher proportion of adjacent hayfields. DF2 showed that Wood Ducks were less likely to use structures with a higher proportion of forest within both 100 and 300 meter buffer but more likely to nest within close proximity to shrubby vegetation (within 15 meters). In addition, Wood Ducks were more likely to nest in structures located within wetlands with high gastropod abundance.

The DFA correctly classified 81.2 % of the original 133 HHs. Of the 33 HHs used by Mallards, 83.3 % were correctly classified. Misclassified cases were equally split between HHs used by Wood Ducks and unoccupied structures. Of the 29 HHs used by Wood Ducks, 86.5 % were correctly classified; misclassifications were equally split between the other two groups. Of the 68 unoccupied HHs, 78 % were correctly classified, and miscalculations were also equally split between the other two groupings.

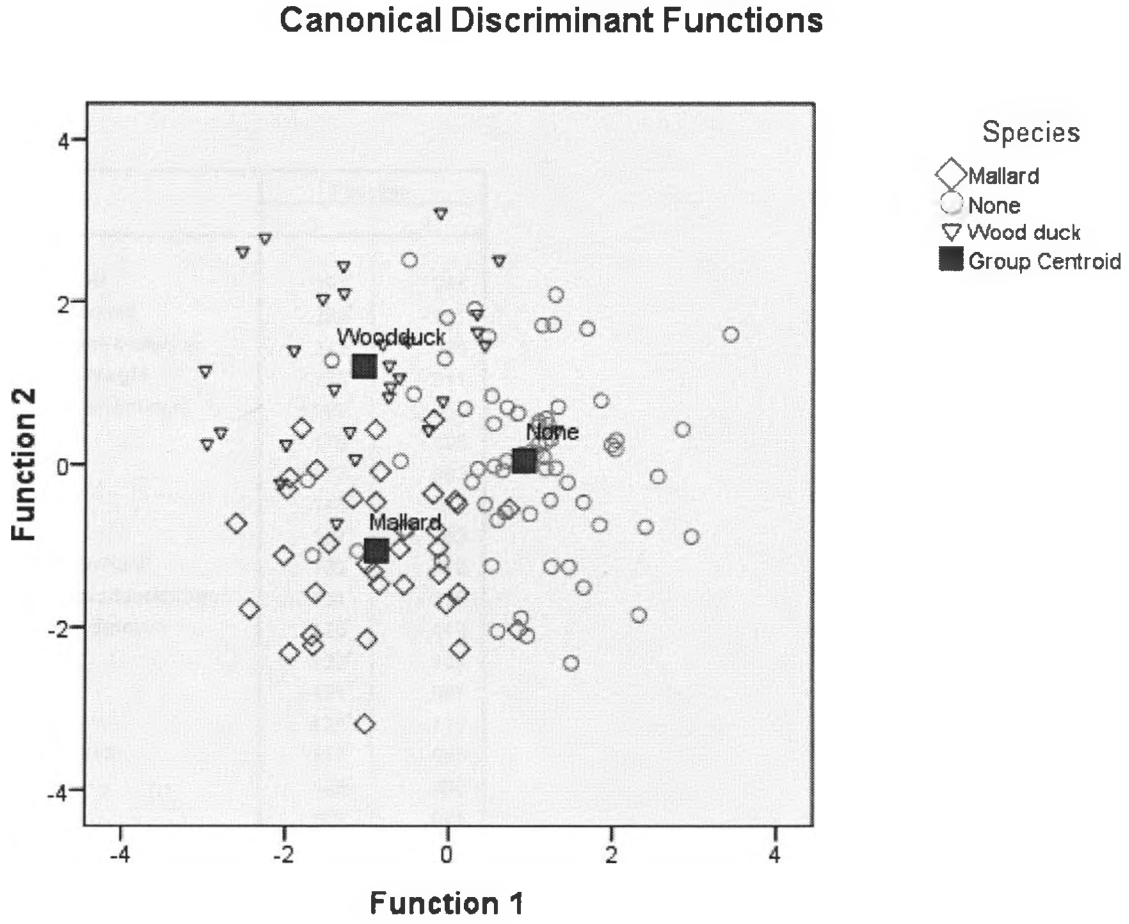

Figure 3.1: Discriminate function analysis used to separate HHs used by Wood Ducks, Mallards, and unoccupied structures. Function at group centroids differs significantly between groups (DF 1-2 Wilks $\lambda = 0.321$, $X^2 = 125.7$, Df 80, p =0.001).

Table 3.1: Pooled within-group correlations between discriminating variables and standardized conical discriminant functions for HHs in northwest Pennsylvania. Variables ordered by absolute size of correlation within function.

	Function	
	1	2
DepthatHH	-.297*	.065
Distfromshore	-.289*	-.051
DistanceofHHofwater	.242*	.229
Ln_GastWeight	-.205*	-.041
openwater15meters	-.186*	-.055
wetlands	-.179*	-.106
H300	-.172*	.093
FA300	.145*	-.023
W100	-.137*	-.063
Ln_clamweight	-.132*	.110
visablewoodduckboxes	.131*	-.036
forested15meters	.123*	-.119
shrub	.122*	.105
G300	-.121*	.001
M100	.120*	-.111
Lnpondarea	.117*	-.063
M300	.106*	-.099
H100	-.103*	.074
W300	-.097*	.041
Nonpersistent	-.087*	-.052
Emergentvegitation15meters	.067*	-.005
F100	-.071	-.281*
Ln_totalGast	-.147	.215*
F300	.006	-.178*
shrub15meters	.160	.171*
S300	.013	.149*
S100	.033	.147*
Ln_totalclams	-.015	.123*
C100	-.050	.110*
C300	-.032	.100*
FA100	.092	.099*
Nonpersistent15meters	-.020	.076*
G100	-.068	-.068*
Emergentvegitation	-.013	.045*
openwater	-.024	-.041*
Depth1meter	-.013	-.032*
Ln_totalother	-.024	.027*
LN_otherweight2	.011	.023*
Latitude	.000	-.019*

*. Largest absolute correlation between each variable and any discriminant function

Table 3.2: Mean (±SD) for habitat and Hen House (HH) variables used to discriminate among HHs used by Mallards, Wood Ducks, and structures not used

