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The Effects of Parental Age and Housing Type on the Reproductive Success of the Purple Martin (*Progne subis subis*)

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The Effects of Parental Age and Housing Type on the Reproductive Success of the Purple Martin (*Progne subis subis*)

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by

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ABSTRACT

The Effects of Parental Age and Housing Type on the Reproductive Success of the Purple Martin (*Progne subis subis*)

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The reproductive success of the Purple Martin is dependent upon many factors. This study measured reproductive success of the Purple Martin (*Progne subis subis*) based on parental age and type of housing used. Reproductive parental ages consist of adults (experienced breeders) and subadults (first time breeders). Housing types included in this study were aluminum housing, wooden housing, plastic gourds, natural gourds, SuperGourds, and mailbox housing. Reproductive success was defined as the percentage of the original clutch that fledged. Study sites were located in Alabama, Indiana, North Carolina, Oklahoma, Tennessee, and Virginia. Pairs mating nonassortatively by age group had lower reproductive success than adults and subadults that were paired assortatively. Purple Martins were most reproductively successful in SuperGourds and least reproductively successful in wooden housing. This study provides evidence that may be basis for further research, help support conservation of Purple Martins, and aid reproductive success on breeding grounds.

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CHAPTER 1

INTRODUCTION

The Purple Martin is a unique bird, with characteristics different from many other birds in North America. Unlike any other, the Purple Martin is a secondary cavity nesting bird that is adapted to rely almost solely upon man-made nesting cavities for breeding (Allen and Nice 1952; Finlay 1971; Jackson and Tate 1974). Before 1900, Purple Martins used dead snags and woodpecker holes as natural nesting sites, but nest site competitors have made those sites quite scarce (Bent 1963; Sauer et al. 1986; Brown 1997). If it were not for human intervention and colony management, nest competitors would make the martins' nests sites permanently unsuitable for further use. These competitors can cause Purple Martins to become locally extinct in an area without human intervention.

The purple martin is a member of the swallow family, Hirundinidae, and is the largest swallow in temperate North America (Peterson 1980). One characteristic of the Purple Martin is its quick flight and beautiful aerial shows while foraging. It often forages at altitudes of at least 50 meters and has been documented foraging up to 150m (Brown 1997). It feeds on insects year round. In addition to the birds' core diet, landlords, the people who provide the nesting for the birds, will often provide nutritional treats while the birds occupy their breeding grounds. These nutritional treats often include crushed eggs shells and mealworms (Bent 1942; Stokes and Stokes 1997). The Purple Martin breeds in northern Mexico, the United States, and south-central Canada (Figure 1). It spends its winters in South America. The most popular wintering areas are in east Bolivia, the provinces of southern Mato Grosso, São Paulo, Rio de Janeiro, and Espírito Santo in Brazil, and northern Argentina (Sick 1993). There are 3 subspecies of the Purple

Martin, *Progne subis arboricola*, *hesperia*, and *subis*. *Progne subis subis* breeds from the east coast in the United States west to the Rocky Mountains and into south-central Canada. Weighing an average of 54.4 grams, it is intermediate in size when compared to the other subspecies (Behle 1968; Brown 1997). Pr*ogne subis arboricola's* breeding range includes the Rocky Mountains, the Pacific Northwest, and the west coast from Baja California to British Columbia (Brown 1997). This subspecies is the largest in size, weighing approximately 59.1 grams (Behle 1968). *Progne subis hesperia* weighs an average of 46.2 grams and is the smallest of the subspecies (Behle 1968). It breeds mostly in desert areas of southern Baja California and southern Arizona (Banks and Orr 1965). In Arizona, this subspecies nests almost exclusively in the large Saguaro cactus (Phillips and others 1964). There are also records of breeding grounds south of Arizona to south-central Sonora, Mexico and along the west coast to northern Sinaloa (Phillips et al. 1964; Brown 1997). *Progne subis hesperia* has also been documented breeding on islands that are in the Gulf of California (Banks and Orr 1965). The subspecies studied in this research project is *P. s. subis.*

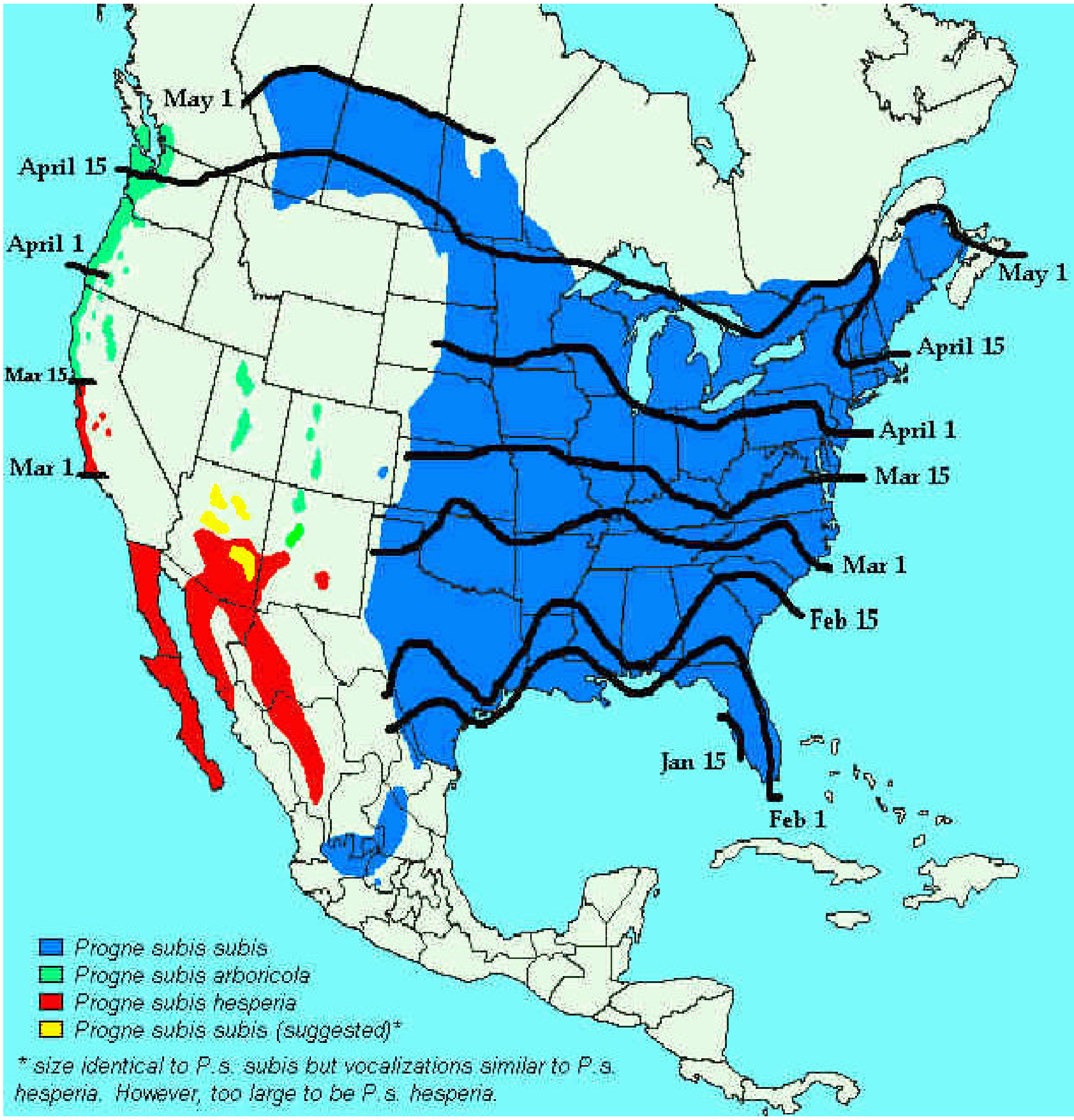


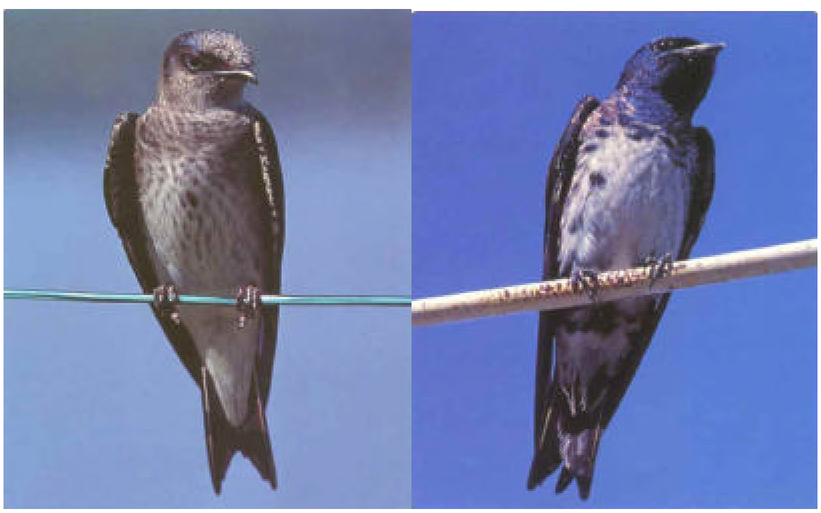
Figure 1. Breeding Range Map

Map: James R. Hill, III
Purple Martin Conservation Association

There are often population fluctuations in the Purple Martin. One cause of population changes that can be extremely damaging is adverse weather (Bent 1963; Benton and Tucker 1968; Sauer et al. 1986; Brown 1997). Birds are not able to find insects in cold weather, and substantial die-offs can occur when cold conditions last more than 3 or 4 days. Cold spells during the breeding season can deplete a colony entirely (Bent 1963). Mortality can also occur during migration when Purple Martins face adverse weather (Robbins et al. 1964). Predation also causes mortality among Purple Martins (Bent 1963; Brown 1997; Stokes and Stokes 1997). Owls and snakes can pose a significant threat, and at times all the nests at a colony are lost to predators (Brown 1997). Nest site competitors are another threat to the Purple Martin. Eggs and nestlings can be lost to nest site competitors. The most common nest site competitors are the House Sparrow (*Passer domesticus*) and the European Starling (*Sturnus vulgaris*) (Brown 1977; Brown 1981). Parasites can also play a role in the mortality of nestlings at a single colony, but they do not seem to have an effect on the martin population as a whole (Moss and Camin 1970; Hill 1984; Hill 1994).