Environmental Variable	Mallard (N=36)	Not Used (N=68)	Wood Duck (N=29)
Water Depth at HH (cm)	47.9±19.2	38.15±21.35	52.03±22.59
# visible Wood Duck boxes	1.3±2.6	1.74±2.22	1.03±2.31
Forested habitat within 15m	0.01±0.04	0.02±0.05	0.00±0.01
Open water within 15m	0.58±0.32	0.46±0.30	0.55±0.28
Shrub habitat within 15m	0.02±0.05	0.08±0.13	0.07±0.13
Open water pond	0.61±0.31	0.58±.29	0.58±0.31
Shrub vegetation within pond	0.03±0.06	0.06±0.09	0.05±0.07
% Forested Cover within 100m	0.22±0.23	0.14±0.18	0.10±0.12
% Fallow fields within 100m	0.05±0.13	0.09±0.17	0.08±0.20
% Hayfields within 100m	0.05±0.12	0.04±0.12	0.08±0.19
% Shrubby Vegetation within 100m	0.17±0.15	0.21±0.19	0.23±0.17
% Mowed within 100m	0.04±0.14	0.05±0.16	0.00±0.16
% Grassland within 100m	0.01±0.02	0.01±0.05	0.01±0.04
% Cropland within 100m	0.03±0.10	0.03±0.13	0.07±0.18
% Forested cover within 300m	0.29±0.17	0.26±0.17	0.22±0.15
% Fallow fields within 300m	0.08±0.12	0.11±0.19	0.09±015
% Hayfields within 300m	0.07±0.11	0.05±0.10	0.10±0.14
% Shrubby vegetation within 300m	0.15±0.13	0.18±0.14	0.20±0.13
% Mowed within 300m	0.03±0.08	0.03±0.10	0.01±0.01
% Grassland within 300m	0.01±0.02	0.0±0.2	0.01±0.02
% Cropland 300m buffer	0.06±0.07	0.07±0.12	0.09±0.15
Latitude	41.558±.306	41.550±0.373	41.544±0.271
Longitude	80.155±0.136	80.112±0.166	80.240±0.109
Pond area (km²)	0.102 ±0.146	0.129.0±0.206	0.173±0.371
Clam count	54.36±52.0	95.4±200.9	235.5±447.7
Gastropod count	233.08±417.3	134.01±158.8	315.0±452.9
Other Invertebrate count	519.8±461.0	470.35±395.7	767.8±863.9
Clam mass (g)	0.16±.0.21	0.14±0.18	235.50±447.70
Gastropod mass (g)	1.44±2.60	0.57±0.74	1.36±2.72
Other Invertebrate mass (g)	0.12±0.12	0.12±0.14	0.12±0.13
Wetland Density (300m)	2.89±2.09	2.044±1.63	2.48±2.28
Distance of HH from shore	14.08±10.5	9.13±7.62	13.48±8.03
Height of HH above water (cm)	49.36±27.41	71.40±30.70	64.72±39.18
Water Depth 1 meter from shore (cm)	17.83±7.44	17.37±8.43	17.28±7.52
%Wetland area within 100m	0.04±0.09	0.02±0.05	0.03±0.06
%Wetland area 300m buffer	0.08±0.12	0.07±0.13	0.10±0.15
% Emergent Vegetation within 15m	0.27±0.33	0.31±0.32	0.27±0.27
% Non-persistent Emergent Vegetation within 15m	0.04±0.16	0.05±0.13	0.07±0.21
% Emergent Vegetation on Pond	0.30±0.32	0.31±0.29	0.33±0.32
Non-persistent Emergent Vegetation on Pond	0.05±0.14	0.02±0.06	0.03±0.13

3.2 Ontario Hen House Selection

In the DFA, two discriminate functions accounted for 62.8 % and 37.2 % of the between group variation. The group centroids significantly differed between groups (DF 1-2 Wilks $\lambda = 0.387$, $X^2 = 108.329$, Df 82, $p = 0.027$). DF1 separated HHs used by Mallards from the other two groups. DF2 separated HHs used by Wood Ducks from unoccupied structures. Mallards were more likely to use HHs in areas of high wetland density and containing a high proportion of grassland, hayfields, and shrubby vegetation within a 100 meter buffer as well as grassland within a 300 meter buffer. In addition, Mallards were more likely to nest in HHs that were further from shore. However, the DFA indicates that Mallards were less likely to use HH with a higher proportion of woods or cultivated fields within a 100 meter buffer as well as a 300 meter buffer as compared to HHs used by Wood Ducks and unoccupied structures. The density of wetlands within a 300 meter buffer had the highest correlation to DF1 ($r = 0.493$) (Table 3.2).

DF2 separated HHs used by Wood Ducks and unoccupied structures. Relative to unoccupied HHs, Wood Ducks tended to use structures in ponds with high invertebrate biomass and placed in deep water. Wood Ducks were also more likely to use HHs in close proximity to forests and with a high proportion of hayfields within the 300 meter buffer. However, Wood Ducks were less likely to use HHs with a high proportion of shrubby vegetation in the 300 meter buffer and emergent vegetation on both the pond and within the 15 meter buffer.

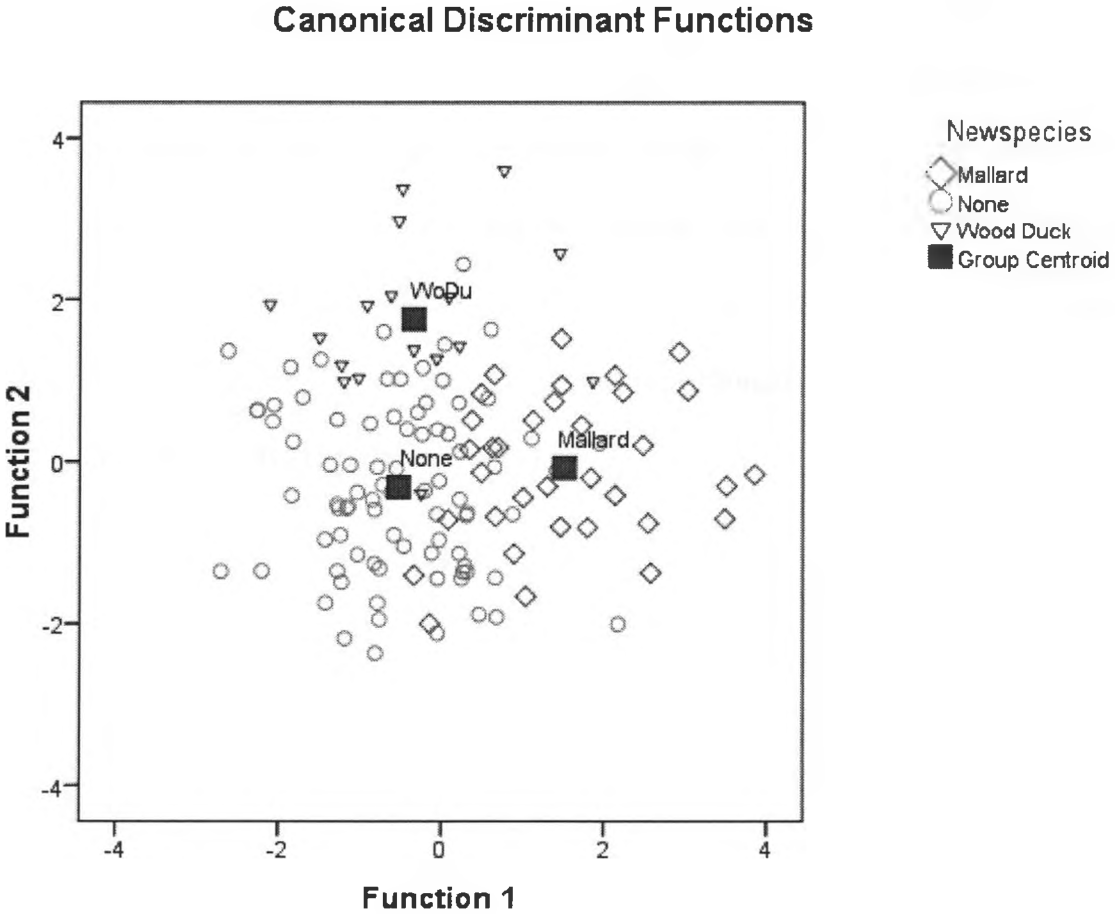

Figure 3.2: Discriminate function analysis used to separate HHs in southern Ontario that were used by Wood Ducks, Mallards, and unoccupied structures. Function at group centroids significantly differs between groups (DF 1-2 Wilks $\lambda = 0.387$, $X^2 = 108.329$, Df 82, $p = 0.027$).

The DFA correctly classified 79.6 % of the 133 HHs. Of the 33 HHs used by Mallards, 85.3 % were correctly classified. Misclassified cases tended to be disproportionally classified as unoccupied HHs compared to those used by Wood Ducks (14.7 % vs. 0.0 %). HHs used by Wood Ducks were correctly classified 88.2 % of the time, misclassifications were equally split. Of the 86 unoccupied HHs, 75.6 % were correctly classified, misclassifications were disproportionally classified as Wood Ducks compared to Mallards (15.1 % vs. 9.3 %).

Table 3.3: Pooled within-group correlations between discriminating variables and standardized conical discriminant functions for HHs in southern Ontario. Variables ordered by absolute size of correlation within function.

	Function	
	1	2
Wetlandcount	.493*	-.025
Grassland300	.278*	-.011
Hay100	.278*	.011
Forested100	-.277*	.141
Shrub100	.255*	-.091
Distfromshore	.235*	.144
Forested300	-.205*	.126
Grassland100	.197*	-.136
Long	-.179*	.018
Cultivated100	-.179*	.077
LNCountGast	-.158*	-.035
Nonperveg15	.117*	.107
Depth1meter	-.117*	-.066
LNCountother	.110*	.048
Cultivated300	-.097*	.029
Latitude	.094*	.071
Shrub15mete	.045*	-.020
Pasture100	.043*	.028
Numbervisable Henhouses	.030*	-.014
OpenwaterPond	-.018*	-.015
Shrub300	.124	-.234*
Emergveg15	-.018	-.232*
LNOtherweight	.120	.226*
DepthatHH	.122	.221*
Emergveg	.021	-.195*
For15meters	-.071	.171*
Hay300	.102	.165*
DistanceofHHofwater	.034	-.161*
ForestedPond	-.089	.140*
LNClamweight	-.076	.128*
Other300	.000	-.111*
NonpersistentPond	.044	.106*
LNGastweight	-.011	-.105*
shrubPond	.003	-.097*
Pasture300	.044	.091*
Openwater15meters	-.004	.090*
LNCountclams	-.023	.090*
Mowed100	.065	.087*
Numberofvisablewoodduckboxes	.015	-.070*
LNarea	.019	-.041*
Other100	-.005	-.006*

*. Largest absolute correlation between each variable and any discriminant function

Table 3.4: Mean (±SD) for habitat and Hen House (HH) variables used to discriminate among HH used by Mallards, Wood Ducks, and unoccupied HH.

Environmental Variable	Mallard (N=34)	Not Used (N=86)	Wood Duck (N=17)
Water Depth at HH	58.7±20.0	51.70±25.74	62.9±13.1
# visible Wood Duck boxes	0.8±0.8	0.7±1.8	0.5±0.9
Forested habitat within 15m	0.04±0.11	0.06±0.12	0.35±0.35
Open water within 15m	0.50±0.27	0.49±0.25	0.54±0.25
Shrub habitat within 15m	0.08±0.10	0.07±0.10	0.07±0.08
Open water pond	0.59±0.28	0.60±0.29	0.059±0.27
shrub vegetation within pond	0.09±0.08	0.09±0.09	0.08±0.08
% Forested cover within 100m	0.12±0.21	0.28±0.31	0.35±0.35
% Hayfields within 100m	0.04±0.14	0.00±0.1	0.01±0.03
% Shrubby Vegetation within 100m	0.24±0.26	0.14±0.18	0.11±0.14
% Mowed within 100m	0.14±0.18	0.11±0.22	0.15±023
% Grassland within 100 meters	0.22±0.24	0.14±0.23	0.08±0.15
% Cropland within 100m	0.08±0.16	0.16±0.25	0.19±0.26
% Forested Cover within 300m	0.18±0.18	0.26±0.23	0.31±0.19
% Hayfield within 300m	0.30±0.06	0.01±0.06	0.04±0.09
% Shrubby Vegetation within 300m	0.13±0.16	0.10±0.13	0.04±0.03
% Grassland within 300m	0.13±0.11	0.08±.09	0.08±010
% Cropland within 300m	0.23±0.22	0.28±0.28	0.29±0.28
% Other within 300m	0.07±0.15	0.047±0.17	0.08±0.18
%Pasture within 300m	0.07±0.15	0.05±0.17	0.08±0.18
Latitude	43.053±0.263	42.337±4.321	42.903±0.225
Longitude	78.162±13.731	80.619±0.226	80.660±0.294
Pond area (km²)	0.0143±0.0164	0.0149±0.0265	0.0113±0.0141
Clam count	4.17±8.56	14.21±73.55	13.91±43.28
Gastropod count	90.87±261.16	174.38±366.99	58.51±70.51
Other invertebrate count	619.10±641.23	576.44±766.87	945.51±1656.71
Clam mass (g)	0.01±0.05	0.03±0.09	0.05±0.16
Gastropod mass	0.41±1.25	0.46±1.33	0.20±0.33
Other mass	0.22±0.18	0.15±0.19	0.33±0.64
Wetland density within 300m	3.03±1.45	1.77±1.06	1.82±1.70
Distance of HH from shore	8.8±6.2	6.2±4.2	8.0±6.4
height of HH above water (cm)	50.8±31.6	49.8±33.2	38.9±34.8
Water depth 1 meter from shore (cm)	17.2±11.4	20.2±12.3	18.3±6.8
% Emergent vegetation within 15m of HH	0.11±0.14	0.13±0.15	0.06±0.08
% Non persistent Vegetation within 15m of HH	0.14±0.22	0.09±0.19	0.14±021
% Emergent Vegetation on Pond	0.12±0.13	0.12±0.12	0.08±0.05
% Non-persistent on Pond	0.14±0.24	0.12±0.22	0.17±0.29
% Pasture within 100m	0.08±0.21	0.06±0.21	0.7±0.20
# of visible HH	0.65±0.81	0.60±0.67	0.59±0.80
% forest cover on pond	0.05±0.09	0.06±.10	0.06±0.10

3.3 Pennsylvania Occupancy and Success Rates

During the study, Mallard occupancy rates differed between years ($X^2 = 7.80$, df=2, P=0.020). However, Wood Duck occupancy was similar among years ($X^2 = 1.13$, df=2, P=0.567). In 2007, a total of 56 (31%) HHs were occupied consisting of 29 Wood Duck nests and 27 Mallard nests (Figure 3.3). The overall occupancy rate for northwest PA increased 40 % from 40 occupied HHs in 2006 (15 Mallards and 25 Wood Ducks). There was also a 69 % increase in Mallard nests and a 16 % increase in Wood Duck nests from 2006. In 2006 and 2007, one HH was used twice by Wood Ducks

In 2008, Pennsylvania had a slight decline (4 %) in HH occupancy rates over 2007. A total of 54 (30 %) HHs were occupied consisting of 22 Wood Duck nests and 32 Mallard nests. However, there was a 19 % increase in Mallard nests and a 24 % decrease in Wood Duck nests from 2007. The largest contribution to the overall decline in occupancy rates for Pennsylvania was a reduction in Wood Duck nests. In 2008, four HHs were used twice. Three HHs were used twice by Mallards and one was used by a Mallard followed by a Wood Duck.