Reproductive success can be defined as the percentage of the original clutch that has fledged (Brown 1978). Purple Martins have 2 reproductive age categories, adults and subadults (Figure 2). Adults are experienced breeders (2 years or older), and subadults (1 year old or first spring birds) are returning to the breeding colonies for the first time. Adult females lay an average of 5 to 7 eggs whereas the subadult females lay an average of 3 to 5 eggs (Johnston 1964; Finlay 1971; Stokes and Stokes 1997). Past research has demonstrated that subadult martins raise fewer young than adults and that a lower percentage of the clutches of subadults fledged (Lee 1967; Hill 1995). In contradiction to these findings, Brown (1978) demonstrated that subadult martins fledged nearly the same percentage of their clutch as the adult martins. Hill (1997) demonstrated that clutch size, hatch size, and number of fledglings are highest in adult pairs followed by adult males paired with subadult females, subadult males paired with adult females, and lowest in subadult pairs. As scientists continue to study the success of these reproductive age groups, it may become possible to determine that one age group is more successful than the other.

Adult Female Adult Male



Subadult Female Subadult Male

Photos: James R. Hill, III
Purple Martin Conservation Association

Figure 2. Plumage of Parental Ages

Purple Martins have variable reproductive success rates in different types of housing (Wade 1966; Brown 1981; Perry and Bloch 1987; Hill 1998). Many different types of housing are made available to the martins. Houses and gourds that can be purchased from retail stores and some landlords prefer to make their own housing plans. Past research comparing wooden versus aluminum housing (Perry and Bloch 1987), demonstrated that of 167 compartments occupied by martins, 54.0% nested in the wood houses while 68.1% nested in the aluminum. When comparing aluminum versus wooden housing, Brown (1981) found that the difference in nesting success was not statistically significant. In Brown's study, 82.25% of the original clutch fledged from the aluminum housing while 85.67% fledged from the wooden housing. Though lacking scientific evidence for his claims, Wade (1966) states that aluminum housing is more efficient than wooden housing as well as more efficient than using gourds as did the Native Americans. In more recent studies, Hill (1998) conducted a study that compared natural gourds, aluminum housing, and wooden housing. He found that Purple Martins had higher rates of reproduction in natural gourds than in either wooden and aluminum housing. Housing type, along with other factors such as nest compartment size, entrance hole measurements, placement of house, predator guards, and proper colony monitoring may affect the fledgling rate of Purple Martins. The reproductive success of the martins may be improved based upon additional research on housing type.

Housing type, reproductive age, and mortality are not the only factors that determine reproductive success at a colony. Research on the evolution of coloniality has shown that reproductive success may be affected by the size of the colony as well (Moss and Camin 1970; Morton et al. 1990). Davis and Brown (1999) state that Purple Martins do not experience any direct benefits of group living, and that colonies form because of the lack of nesting sites available.

Reproductive success may be lowered in large colonies because of an increase in parasite load (Moss and Camin 1970). Contradictory to these findings, Davis and Brown (1999) present evidence that parasite load will not significantly affect reproductive success in even the largest of Purple Martin colonies. Moss and Camin (1970) state that it could also be costly to have a large colony because of an increase in intraspecific competition for resources. Davis and Brown (1999) present evidence that colonies do not get large enough for intraspecific competition to have an effect on success rates. One factor that might increase reproductive success in a large colony is the presence of extra-pair fertilizations (Morton et al. 1990; Wagner et al. 1996; Brown 1997). Usually an adult will force copulation with a female martin that is already paired to another male, often a yearling male. This increases the chances of reproductive success for the male that forced copulation. Females paired to subadult males may also actively participate in extra-pair fertilizations to increase their reproductive success (Morton et al. 1990; Wagner et al. 1996; Brown 1997). Increasing paternity, at least for adult martins, appears to be a possible benefit of a large colony.

This project pursues 2 objectives. The first is to collect data from 6 different colonies during the breeding season and determine whether parental age has an effect on reproductive success. Colony sites range from few nest compartments offered to dozens of compartments. These colonies offer a variety of housing types for martins. The core data recorded will be the parental age of the birds at each nest, number of eggs laid at each nest, number of eggs hatched at each nest, and number of young fledged at each nest. This will be done at each of the sites in the study. The number of eggs laid, the percent of those eggs that hatched, and the percent of those eggs that fledged from each nest will also be analyzed. Data will be taken from each brood with documentation of the parental ages (subadult or adult) at each nest. This includes adult pairs, subadult pairs, adult males paired with subadult females, and subadult males paired with adult females. The reproductive success adult and subadults will be analyzed to determine whether adults have higher reproductive rates than subadults. Nonassortative mating by age will also be compared to mating with a bird of the same age. The proposed research will test for a trend in the percentage of the clutch that fledged in parental adults, parental subadults, and mixed age pairs as well. These results of this research will provide a basis for the understanding as to why there may be differences in the reproductive success of the age groups, if a difference occurs.

The second objective is to record the type of housing used for each nest. From each nest, the number of eggs laid, the percent of those eggs that hatched, and the percent of those eggs that produced fledged young, will be compared by housing type to see if there is a correlation between housing type and reproductive success. If a certain housing type appears to be more reproductively beneficial to martins, this will provide information for landlords on how to better monitor and care for their colonies. This will also provide the people who construct martin houses with the proper information to maximize reproductive success.

CHAPTER 2

MATERIALS AND METHODS

Study Sites

The colony sites in this study are located in Vincennes, Indiana; Abingdon, Virginia; Tiptonville, Tennessee; Hendersonville, North Carolina; Marietta, Oklahoma; and Madison, Alabama. These study sites were chosen because a better idea of overall reproductive success could be gained by convering a large area. Characteristics of each colony include: close monitoring during each breeding season, landlords experienced in conducting Purple Martin nest checks, landlords experienced in determining parental ages, and all housing types were nest-check accessible.

Vincennes, Indiana

Vincennes (Figure 3) is located in Knox County at 38° 41'N and 87° 21'W in southwestern Indiana, along the Wabash River, bordering Illinois. Vincennes is the northernmost study site in this project. The site is located on the west side of a new subdivision where there are no more houses being built and is owned by Jack Eads. This colony was a first year colony in the breeding season of 2000. The martin colony was placed in an open, grassy field, a creek exists behind the colony in a wooded area, and there are small areas of grasses and wildflowers scattered about the site. In addition to the martin colony, there is a wood fence bordering the owner's property with Eastern Bluebird houses mounted on the fence. The entire open area surrounding the martin colony is approximately 3 acres of open field. This martin colony offers an aluminum hexagonal house with 24 rooms.

Figure 3. Indiana Colony Site

Abingdon, Virginia

Abingdon is located in the southwestern part of Virginia, in Washington County. It is situated near Virginia's border with northeast Tennessee at 36° 43'N and 81° 59'W.   Tom Brake is the landlord, the colony is 6 years old, and it is located behind the landlord's home (Figure 4). This colony is not in an urban setting; it is surrounded by almost entirely open area. This site has an aluminum Trio Castle, 25 natural gourds, 2 SuperGourds, a T-14 wooden house, and a 4-compartment modified aluminum Trio house for a total of 82 compartments. All units have vertical raising and lowering mechanisms, gourds have access lids, and poles have predator guards. There is a European Starling (*Sturnus vulgaris*) trap present at this site, and starling resistant entrance holes are on one of the houses.

Figure 4. Virginia Colony Site

Tiptonville, Tennessee

This study site is located in Lake County, in northwest Tennessee (36° 23'N, 89° 28'W). This colony is 4 years old and is owned and maintained by Dennis Whitson (Figure 5). The site is situated on 1,200 acres of land, located behind a house, and there is a wood fence near the colony. Directly behind the colony is an open grassy field. This colony consists of 12 aluminum Trio houses, a T-12 wooden house, 110 plastic and natural gourds (14 are SuperGourds), 3 wooden houses, and a house made out of 4 mailboxes consisting of 12 nest compartments. There are a total of 288 nesting compartments at this colony. All the wooden houses have European

Starling resistant holes, and there are 4 European Starling and House Sparrow (*Passer domesticus*) traps being used at this colony.

Figure 5. Tennessee Colony Site

East Flat Rock, North Carolina

This colony is located in Henderson County in west North Carolina (Figure 6) at 35° 17'N and 82° 25'W. The landlord of the colony is Reece Mitchell, and this colony has been established for 20 years. Trees and brush immediately surround this site, large trees are located approximately 30 feet from the houses and gourds, and there is also a small house located approximately 50 yards to the side of the colony. This colony is in an urbanized area, located approximately 30 feet from the road, with tall grasses and an old wire fence enclosing the property. There are a total of 82 nesting compartments present at this site. The housing consists of 3 aluminum houses, a 24 room hexagonal aluminum house, 4 small aluminum compartments attached to the gourd rack, and 18 natural gourds on a man-made wooden gourd rack.