During the study, Mallard nest success was similar among years ($X^2 = 4.99$, df=2, P=0.082). However, nest success for Wood Ducks differed among years ($X^2 = 10.60$, df=2, P=0.005). Mallard nest success decreased from 2006 (93 %) to 2007 (67 %). In 2008, Mallard nest success increased in Pennsylvania (88 %) from 2007 (67 %). Wood Duck nest success also declined in Pennsylvania from 2006 (60 %) to 2007 (40 %). However, Wood Duck success increased in Pennsylvania from 2007 to 2008 (40 % vs. 67

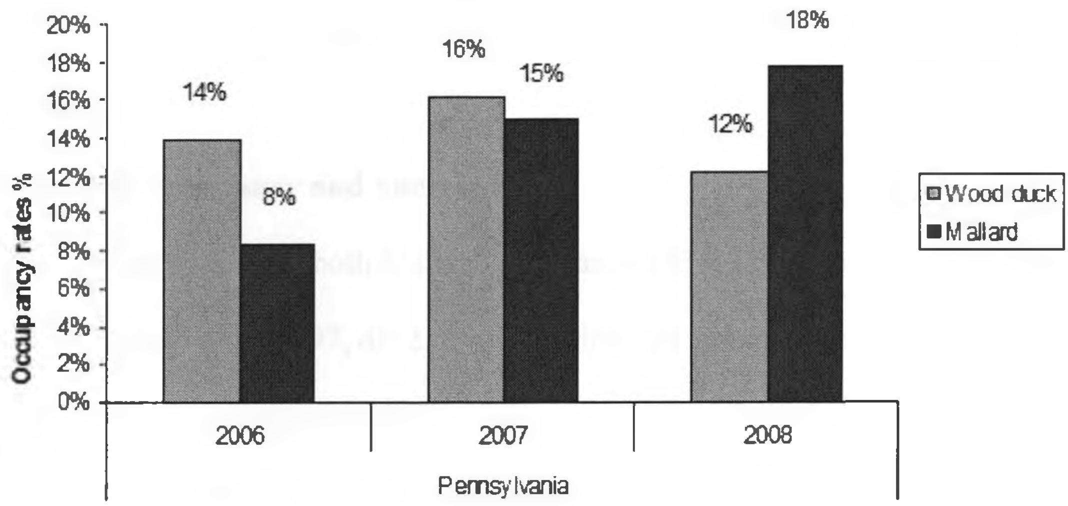

Figure 3.3: The percent occupancy of HHs in northwest Pennsylvania (n=180).

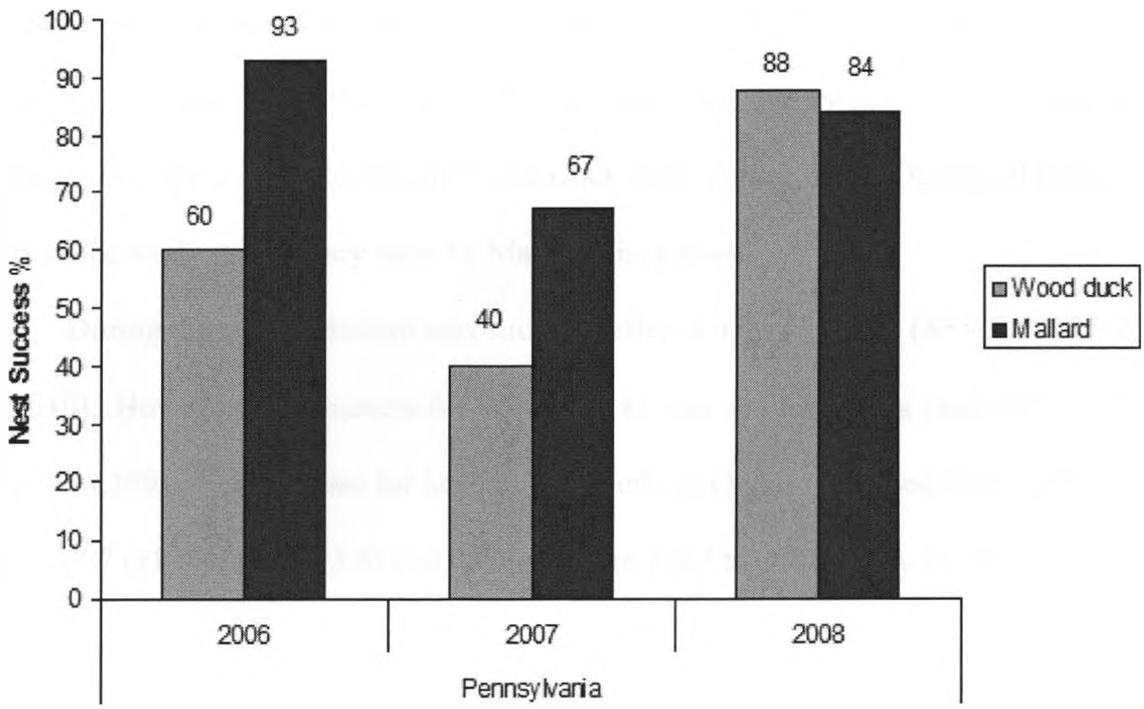

Figure 3.4: Nest success rates of Wood Ducks and Mallards in northwest Pennsylvania. Nest success is defined by the presence of at least one shell membrane.

%). Causes for nest failure for Mallard and Wood Ducks during 2006-2008 in PA were nest abandonment (n = 30 nests) as well as nest predation (n = 4). One nest predation was caused by Common Grackles (*Quiscalus quiscula*) and the other three were unknown.

3.4 Ontario Occupancy and Success Rates

During the study, both Mallard occupancy (X^2 = 11.99, df=2, P=0.002) and Wood Duck occupancy (X^2 = 7.97, df=2, P=0.019) differed among years. In 2007, a total of 32 (17 %) HHs were occupied in Ontario consisting of 24 Mallards and 8 Wood Duck nests (Figure 3.5). In 2007, the overall occupancy rate increased 78 % from 18 occupied HHs in 2006. There was also a 350 % increase in Mallard occupancy and a 56 % decline in Wood Duck occupancy from 2006 to 2007. In 2008, southern Ontario had a decline in HH occupancy compared to 2007 (6 %); a total of 30 (17 %) HHs were occupied, including 27 Mallards and three Wood Ducks. However, there was a 13 % increase in Mallard nests and a 38 % decline in Wood Duck nests during 2008. During all three years of the study, occupancy rates by Mallards increased.

During the study, Mallard nest success differed between years (X^2 = 9.29, df=2, P=0.010). However, nest success for Wood Ducks was similar among years (X^2 =3.36, df=2, P=0.189). Nest success for Mallards in southern Ontario declined from 2006 (100 %) to 2007 (71 %) (Figure 3.6) and declined from 2007 to 2008 (71 % vs. 44 %).

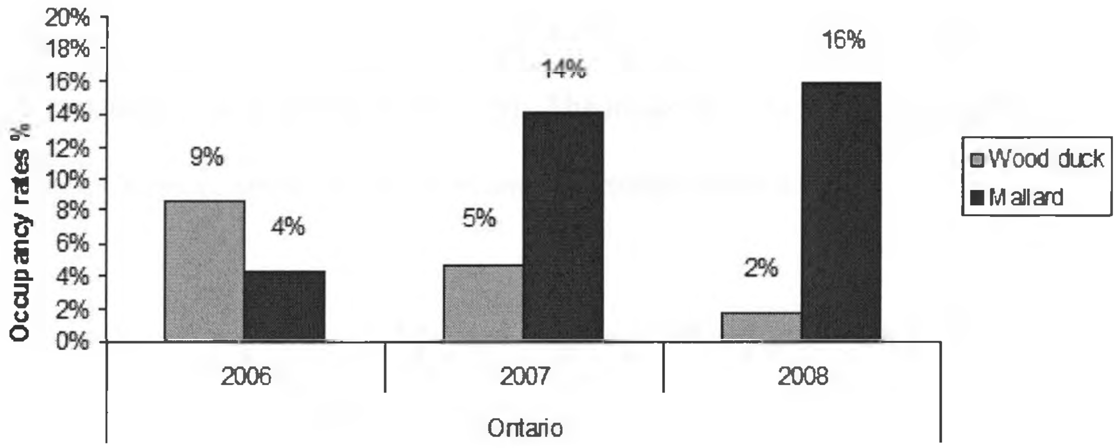

Figure 3.5: The percent occupancy of HHs in northwest Southern Ontario, 2006-2008 (n=170).

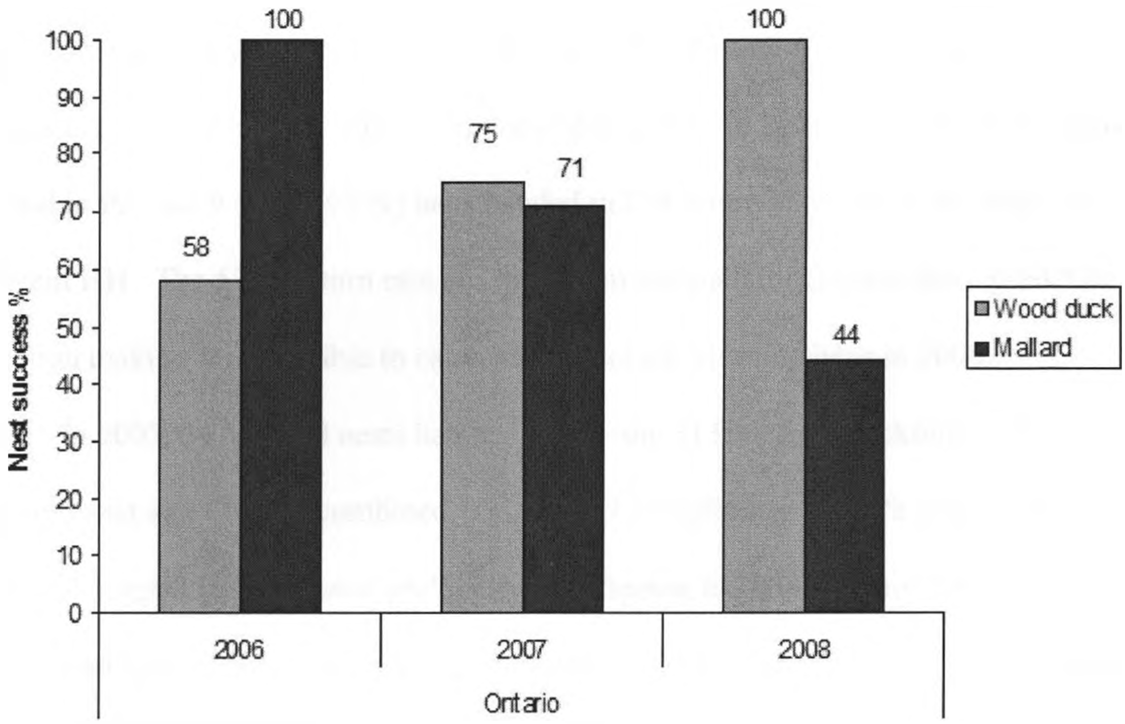

Figure 3.6: Hen House nest success rates for Wood Ducks and Mallards in southern Ontario. Nest success is defined by the presence of at least one shell membrane.

However, Wood Duck nest success increased from 2007 (58 %) to 2008 (75 %) and increased from 2007 to 2008 (75 % vs. 100 %), although Wood Duck occupancy declined both years. Causes for nest failure during 2006-2008 in ON were nest abandonment (n = 6 nests) as well as nest predation (n = 23). The majority of nest depredations were due to American Crows (*Corvus brachyrhynchos*) (personal observation).

3.5 Pennsylvania and Ontario Mallard Hen and Offspring Philopatry

During the 2006 nesting season, 15 Mallard hens (11 in Pennsylvania and 4 in Ontario) were captured and banded to study hen philopatry and nest site fidelity. Also, 146 Mallard ducklings (107 Pa and 39 ON) were web tagged to study offspring philopatry. During 2007, eight Mallard hens (55 %) that were banded in 2006 were recaptured in the same or nearby HH. However, none of the ducklings that were web tagged in 2006 subsequently nested in HHs in 2007. Twenty five additional hens (consisting of 5 SY and 20 ASY) were banded in 2007. In 2008, 14 of 16 (87 %) hens banded in PA and 9 of 17 (53 %) hens banded in ON returned to nest in the same or adjacent HH. The 53 % return rate is a minimum estimate for Ontario since predation was high making it impossible to catch and detect all returning hens in 2008.

In 2007, 34 Mallard nests hatched producing 313 Mallard ducklings in both Pennsylvania and Ontario combined. Of those, 251 ducklings (132 Pa and 119 ON) were web tagged to study natal philopatry of offspring to HHs. During 2008, only four web tagged hens (1.5 %) returned to nest in HHs. Three of the four nested in adjacent HHs (mean ± SE = 498 m ± 224) to where they hatched while one hen nested in the same HH that she hatched from in 2007. This hen initiated her nest a few weeks after her mother hatched a successful clutch in the same HH. During the three year study, over 130 Mallard nests were initiated producing approximately 900 ducklings.

3.6 Mallard Clutch Size, Hatchability Rates, and Initiation Dates in Pennsylvania and Ontario.

Clutch size, hatchability, and initiation date data were collected from Mallard nests (n = 57 in PA, n = 44 in ON) since they were intensely monitored to web tag ducklings. However, data for Wood Ducks were limited since they were only monitored for HH use and nest success. The mean (± SD) Mallard clutch size for PA among years was 11.5 ± 1.8 eggs per incubating nest. Compared to 2006 and 2007 (10.88 ± 1.4 and 12.11 ± 2.1), 2008 had a higher average clutch size of 12.5 ± 1.3 (F=7.8, df=2,54 p=0.001). However, I detected no annual difference in hatchability among successful nests (F=0.36, df=2,45 P=0.696). Hatchability rates averaged 0.92 ± 0.16 of eggs hatched over the three years.

Mean clutch size for Ontario was 10.6 ± 1.6 eggs per nest. I detected neither a difference in clutch size between years (F=0.680, df=2,41 p=0.512,) nor hatchability (F=1.7, df=2,31, p=0.193,). The mean hatchability rate for southern Ontario was 0.91 ± 0.14 eggs over the three years.

In Pennsylvania, approximately 50 % of nests initiated in HHs occurred between March 24 and March 31, 20 % occurred between March 31 and April 7, and the remaining nest occurred after April 7 (Figure 3.7). In Ontario, approximately 30 % of nests initiated in HHs between March 31 and April 14, 50 % occurred between April 14 to 21, and approximately 20 % occurred after April 21 (Figure 3.7).