Figure 6. North Carolina Colony Site

Marietta, Oklahoma

The Marietta colony is in south central Oklahoma, in Love County, at 33° 56'N and 97° 07'W (Figure 7). It is one mile north of the Red River, in a rural setting, and surrounded almost entirely by open area. The river nearby provides a foraging habitat for Purple Martins. The colony is on 4 acres of land, owned and maintained by Danny Frazier, and is 5 years old. There are 3 poles with martin housing, and the distance between each of the poles is 15 feet. There are racks with SuperGourds on 2 of the poles, and the other pole has 3 aluminum houses attached to it. Each of the houses has starling resistant entrance holes, owl guards, and House Sparrow and European Starling traps. The entire colony is situated 100 feet from the owner's home.

Figure 7. Oklahoma Colony Site

Madison, Alabama

A small colony consisting entirely of natural gourds is located in Madison County, Alabama (Figure 8). Madison, Alabama is 13 miles southwest of Huntsville (34° 42'N, 86° 45W) and is located in north central Alabama. This colony is owned and maintained by Dean Cutten, and it is 7 years old. There are a total of 8 natural gourds at his colony, located at the back of a quarter acre suburban block, with human houses on both sides of the colony. Directly above the gourds are power lines, and behind the colony is a large, open field. There are pine trees that are approximately 15 feet high in the field adjacent to the colony.

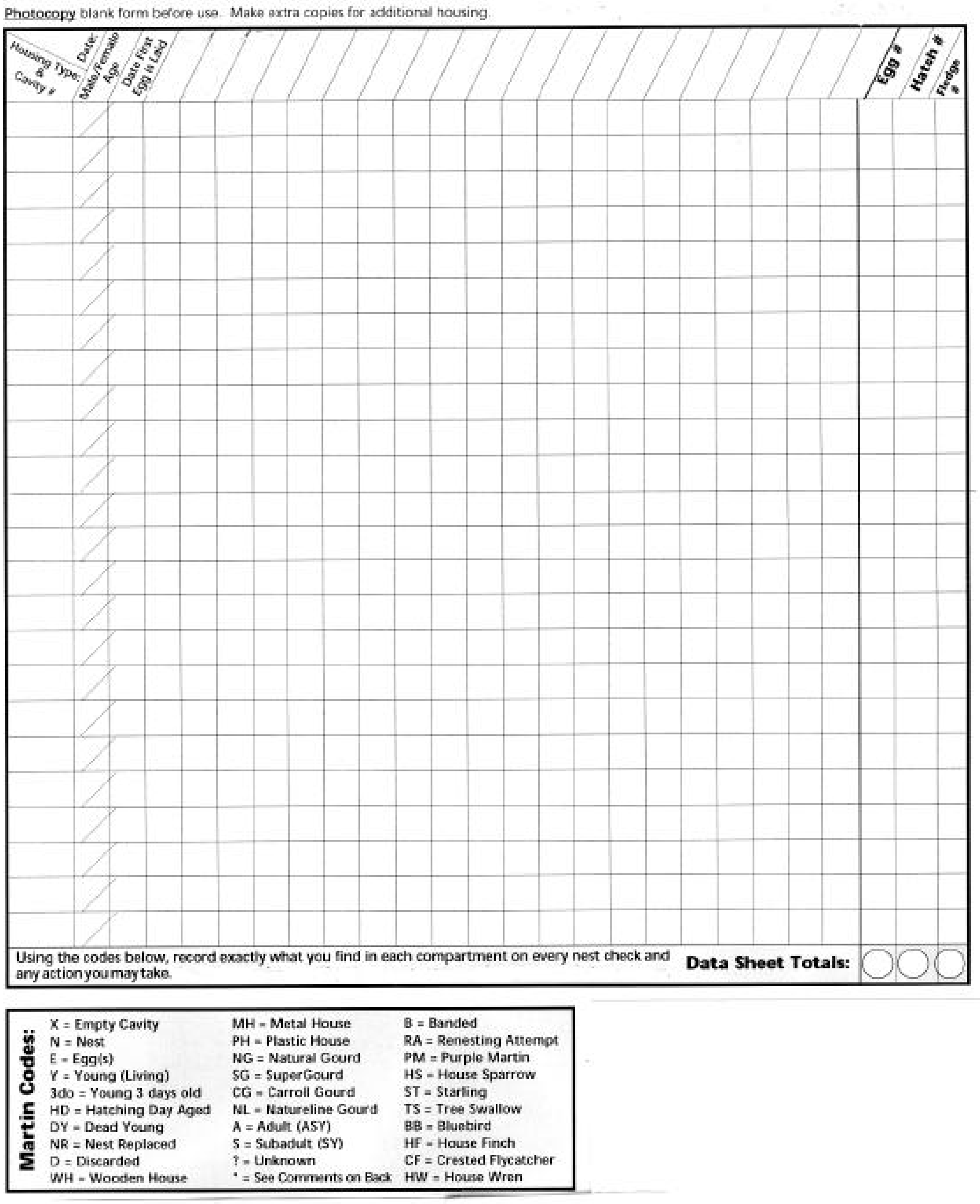
Figure 8. Alabama Colony Site

Methods

Housing type, parental ages (subadult or adult), number of eggs laid, number of eggs that hatched, and number of young that fledged for each nest were recorded from the 6 colony sites during the breeding season of 2000. I visited colonies in Indiana, Virginia, and North Carolina, and I was present for all but three of the nest checks in Indiana. The landlords obtained the data from all other colonies. Nest checks, in which numbers of eggs and young were counted, were done every 4-7 days throughout the breeding season. Young can fledge anywhere from 27 to 36 days after they hatch, but typically they leave the nest after about 28 or 29 days (Allen and Nice 1952.) The beginning of the breeding season is dependent upon where the colony is located.

The more northern the colony, the later in the spring the birds begin nest building and, therefore, the later in the summer young will fledge.

Data from nest checks were recorded on “Martinwatch sheets” from the Purple Martin Conservation Association (Figure 9) and are available from the association’s website. Data collected consist of housing type and cavity number, parental ages, date the first egg is laid, earliest possible fledge date, nest check observations, and total numbers of eggs, hatchlings, and fledglings. During nest checks, the eggs as well as the young were handled, and any dead young were discarded. Unhatched eggs were also discarded if all other eggs had hatched and parental care had begun or if the egg had been broken. If an egg was missing, this was recorded as well.


Photocopy blank form before use. Make extra copies for additional housing.

Housing Type: & Cavity # | Date: Male/Female Age | Date First Egg is Laid | Egg # | Hatch # | Fledge #

Using the codes below, record exactly what you find in each compartment on every nest check and any action you may take.

Data Sheet Totals:

Martin Codes:

X = Empty Cavity	MH = Metal House	B = Banded
N = Nest	PH = Plastic House	RA = Renesting Attempt
E = Egg(s)	NG = Natural Gourd	PM = Purple Martin
Y = Young (Living)	SG = SuperGourd	HS = House Sparrow
3do = Young 3 days old	CG = Carroll Gourd	ST = Starling
HD = Hatching Day Aged	NL = Natureline Gourd	TS = Tree Swallow
DY = Dead Young	A = Adult (ASY)	BB = Bluebird
NR = Nest Replaced	S = Subadult (SY)	HF = House Finch
D = Discarded	? = Unknown	CF = Crested Flycatcher
WH = Wooden House	* = See Comments on Back	HW = House Wren

Figure 9. Nest Check Sheet

Courtesy of: James R. Hill, III
Purple Martin Conservation Association

During nest checks, houses were lowered and the gourds' lids were unscrewed to gain access to the nests. Nest checks are conducted so that parents and the young birds were disturbed as little as possible. Some landlords include the number of dead young, the presence of parasites, and the number of missing eggs. If nest replacements by landlord have taken place, a second nesting attempt by the birds occurred, or the presence of a nest from a different species is observed, this information will also be included in nest check data. The date of each nest check is recorded in the space provided on the nest check sheet. The type of housing offered in this study consisted of aluminum housing, wooden housing, natural gourds, plastic gourds, SuperGourds (a larger version of the plastic gourd), and mailboxes.

The parental ages were determined using the *Purple Martin Book's* (Stokes and Stokes 1997) guidelines for distinguishing between adults and subadults. Binoculars were often used to observe the nesting birds in order to make the determination of parental ages. Parental ages from the colony in Tiptonville were not recorded according to nest compartment because of the large size of the colony and the difficulty in determining the parental age of the birds at each nest. During the analysis of reproductive success by age group, this colony was not included. However, reproductive success by housing type was analyzed at this colony. Parental ages for other colonies were successfully recorded.

Data Analysis

There were 2 variables considered during analysis. The first was reproductive success rate based on the parental ages at each nest. A total of 119 nests were available for analysis of reproductive success based on parental age. The 119 nests come from five of the Purple Martin colonies combined. The 105 nests from Tiptonville, Tennessee were not included in this analysis because of indistinguishable parental ages due to the size of the colony. If there was a pair of birds at one of the other colonies in which parental age was indistinguishable, that nesting pair was not included in the analyses either.

The mean number of eggs, the percent hatched, and the percent fledged was calculated for each nest. This was calculated once with the all of the data, regardless of the parental age, and once with the age data included. Note that the sample size was smaller when the ages are included because 105 of the nests from Tennessee were not included. Data included in the statistical analyses were comparisons of the 4 different parental pairs with regard to the average number of eggs that were laid, the percent of those eggs that hatched, and the percent of eggs that led to fledged young. A comparison of the average number of eggs laid by adult females versus subadult females was completed without recognition of the parental age of the male. In addition, the average number of eggs belonging to adult males was compared with the average number of eggs belonging to subadult males without recognition of the parental age of the female. The same analyses were completed for the percent of those eggs that hatched and the percent of those eggs that led to fledged young. Using MINITAB (1998) software, a general linear model for unbalanced sample size was completed for parental analyses. If the general linear model indicated a significant difference occurring somewhere in the data, Tukey's pairwise comparisons located where those significant differences occurred. In the comparison of males and females without consideration of the age of their mate, a one-way ANOVA and Tukey's pairwise comparisons determined where differences occurred. The Type I error rate used in all analyses was $\alpha = .05$. When doing a large number of multiple comparisons, Type I errors pose a problem when the null hypothesis is rejected. However, Tukey's multiple comparisons control for family error rate at $\alpha = .05$.