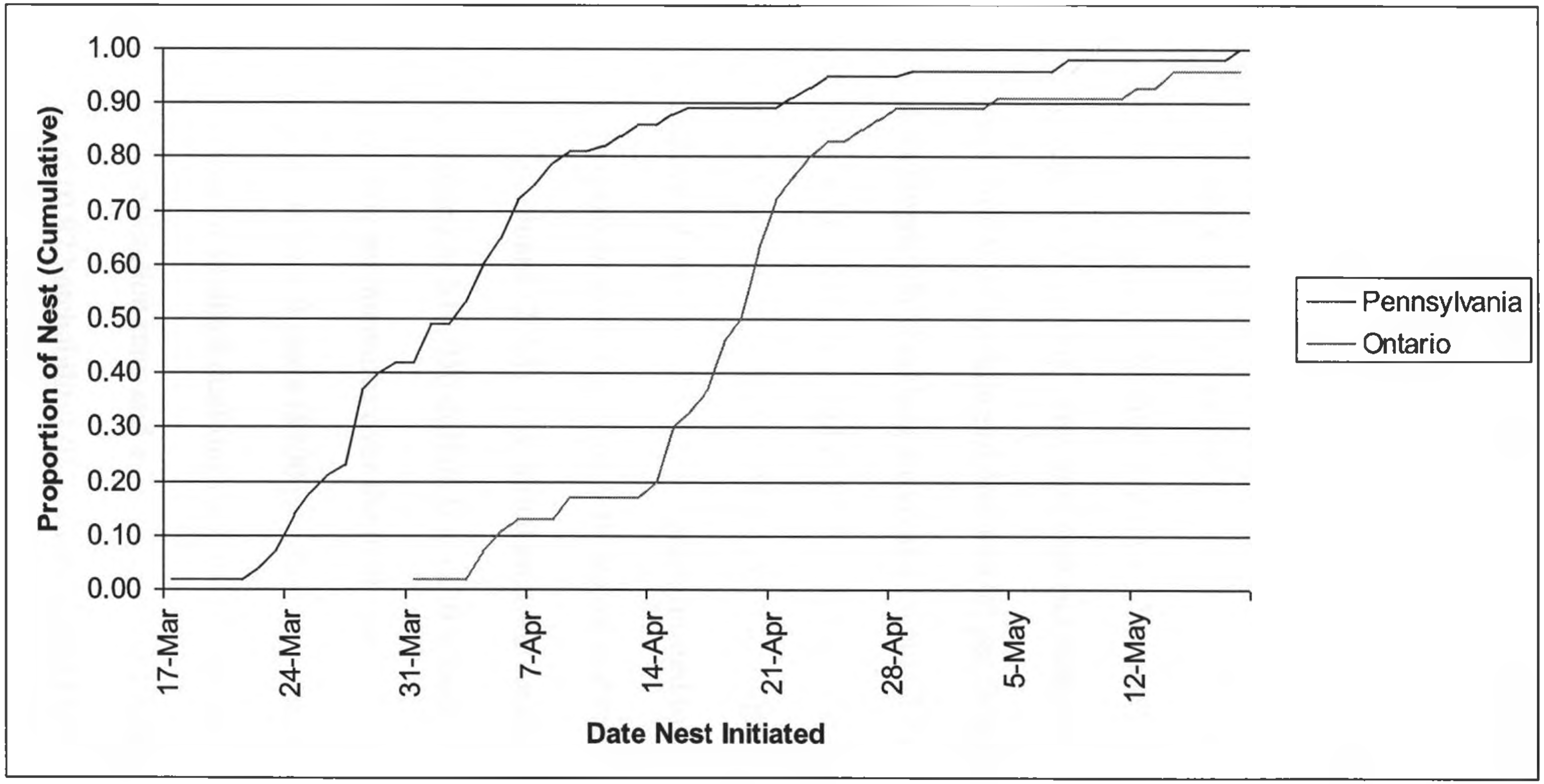

Figure 3.7: Pooled cumulative proportion of nest initiation dates of Mallards using Hen Houses in northwest Pennsylvania and southern Ontario from 2006-2008.

3.7 Cost Analysis

The total initial cost and installation of HH in PA and ON was $15,010 U.S dollars [i.e. (220 tripods)($29.00)+(130 single poles)($59.00)+(3000 km X $0.32/km U.S.)]. By including maintenance over the next nine year period, the total cost would equal $45,960 [i.e. $15,010 + 9 years ($1200 per person x 2 study sights) + (3000km)(U.S $ 0.32/km) + ($80.00 hay)]. The estimated number of Mallard ducklings produced over the hypothetical 10 year period (assuming a 17 % utilization rate, and a 77 % mallard success rate) would be 4,598 ducklings [i.e. (59 nests) (11 eggs) (0.92 hatchability) (0.77 nest success) (10 years)]. The total cost per Mallard duckling is estimated at $10.00 [i.e. ($45,960/4598 ducklings)] and $20.00 per fledged duck [i.e. (45,960/4598 ducklings)(0.50 duckling survival)] (Figure 3.8). Including Wood Ducks, the total cost per duckling is estimated at $7.35 per duckling [i.e. $45,960/6254 ducklings] and $14.70 per fledged duck [i.e. ($35,650/6254 ducklings) (0.50 duckling survival)]. In addition, I calculated the cost of a HH program limited to a small area, such as a wildlife management area, requiring little travel to directly compare my study to one conducted by Chouinard (2003). The initial cost and installation assuming a $10 per hour wage was calculated as $14,050 dollars [i.e. (220 tripods)($29.00)+(130 single poles)($59.00)]. By including maintenance over the next nine year period, the total cost would equal $29,650 [i.e. $14050 + 9 years ($800 per person x 2 study sights) + ($80.00 hay)]. The estimated number of Mallard ducklings produced over the hypothetical 10 year period (assuming a 17 % utilization rate, and a 77 success rate) would be 4598 ducklings [i.e. (59 nests) (11 eggs) (0.92 hatchability) (0.77 nest success) (10 years)]. The total cost per Mallard duckling is estimated at $6.45 [i.e. ($29,650/4598 ducklings)] and $12.90 per fledged

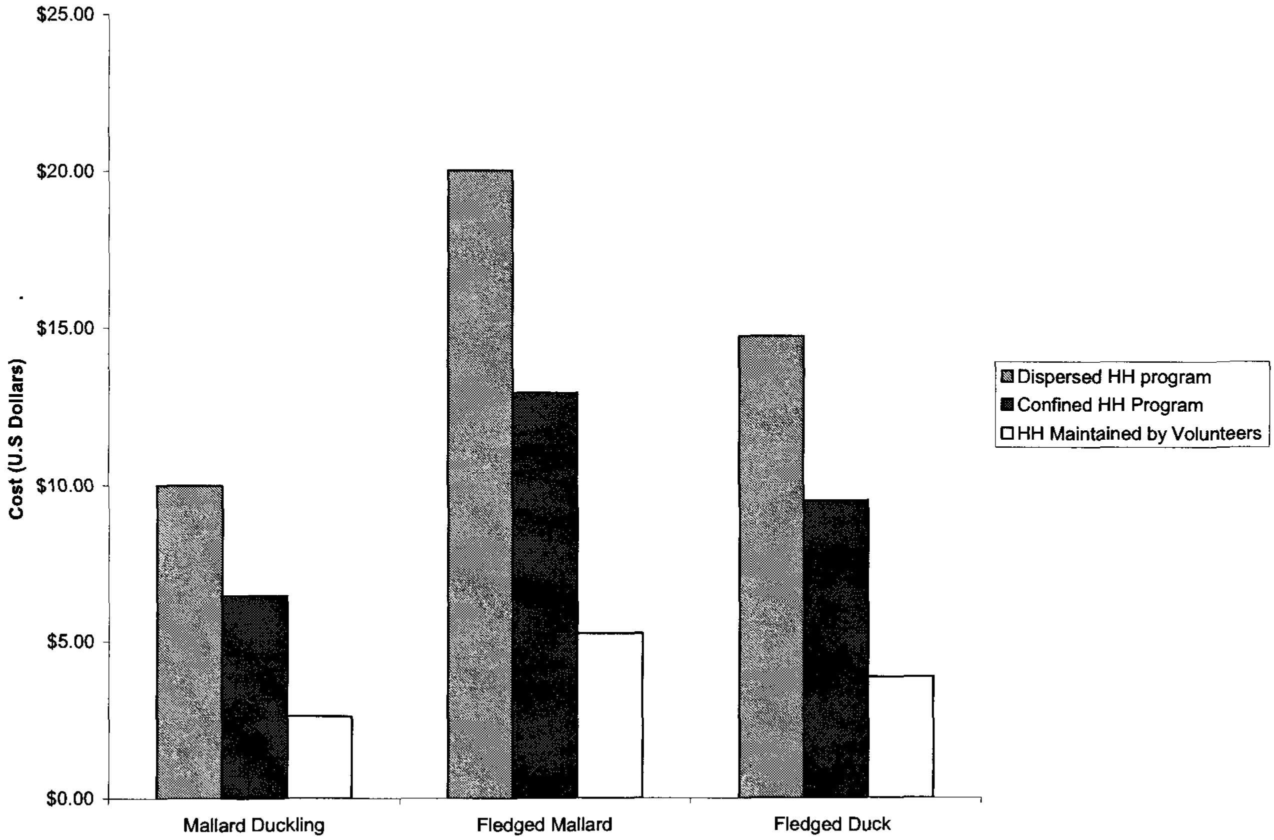

Figure 3.8: The cost per Mallard duckling, fledged Mallard, and fledged duck (Mallard and Wood Duck) for a Hen House program that is dispersed, confined, and Maintained by volunteers.