The second variable being considered was the reproductive success based on the type of housing. Of the nesting compartments offered, there were 224 nests available for analysis. Parental age was not incorporated into this part of the study; therefore, the 105 nests from Tiptonville, Tennessee were included in these analyses. Analyses of housing type were not confounded by parental age. A 2-way ANOVA showed that there was no trend in the age of the birds at a certain housing type. There were 6 different housing types analyzed. Using MINITAB software, a general linear model was the method of statistical analysis for unbalanced sample sizes with Tukey's pairwise comparisons to locate differences between housing types. Tukey's multiple comparisons were made only if the general linear model indicated a significant difference occurring somewhere in the data. This type of statistical analysis was used to compare the average number of eggs at each housing type, percent of eggs that hatched, and percent of eggs that led to fledged young.

In the results section, ranges for reproductive data are followed by mean values ± standard error of the mean in parentheses. The graphs in the results sections include boxplots. The medians are displayed as horizontal lines in the box, the means are displayed as red marks, and the asterisks represent outliers in the data.

CHAPTER 3

RESULTS

There were 224 nests, 1109 eggs, 975 hatchlings, and 942 fledglings. Excluding the 105 nests from the colony in Tiptonville, Tennessee, 84 nests were occupied by adult parents, 17 nests were occupied by subadult parents, 2 nests were occupied by a subadult male and an adult female, and 16 nests were occupied by an adult male and a subadult female. There were 242 aluminum compartments offered for nesting, 36 wooden compartments, 71 plastic gourds, 39 Supergourds, 117 natural gourds, and 12 mailbox compartments. Only 224 of the 517 compartments offered for nesting were occupied. Of the nest compartments that were occupied, 82 were aluminum compartments, 10 were wooden compartments, 24 were plastic gourds, 74 were natural gourds, 29 were SuperGourds, and 5 were in mailbox housing. The mean number of eggs for each type of housing was calculated along with the percent hatched and percent fledged for each type of housing. Means for number of eggs, hatchlings, and fledglings are shown in Table 1. The percent of eggs that hatched and percent of eggs that led to fledged young are also placed in Table 1.

Table 1. Overall Success without Consideration of Housing Type or Parental Age

Number of eggs, hatchlings, and fledglings, percent hatched, and percent fledged from 224 nests.

Totals	
Mean number of eggs	4.95± .03
Mean number of hatchlings	4.35± .11
Mean number of fledglings	4.20± .12
Percent of eggs hatched	87.9
Percent of eggs leading to fledged young	84.9

Part One: Reproductive Success Based on Parental Age

Nests

Table 2 shows the number of nests for each parental pair. Assortative mating by age class occurs more often that pairing nonassortatively (Figure 10). Figure 10 displays the distribution of all of the pairs in the study. Parental adult pairs comprised the largest part of this data, followed by subadult pairs, adult males mated to subadult females, and subadult males mated to adult females. Nests from Tiptonville were not used because of colony size.

Table 2. The Number of Nests Belonging to Different Parental Age Pairs

This table represents the numbers and percentages of the 119 nests belonging to each of the four pairs.

Age class of parents	Number of nests	Percentage of total nests
Adult male/adult female	84	70.6
Adult male/subadult female	16	13.4
Subadult male/adult female	2	1.7
Subadult male/subadult female	17	14.3

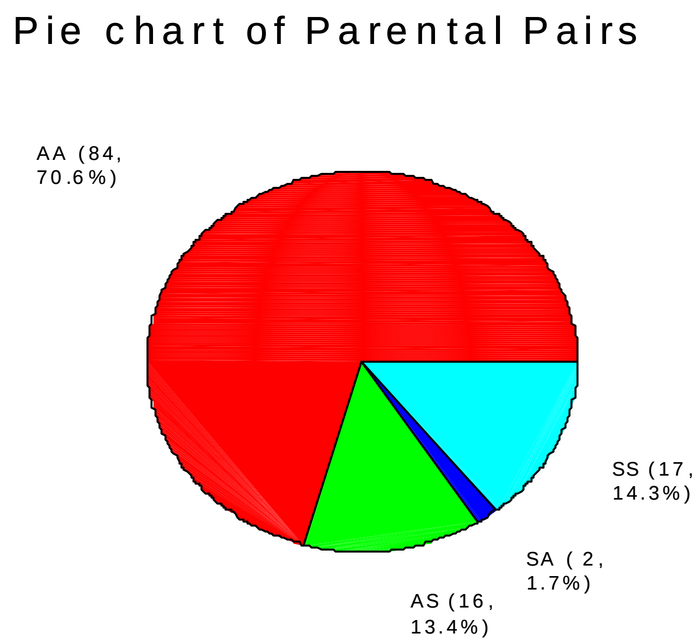


Figure 10. Pie chart of Parental Pairs

This figure is representing 119 nests. It shows the distribution of the number of nests belonging to each parental pair. The number of each parental pair and percent of each parental pair are in parentheses.

AA=adult male/adult female
AS=adult male/subadult female
SA=subadult male/adult female
SS=subadult male/subadult female

Eggs

Adult females lay more eggs on average than do subadult females ($p=0.00, f=16.46, df=1$). Adult females lay 5.23± .11 eggs and subadult females lay 4.39± .18 eggs. Figure 11 shows the average number of eggs laid by females, without the age of the male considered. The figure represents 86 adult females and 33 subadult females.

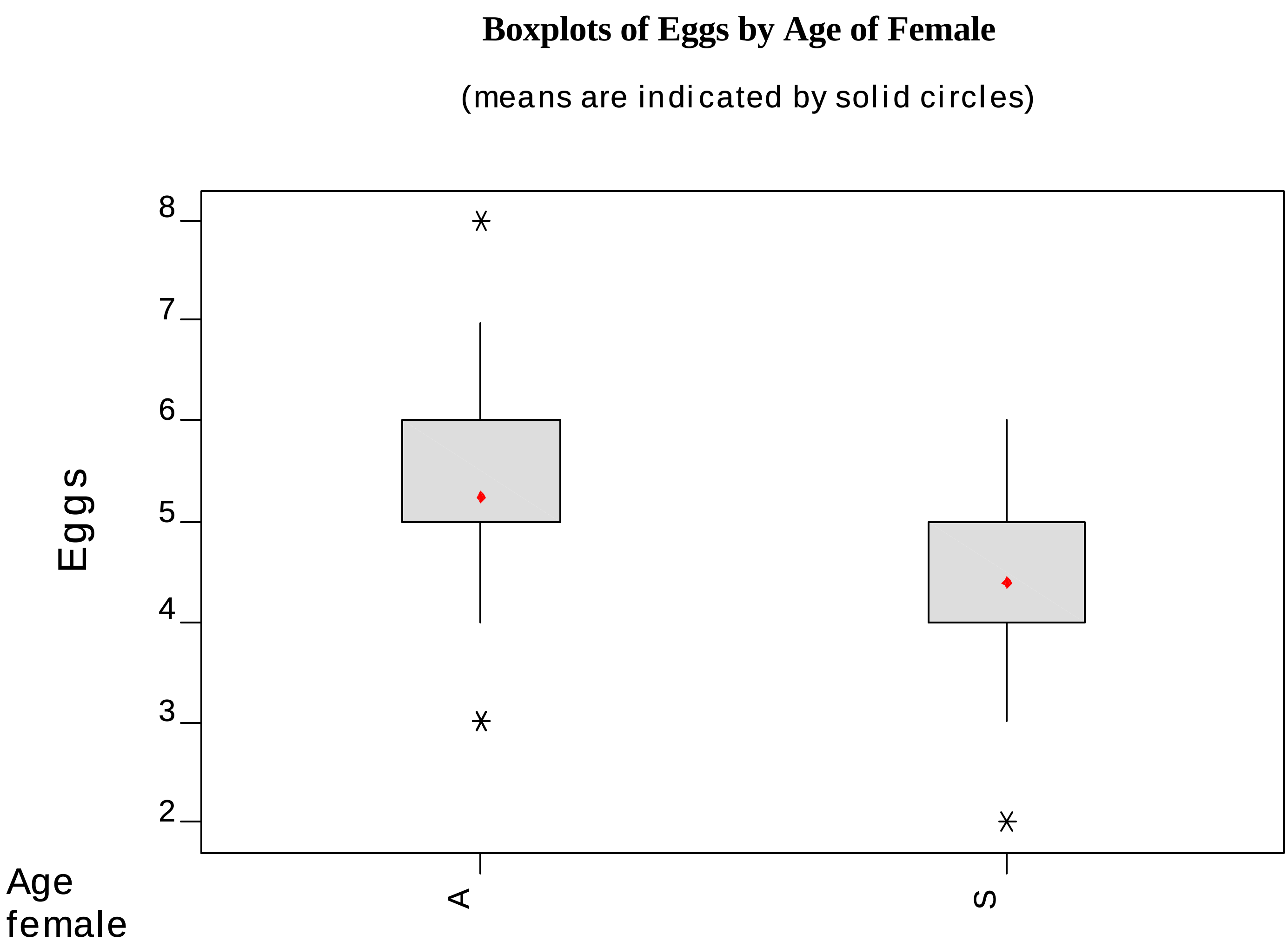


Figure 11. Boxplots of Eggs by Age of Female

Based on 119 nests, this graph includes the average number of eggs laid in two age classes considering only the female. Means are indicated by red dots, and asterisks represent data outliers.