duck [i.e. (29,650/4598 ducklings)(0.50 duckling survival). Including Wood Ducks, the total cost per a duckling is estimated at $4.74 per duckling [i.e. $4.74/6254 ducklings] and $9.48 per fledged duck [i.e. ($29,650/6254 ducklings) (0.50 duckling survival)]. If the structures were installed and maintained by volunteers, the total cost per Mallard duckling produced is estimated at $2.62 per duckling [i.e. (220 tripods x $22.00) + (130 single poles x $50.00)+(9 years x 80.00 hay))/4598)] and $5.24 per fledged Mallard over the 10 year period.

CHAPTER 4: Discussion

4.1 Mallard Hen House Selection Preference

Previous studies from the Prairie Pothole Region have reported that Mallards tended to use Hen Houses that were 0.9-1.2 m above water (Bishop and Barratt 1970), in water 0.9-1.7 meters deep (Haworth and Higgins 1993) and in areas with ample open water adjacent to the nesting structure (Zicus et al. 2005). Although my findings differed from other studies, I also found these variables influenced occupancy rates by Mallards. Mallards in Pennsylvania were more likely to choose structures that were placed closer to the water (0.49 meters), in deeper water (mean = 0.47 meters), further from shore (14 m), and in areas of open water directly adjacent to the nesting structures with > 58% open water. My results were consistent with the 0.6 meter above water recommendation by Knowlton and Zolnowski (1998).

In both Pennsylvania and Ontario, Mallards were more likely to choose structures in areas with high wetland density. Reynolds et al. (1996) reported that wetland type and distribution were the primary determinants of breeding duck abundance in the prairies, whereas Yerkes et al. (2007) found pairs were most often found on small palustrine emergent and forested wetlands. Although I did not find an influence of wetland size on utilization, areas with higher wetland densities can support more breeding pairs, which could explain why structures placed in areas with higher wetland densities were more likely to be used on both study sites.

It has been previously suggested that Hen House placed in areas of marginal nesting habitat will have higher utilization than areas with high quality nesting habitat because these structures would be the most attractive nesting site available (Cowardin et al. 1985, Eskowich et al. 1998). However, Artmann et al. (2001) and Zicus et al. (2005) found that pair density and occupancy rates increased as the quality and abundance of nesting habitat increased. Hoekman et al. (2004) found that in southern Ontario, Mallard hens nested in grasslands and hayfields more than expected and nested in shrubby vegetation in proportion to availability suggesting that these are the most preferred nesting sites. My results in the GLR also suggest similar results. For example, in Ontario, Mallards were more likely to use Hen Houses that were associated with a higher proportion of grassland, hayfields, and shrubby vegetation than those associated with other land uses while in Pennsylvania; Mallards were more likely to use structures with a high proportion of hayfields adjacent to the nesting structures. However, utilization was not influenced by grassland in Pennsylvania, likely because grassland habitat was limited throughout the region. Therefore, results of this project support the hypothesis that Hen Houses use by Mallards is greater in areas with attractive nesting habitat (hayfields and grasslands). Therefore, hens likely key in on suitable nesting habitat rather than a Hen Houses, especially in areas where Hen Houses have never before been used. Therefore to maximize occupancy rates, Hen Houses should be placed in areas of moderate to high quality nesting habitat.

4.2 Wood Duck Hen House Selection Preference

In Pennsylvania, Wood Ducks had similar Hen Houses selection preferences to Mallards with respect to distance from shore and proportion of open water directly adjacent to the Hen Houses. Wood Ducks also had similar preferences for water depths and height of Hen Houses above water in both Pennsylvania and Ontario. In Ontario, Wood Ducks were more likely to nest in areas with a higher proportion of forest adjacent to the HH than elsewhere. Being a cavity nester, Wood Ducks prefer deciduous forest near wetlands for nest site selection (Bellrose 1976). However, in Pennsylvania Hen Houses adjacent to forested areas were less likely to be occupied by Wood Ducks. All Hen houses were located on State Game Lands and The Pennsylvania Game Commission has an extensive and well established Wood Duck box program. Each site contains numerous Wood Duck boxes, as opposed to privately owned wetlands in southern Ontario, with fewer existing Wood Duck boxes. Therefore, it is possible that Wood Ducks prefer artificial boxes or natural cavities when available but will use Hen Houses in areas with lower proportions of forest and possibly a limited number of suitable nesting sites.

Wood Ducks tended to use Hen houses that had a high proportion of shrubby vegetation within close proximity to the pond. Shrubby vegetation provides important cover for Wood Ducks, especially in early spring when herbaceous cover is limited (Hartke and Hepp 2004). In Pennsylvania, Wood Ducks also were more likely to nest in areas that contained a high number of gastropods and a higher biomass of other invertebrates. Invertebrates and gastropods are selected by Wood Ducks in spring (Landers et al. 1977, Bellrose and Holm 1994) and comprise nearly 60 % of their diet (Landers et al. 1977). Invertebrates contain high levels of both protein and calcium which are important for egg production (Landers et al. 1977).

Compared to unoccupied HHs in Ontario, Wood Ducks tended to choose Hen Houses that were in areas with a low proportion of shrubby habitat within 300 meters and low proportions of emergent vegetation directly adjacent to the nesting structures.

Richardson and Knapton (1993) also found that Wood Duck boxes were less likely to be used when surrounded by emergent vegetation; however, when these structures were used, they typically had higher nest success because of better concealment.

4.3 Mallard Occupancy, Nest Success, Hen Offspring Philopatry, Clutch Size, and Initiation Dates.

Hen House occupancy rates for Mallards increased in Ontario and Pennsylvania each year of the study. Previous studies have reported similar trends and have attributed the increased use to offspring and hen philopatry (Doty and Lee 1974, Lokemoen et al. 1990 Chouinard 2003). However, offspring philopatry played a limited role in the annual increase in occupancy rates in this study. During the three years of study, I detected only four nesting hens (3 in Pennsylvania and 1 in Ontario) from the 405 web tagged ducklings. If we assume a 1:1 sex ratio at hatch, then approximately 203 female Mallard offspring were produced, 2 % (4/203) of the females returned to nest in a Hen Houses (Doty and Lee 1974). This estimate is lower than the 5% return rate found in North Dakota (Doty and Lee 1974). Lower return rates observed in this study may be attributed to the difficulty in assessing philopatry rates in Ontario due to high predation rates in 2008.

Although offspring philopatry was low, I observed a high rate of hen philopatry (53 % - 87 %) during 2006-2008. The 53 % return rate in Ontario was slightly higher than the 46 % return rate observed by Doty and Lee (1974) for Mallards using open baskets, and the 49 % return rate for Wood Ducks to boxes (Bellrose et al. 1964). However, since predation was high in Ontario in 2008, we were unable to capture and verify all returning hens. Therefore, my results should be considered the minimum return rate. Considering that annual survival estimates for hens in Ontario and New York are 50 % (Sheaffer and Malecki 1996), almost all hens that use Hen Houses and survive the winter must return to and use Hen houses in subsequent years.