A=adult female S=subadult female

Figure 12 shows the average number of eggs laid based on the age of the male at the nest. This graph includes data from 100 adult males and 19 subadult males. Adult males father 5.20± .09 eggs and subadult males father 3.95± .22 eggs. Adult and subadult males father different numbers of eggs (p=0.00, f=26.42, df=1).

Figure 12. Boxplots of Eggs by Age of Male

Based on 119 nests, the graph shows the average number of eggs laid according to the age of only the male. Means are indicated by red dots, and asterisks represent data outliers.
A=adult male S=subadult male

Figure 13 shows the average number of eggs laid by the female including the age of the male she is paired to. Adult females paired with adult males laid 3 to 8 eggs (5.26 ± .11). Adult females paired with subadult male laid 4.00 ± .00 eggs. Adult males paired with subadult females laid 3 to 6 eggs (4.88± .18). Subadult females paired with subadult males laid 2 to 6 eggs (3.94 ± .25). The age of the male is the most important determining factor in the number of eggs laid ($p = .005$, $f = 8.04$, $df = 3$) by a pair. There were differences ($p = 0.00$) in the number of eggs laid by adult pairs when compared to subadult pairs, and in the number of eggs laid by adult males paired to subadult females when compared to subadult pairs. The sample size of 2 nests for subadult males paired with adult females is considerably smaller in comparison to the others. A larger sample size would have been more reliable.

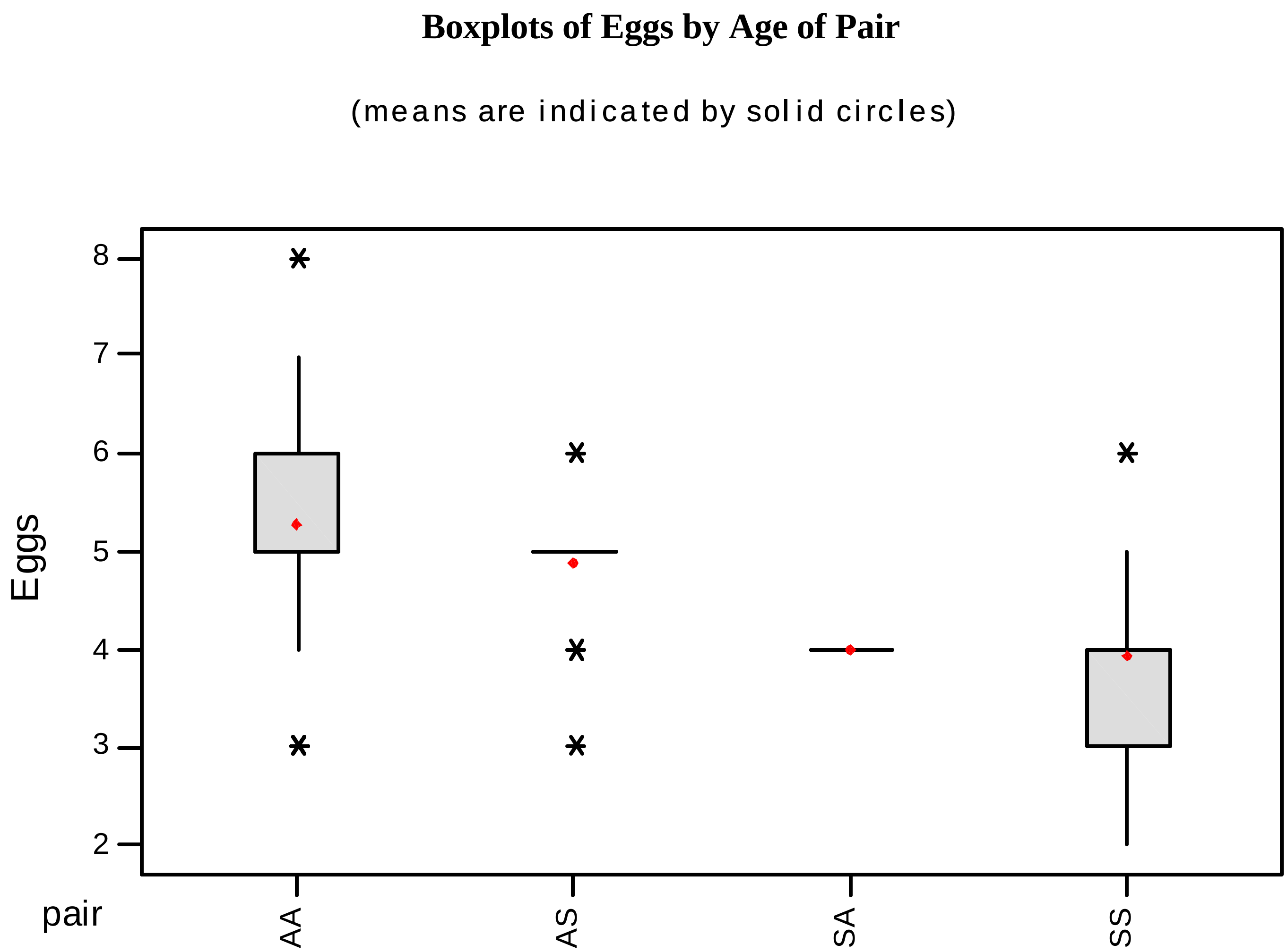


Figure 13. Boxplots of Eggs by Age of Pair

Based on 119 nests, this graph represents the average number of eggs laid for each parental pair. Means are displayed as red dots, and asterisks represent data outliers.

AA=adult male/ adult female AS=adult male/subadult female

SA=subadult male/adult female SS=subadult male/subadult female

Hatchlings

The number of hatchlings for each nest was analyzed to determine if the percent of eggs that hatched differed significantly according to the parental ages of the pair. Figure 14 displays the percent of hatchlings for each parental pair. Adult pairs had 88.53 % ± 2.49% of their eggs hatch. Subadult males paired with adult females had 75.0% ± 0.00% of their eggs hatch. Adult males paired with subadult females had 76.88% ± 7.17% of their eggs hatch. Subadult pairs had 87.06% ± 3.81% of their eggs hatch. There were no differences when comparing the percent of hatchlings belonging to each parental pairs ($p= .262$, $f=1.35$, $df=3$). Although there were no statistical differences between pairs, adult pairs and subadult pairs had more eggs hatch than subadults paired with adults. Even though subadult pairs laid a smaller number of eggs than all other pairs, they had a higher percentage of eggs hatch than both pairs that mated nonassortatively. It would appear that because subadult pairs were the least successful in producing large numbers of eggs, that they would also be the least successful in the ability to successfully yield hatched eggs.

Boxplots of % Hatch by Age of Pair

(means are indicated by solid circles)

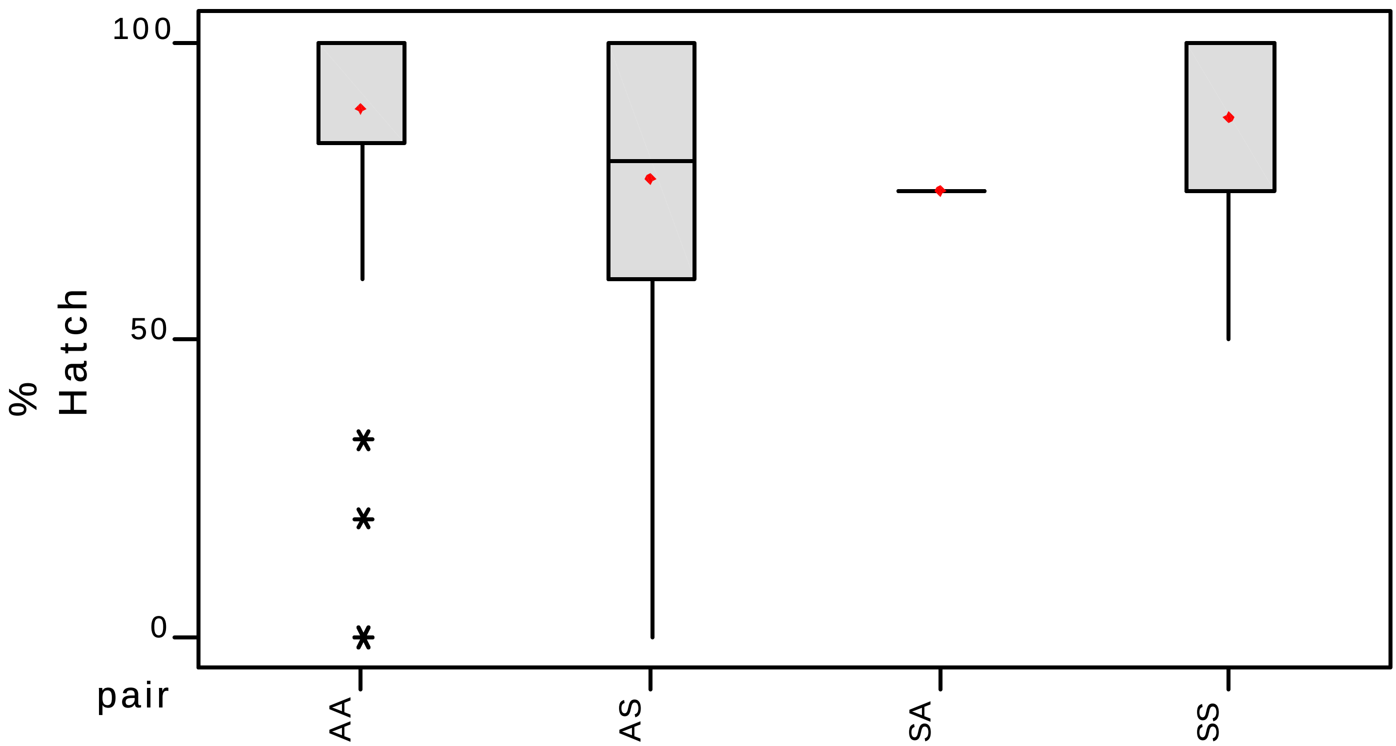


Figure 14. Boxplots of % Hatch by Age of Pair

Based on 119 nests, this graph displays the percent of eggs that hatched for each parental pair. Means are displayed as red dots and asterisks represent data outliers.