The majority of the increased in occupancy over time was due to other hens in the area choosing Hen Houses, particularly After-Second-Year (ASY) birds (2007 25 ASY vs. 5 SY, 2008 9 ASY vs. 5 SY) as well as the return of successful hens. Since Mallards that hatch a successful nest tend to nest in the same or nearby location (Doty and Lee 1974), one hypothesis that may explain the increased use is that previously unsuccessful ground nesting hens chose a Hen House as an alternative nesting site.

Overall, the annual nest success for Mallards was 77 % (range of 44% to 100%) and the majority of nest failures were due to American crow predation. Avian predation of Hen Houses can be substantial, especially by crows and ravens (Chouinard 2003). Although avian nest predation was high in southern Ontario, success rates were still substantially higher than ground nests observed by Hoekman et al. (2004) (13 %) in southern Ontario. Other causes of nest failure in this study were, predation from Common Grackles, eggs freezing during early nesting attempts, abandonment from nest disturbance, flooding, and dump nesting by Wood Ducks.

Mean clutch sizes in Pennsylvania (11.5 eggs) and Ontario (10.6 eggs) were higher than clutch sizes previously reported in southern Ontario (Hoekman et al. 2004) (9.6 eggs). However, previous clutch size estimates included nest attempts throughout the nesting season (Hoekman et al. 2004) and clutch size typically declines with initiation date (Bellrose and Holmes 1995). Most hens using Hen Houses initiated nests early, which could explain why higher clutch sizes were observed in this study. During the onset of the nesting season residual cover is fairly limited, likely explaining why a relatively high proportion of Hen Houses are used by early nesting hens. This early use of Hen Houses and associated high success rates could also be beneficial to Mallard populations because nests that hatch early typically contribute to a large proportion of annual recruitment (Hoekman et al. 2000). Also, considering that the two study sites are only 75 miles apart, it is interesting that there was such a difference in peak initiation dates. Although the dates that ponds thawed were not recorded for the two study sites, this possibly had an influence on initiation dates.

4.4 Wood Duck Occupancy, Nest Success

Wood Duck nest success declined from 60 % to 40 % between 2006 and 2007 and this was followed by a drop in occupancy rates during 2008. Similarly, Mallard return rates were lower for hens that nested unsuccessfully than for hens that were successful (Doty and Lee 1974), likely explaining at least some of the decline in occupancy rates in Pennsylvania. Continual declines in Wood Ducks occupancy rates in Ontario (2006, 12 nest; 2007 8 nest; and 2008, 3 nest) were also likely influenced by the low nest success.

Wood Duck nest success averaged 70 % and was the same for birds using Wood Duck boxes in a portion of the southern Ontario study area (Done 2007). Success rates from other Wood Duck box programs range from 45 % to 90 % (Bellrose and Holm 1994, Semel and Sherman 1995). Therefore, success rates of Wood Ducks nesting in Hen Houses observed in this study were similar to birds using Wood Duck boxes. Of the unsuccessful nests, dump nesting and abandonment due to disturbance were the two main causes of failure. In general, the Hen Houses were placed in open areas visible to hens which could have contributed to higher incidences of nest parasitism (Semal and Sherman 1995). However, since Hen Houses were developed for Mallards, my primary goal was to maximize and study Mallard occupancy rates.

4.5 Cost Analysis

Including mileage, I estimated the cost per duckling as $U.S 10.00 and $U.S 20.00 per fledged Mallard. For comparative purposes, I also calculated the cost per duckling as $U.S 6.45 and $U.S 12.90 for a Hen House program that was restricted to a small area requiring little mileage. Assuming that the utilization rates will remain constant, these estimates are substantially higher than the $U.S 5.35 per fledged duck (Stafford 2000) and $U.S 2.16 per fledged duck (Chouinard 2003) reported for a Hen House program in the Prairie Pothole Region. However, neither study factored mileage into the cost because both were restricted to a small area. Also, considering that Mallard populations and densities in the Prairie Pothole Region are substantially higher, lower costs were expected in the Prairie Pothole Region compared to the Great Lakes Region.

If volunteers were to construct, erect, and maintain the Hen House, the estimated cost ($U.S 5.24 per fledged mallard) is similar to Stafford et al. (2002), and twice the amount estimated by Chouinard (2003). These cost analyses are based on the assumption that occupancy rates will not increase. However, with high return rates, and new hens using Hen Houses, it is quite possible that occupancy rates could continue to increase, reducing the cost per fledged mallard.

The cost effectiveness of a Hen House program relative to other management strategies in the Great Lakes Region is difficult to compare, especially since the cost of alternative management strategies for Mallards in the Great Lakes Region has not been investigated. Lokemoen (1984) reported costs ranging from $U.S 1.88 to $U.S 581 per fledged Mallard ($U.S 3.75-$U.S 1159 after correcting for inflation) for different management strategies conducted in the Prairie Pothole Region. However, since Mallard densities in the Great Lakes Region are substantially lower, the cost of these management techniques in the Great Lakes Region would be much higher than the estimates in the Prairie Pothole Region. Therefore my Hen House estimates for the Great Lakes Region are generally lower than other methods (constructing nesting islands, predator removal, grassland restoration, etc.) used in the Prairie Pothole Region (Lokemoen 1984). Although, cost evaluations of management techniques in the Great Lakes Region have not been conducted, Hen Houses are likely one of the most cost effective techniques that could be used to affect important vital rates in the Great Lakes Region.

4.6 Management implications

Understanding the factors that cause variation in Hen Houses occupancy rates is central to improving efficiency of nesting structure programs outside the Prairie Pothole Region (Artmann et al. 2001). Based on my results, managers in the Great Lakes Region should place Hen Houses in areas with high wetland densities and adjacent to grasslands or hayfields. I also recommend that to maximize use, Hen Houses should be placed in water depths (~ 0.5 meters), further from shore (~ 14m), (~ 0.5 m) above the water and in areas of open water directly adjacent to the nesting structures.

Compared to other management strategies in the Great Lakes Region, Hen House programs can be a cost effective strategy to increase vital rates of nesting Mallards.

When implementing a Hen House program, managers should consider variables affecting the cost, such as Hen House dispersal, design, and monitoring. These estimates were based on the minimum monitoring necessary (once per year), and if intense monitoring is necessary, costs can be substantially higher. Also, considering occupancy rates are lower in the Great Lakes Region than in the Prairie Pothole Region, it may be more cost effective to use tripods rather than the single pole mount design. In addition, volunteer groups or landowners could be used to maintain structures, which reduce the cost from $U.S 20.00 to $U.S 5.24 per fledged Mallard. Annual maintenance is key for a successful Hen House program because the nesting material degrades and substantially reduces the likelihood of use. Structures should be maintained during late winter but prior to the nesting season, which occurred as early as March 17 in Pennsylvania.

Although mammalian predation was low, the southern Ontario site had only 44 % nest success in 2008 and losses were attributed primarily to crows. In South Dakota, perching deterrents have been used successfully to eliminate owl predation (Mammenga et al. 2007). Since crows were observed perching on Hen Houses before entering structures, perching deterrents might be a good alternative for reducing predation in the Great Lakes Region.

Although Mallards and Wood Ducks readily used Hen Houses in Pennsylvania and Ontario, I would not recommend replacing Wood Duck boxes with Hen Houses since Wood Duck boxes are easier to maintain, last longer, and provide better protection against avian predators. Although, it is recommended to focus efforts on placing structures to maximize use by Mallards, Wood Ducks share some of the same selection preference for Hen Houses and, in many cases, Hen Housess will appeal to both species.

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