AA=adult male/ adult female AS=adult male/subadult female

SA=subadult male/adult female SS=subadult male/subadult female

Considering only the parental age of the female, Figure 15 displays the percent of eggs that hatched for each age group. Considering only the parental ages of the male, Figure 16 presents the percent of eggs that hatched for each age group. Of the 86 adult female nests, 88.21% ± 2.45% of the eggs that were laid hatched. Of the 33 subadult female nests, 82.12% ± 4.03% of the eggs that were laid hatched. The percent of hatchlings belonging to adult females is not greatly different than the percent of hatchlings belonging to subadult females (p= .195, f=1.70, df=1). Of the 100 adult male nests, 88.66% ± 2.41% of the eggs hatched. Of the 19 subadult male nests, 85.79% ± 3.51% of the eggs hatched. The percent of hatchlings belonging to adult males versus the hatchlings belonging to subadult males (p= .879, f= .02, df=1) is also not greatly different.

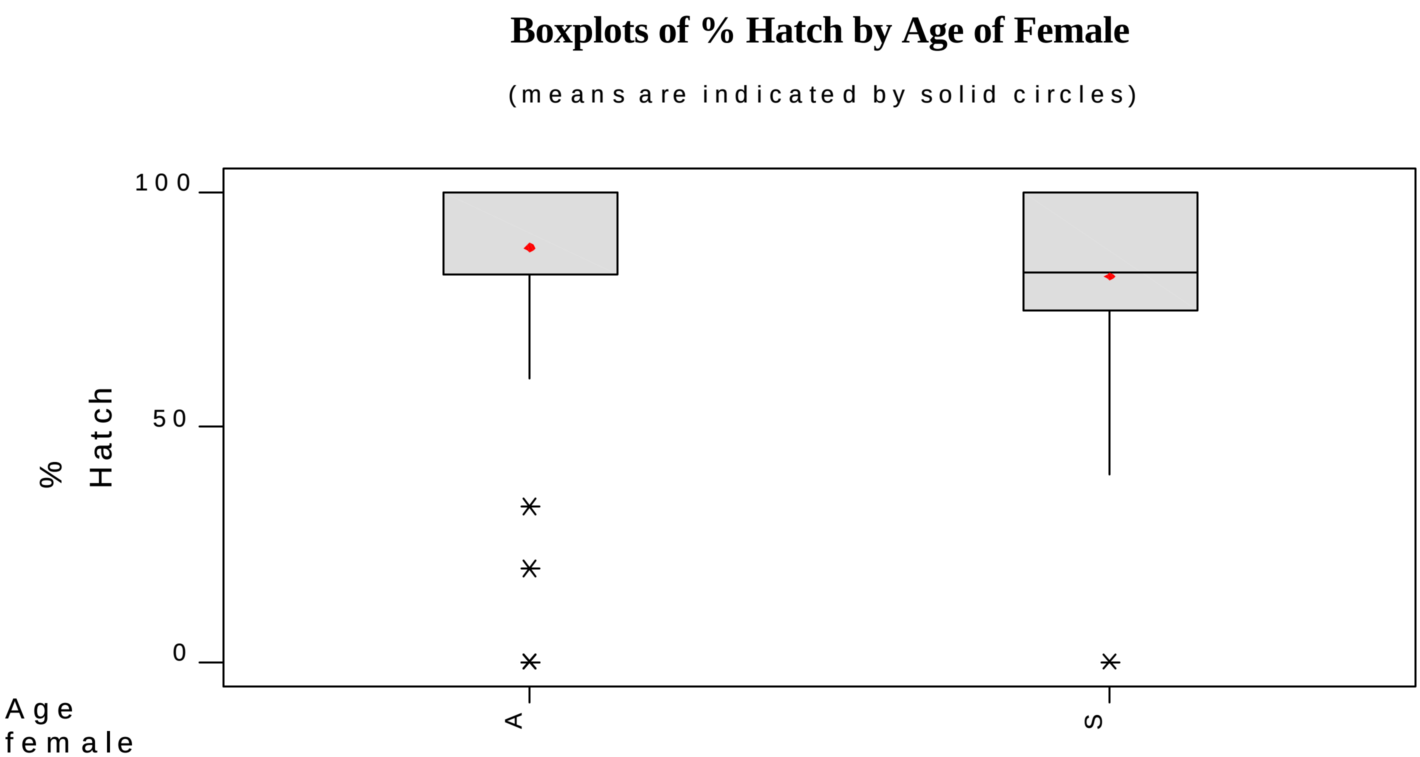


Figure 15. Boxplots of % Hatch by Age of Female

Based on 119 nests, this graph represents the percent of eggs that hatched according to the age of female. Means are indicated by red dots, and asterisks represent data outliers.
A=adult female S=subadult female

Figure 16. Boxplots of % Hatch by Age of Male

Based on 119 nests, this graph represents the percent of eggs that hatched according to the age of only the male. Means are indicated by red dots, and asterisks represent data outliers.
A=adult male S=subadult male

Fledglings

The number of fledglings for each nest was analyzed to determine if the percent that were fledged differed significantly according to the parental ages of the pair. Table 3 represents the total percentages of eggs that hatched and led to fledged young according to the age of the pair. Figure 17 shows the percent of fledglings for each parental pair. The percent of hatchlings belonging to any of the parental pairs (p= .110, f=1.70, df=3) was not largely different. Adult pairs had 84.38% ± 2.77% of their eggs lead to fledged young. Subadult males paired with adult females had 62.5% ± 12.5% of their eggs lead to fledged young. Adult males paired with subadult females had 68.54% ± 7.35% of their eggs lead to fledged young. Subadult pairs had 78.83% ± 6.59% of their eggs lead to fledged young. The sample size of 2 nests belonging to subadult males paired with adult females is considerably smaller than other sample sizes.

Table 3. Reproductive Success Based on Parental Age

This table represents 119 nests. The average number of eggs laid by each parental pair, the percent of those eggs that hatched successfully, and the percent of those eggs that led to fledged young are represented in this graph.

	Adult male/ adult female	Adult male/ subadult female	Subadult male/ adult female	Subadult male/ subadult female
Average number of eggs	5.26± .11	4.88± .18	4.00± .00	3.94± .25
Percent hatched	88.5	76.8	75.0	87.1
Percent fledged	84.4	68.8	62.5	78.7

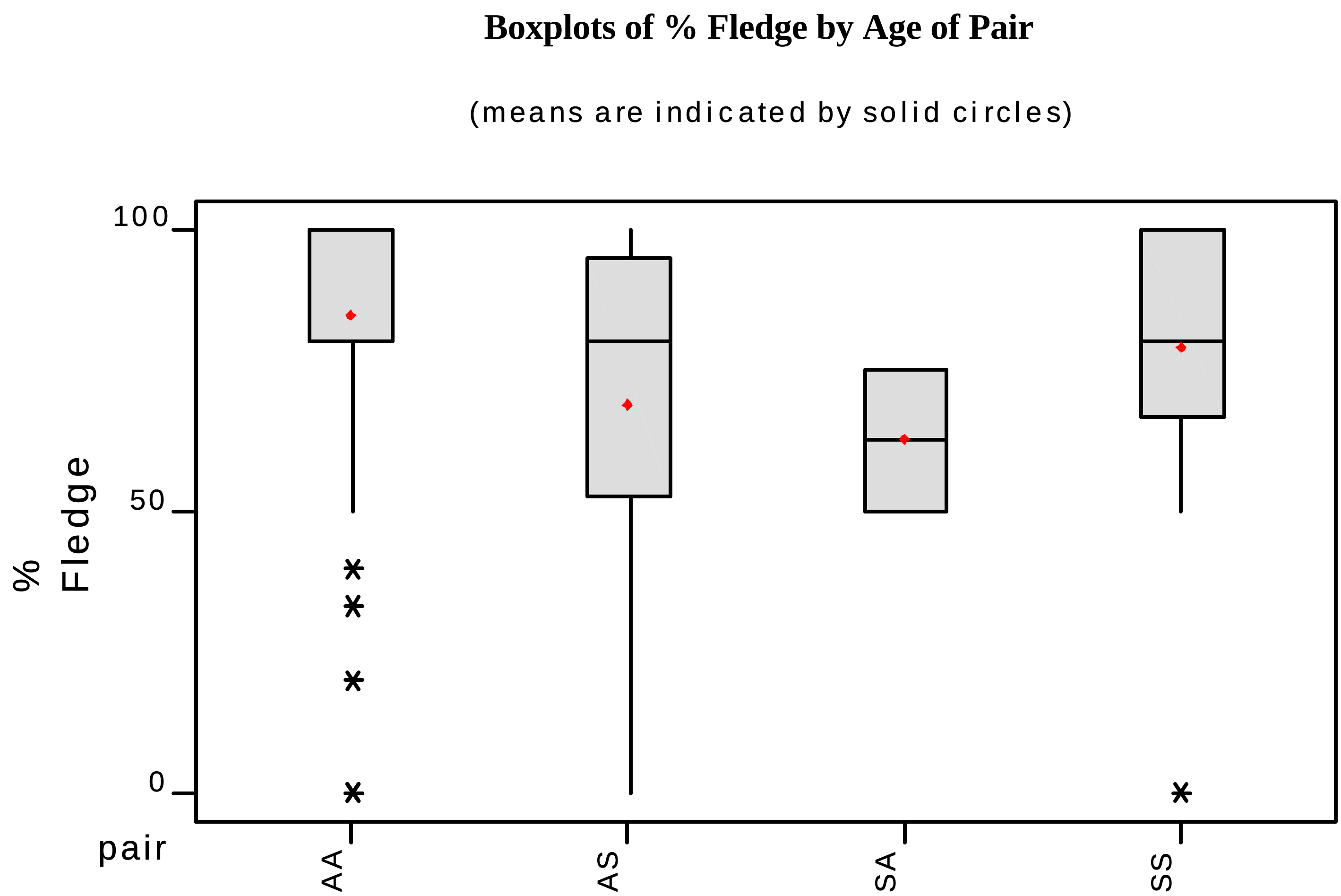


Figure 17. Boxplots of % Fledge by Age of Pair

Based on 119 nests, this graph represents the percent of eggs that led to fledged young according to the age of the parental pairs. Means are indicated by red dots, and asterisks represent data outliers.

AA=adult male/ adult female AS=adult male/subadult female
SA=subadult male/adult female SS=subadult male/subadult female

The percent of fledglings for both parental ages of females is shown in Figure 18. An analysis was also completed considering only the parental ages of the males. The percent of fledglings for both parental ages of males is shown in Figure 19. Of the 86 adult female nests, 83.87% ± 2.74% of the eggs fledged young. Of the 33 subadult female nests, 73.79% ± 4.93% of the eggs that were laid fledged young. The percent of fledglings belonging to an adult female versus the percent of fledglings belonging to a subadult female ($p= .063$, $f=3.53$, $df=1$) was not different. Of the 100 adult male nests, 81.85% ± 2.66% of the eggs fledged. Of the 19 subadult male nests, 77.02% ± 6.07% of the eggs fledged. There was not a difference in percent of fledglings belonging to an adult male versus percent of fledglings belonging to a subadult male ($p= .469$, $f= .53$, $df=1$).

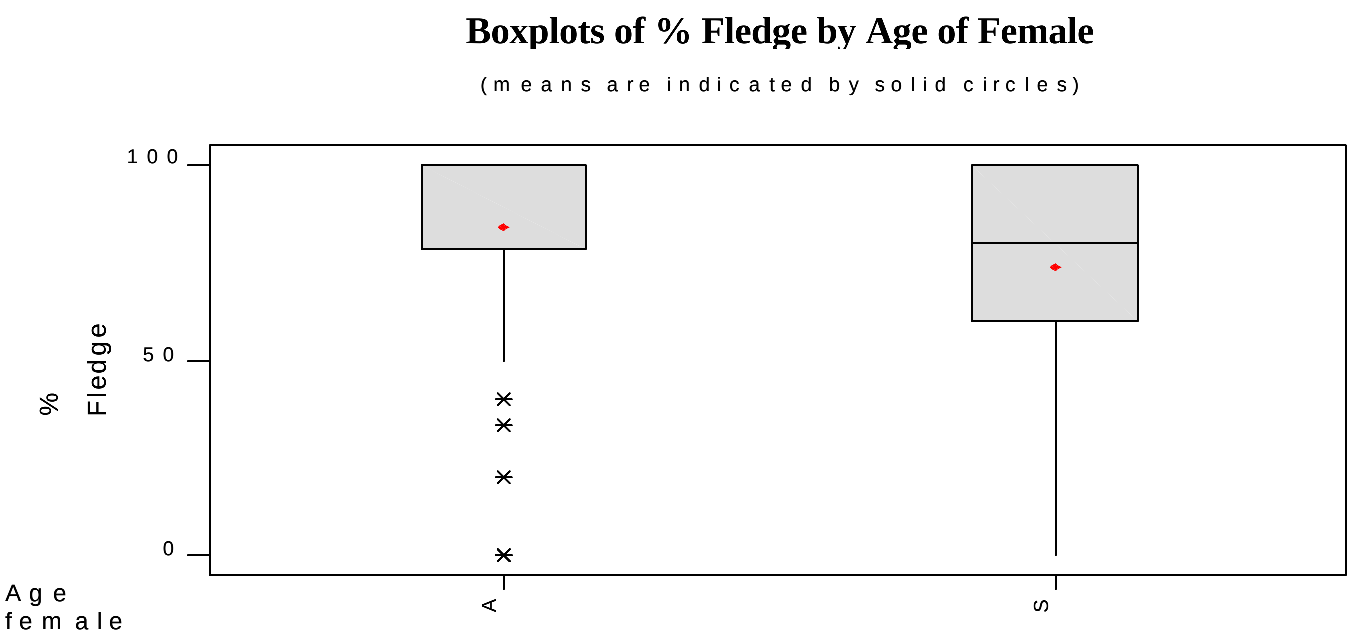


Figure 18. Boxplots of % Fledge by Age of Female

Based on 119 nests, this graph represents the percent of eggs that led to fledged young according to the age of the female. Means are indicated by red dots, and asterisks represent data outliers.
A=adult female S=subadult female

Figure 19. Boxplots of % Fledge by Age of Male

Based on 119 nests, this graph represents percent of eggs that led to fledged young according to the age of the male. Means are indicated by red dots, and asterisks represent data outliers.
A=adult female S=subadult female

Part Two: Reproductive Success Based on Housing Type

Nests

Table 4 illustrates the number of nests at each type of housing for all 6 colonies. It also displays the total number of compartments for each housing type that was offered to the birds, the number of those that were occupied, and the percentage of those nest compartments that were occupied. By looking at the 517 nesting compartments that were offered for nesting, one is able to assess which types of housing had the highest occupancy rates. It is difficult to accurately determine a statistical difference in preference because housing sample sizes are different. When considering the preference of the birds based on the housing type with the highest occupancy rate, SuperGourds appear to be most preferred. The martins nested in 74.4% of the 39 SuperGourds that were offered. Wooden compartments were least preferred with only 2.8% of the 36 wooden compartments occupied.

Table 4. The Percent Occupancy for Each Type of Housing

This table represents all 517 compartments offered. The total number of nests offered at each housing type, the number of those nest that were occupied, as well as the percent of nests that were occupied are represented in this table.
(AL=aluminum house, WH=wooden house, NG=natural gourd, PG=plastic gourd, SG=SuperGourd, MB=mailbox compartment)

	AL	WH	NG	PG	SG	MB
Number offered	242	36	117	71	39	12
Number occupied	82	10	74	24	29	5
Percent occupied	33.9	2.8	63.2	33.8	74.4	41.7

Of 224 nesting compartments that were occupied by Purple Martins, aluminum compartments made up 37.5% of the total nesting compartments occupied, wooden houses 4.5%, plastic gourds 10.7%, natural gourds 33.0%, 12.9% were SuperGourds, and 2.2% of nests were in mailbox compartments. Figure 20 presents this data in a pie chart representing percents of each type of housing.

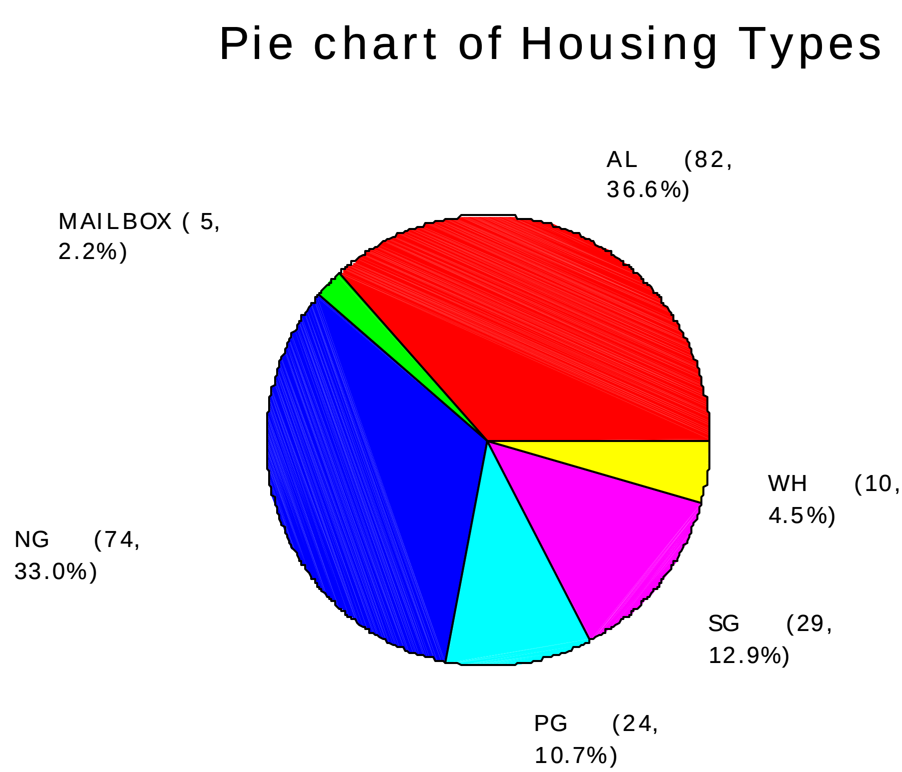


Figure 20. Pie chart of Housing Types

This pie chart represents the distribution of 224 nests among six different types of housing. The number of each type of housing and percent of that type of housing is in parentheses.

AL=aluminum housing **WH**=wooden housing **NG**=natural gourd
PG=plastic gourd **SG**=SuperGourd **Mailbox**=mailbox

Eggs

In the analysis, it was determined that the Purple Martins do better in some types of housing compared to others ($p= .007$, $f=3.30$, $df=5$). Figure 21 shows the average number of eggs at each type of housing. The most eggs were laid in natural gourds, and the least number of eggs were laid in the mailbox compartments. The number of eggs laid ranged from 3 to 8 (5.32± .12) in natural gourds, 4 to 6 eggs (5.20± .29) in wooden housing, 2 to 7 eggs (5.03± .16) in SuperGourds, 1 to 8 eggs (4.76± .14) in aluminum housing, 1 to 7 eggs (4.42± .36) in plastic gourds, and 3 to 5 eggs (4.20± .49) in mailbox compartment housing. There was a significant difference between numbers of eggs laid at aluminum housing when compared to natural gourds. There was also a difference between numbers of eggs laid at natural gourds versus plastic gourds.

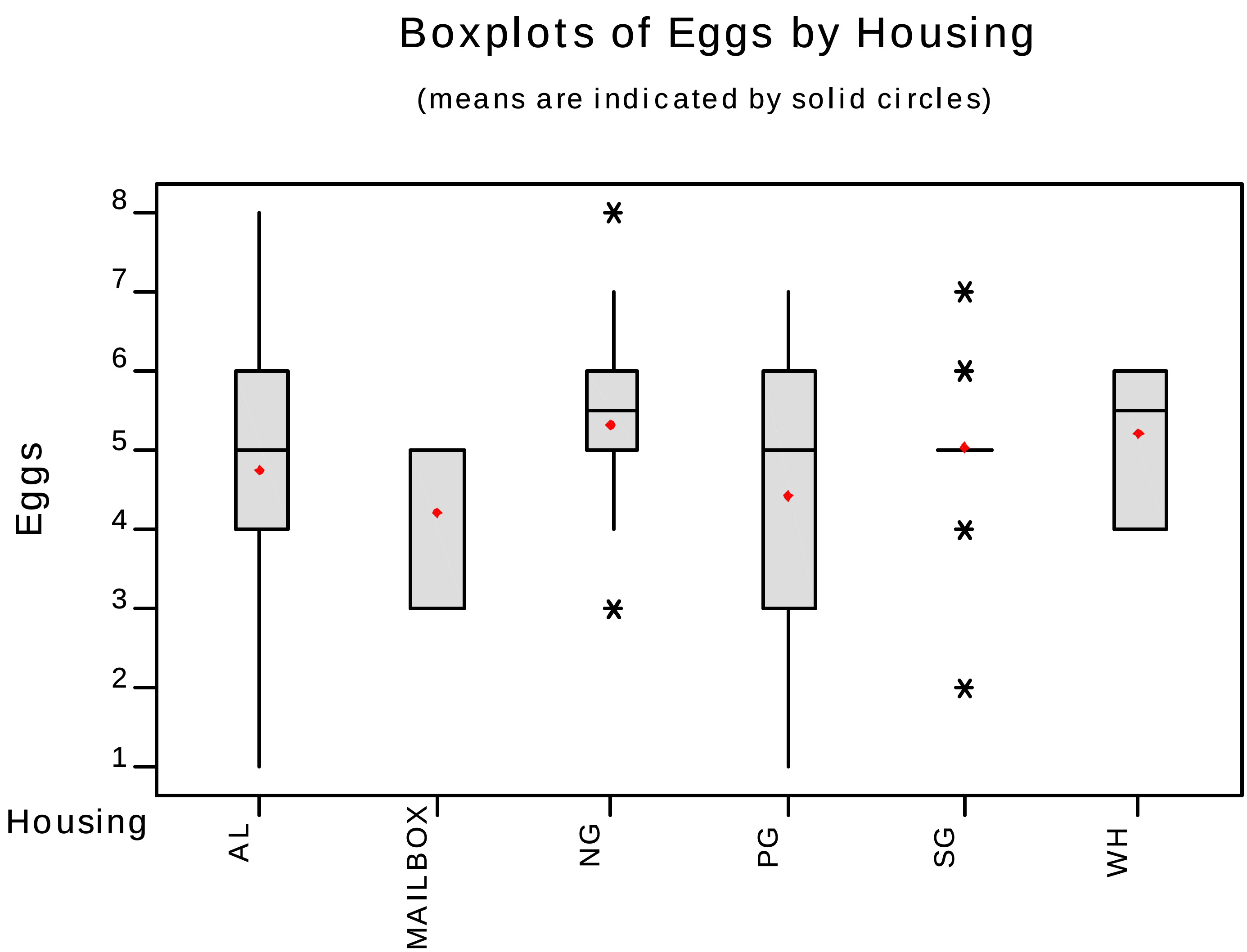


Figure 21. Boxplots of Eggs by Housing

Based on 224 nests, this graph represents the average number of eggs that were laid at each type of housing. The means are indicated by red dots, and astericks represent outliers.

AL=aluminum housing	WH=wooden housing	NG=natural gourd
PG=plastic gourd	SG=SuperGourd	Mailbox=mailbox

Hatchlings

The percent of eggs that hatched was analyzed to determine whether type of housing affected hatchling numbers. Figure 22 shows the percent of eggs that hatched at each type of housing. SuperGourds had the highest percentage of hatchlings at 96.1%, followed by natural gourds with 86.7%, aluminum housing with 86.2%, mailboxes with 85.3%, plastic gourds with 79.3%, and wooden housing with only 75.7% of eggs hatching. There were no differences occurring between the percent of hatchlings at various housing types (p= .193, f=1.49, df=5).

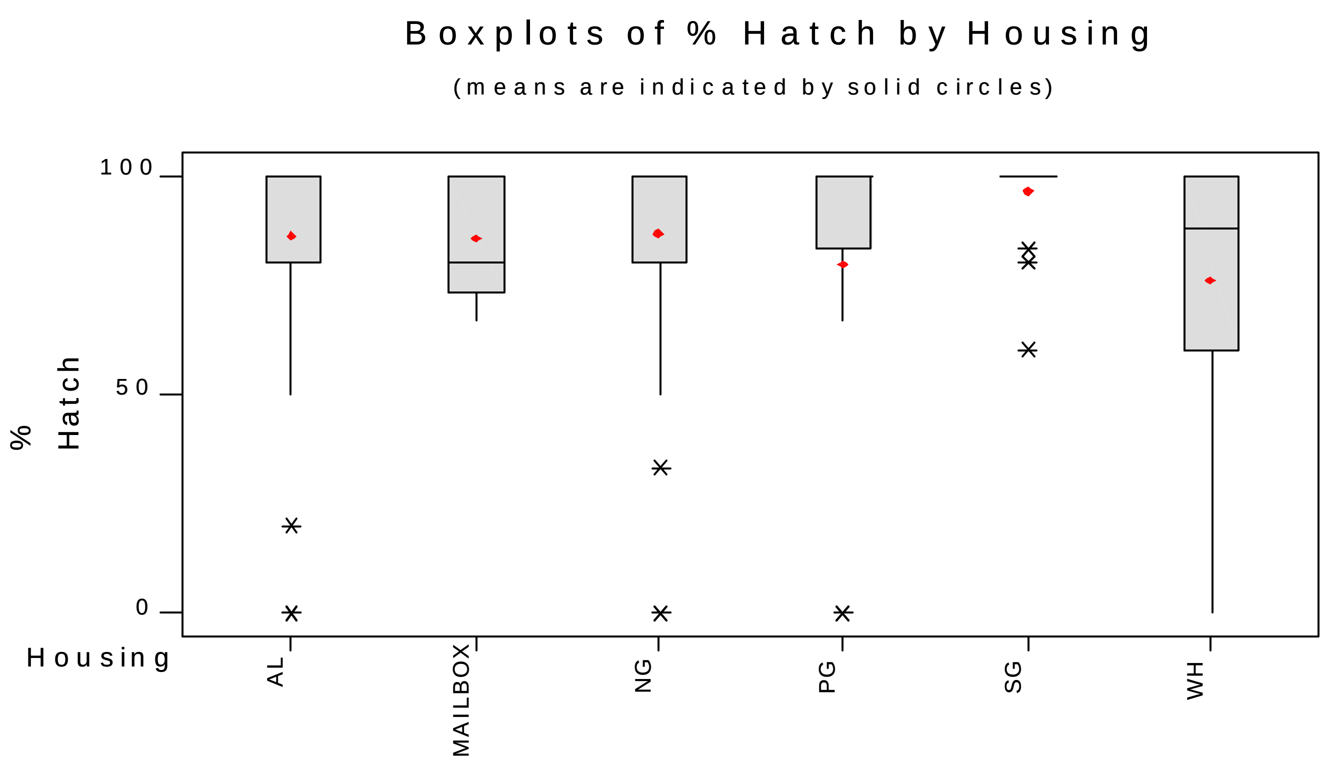


Figure 22. Boxplots of % Hatch by Housing

Based on 224 nests, this graph represents percent of eggs that hatched at each type of housing. The means are indicated by red dots, and asterisks represent data outliers.

AL=aluminum housing WH=wooden housing NG=natural gourd
PG=plastic gourd SG=SuperGourd Mailbox=mailbox

Fledglings

The percent of eggs that led to young that fledged at each housing type was analyzed. There is not a difference in the percent of young that fledge from different types of housing ($p = .061$, $f = 2.15$, $df = 5$). Although the general linear model as well as a one-way ANOVA displayed a p-value of .06, Fisher's pairwise comparisons provide evidence that there may be significant differences between two of the housing types in the percent of young that fledged. There may be significant differences in the percent fledged at aluminum housing compared to wooden housing and at SuperGourds compared to wooden housing. A larger sample size may provide stronger results showing an overall statistical significant difference. The percent of young that fledged from each type of housing is shown in Figure 23. SuperGourds had the highest percentage of young fledge (95.2% ± 1.9%), and wooden housing had the lowest percentage of young fledge (64.5% ± 13.7%). Table 5 displays the average number of eggs laid at each type housing, percent hatched for each type of housing, and percent fledged for each type of housing.

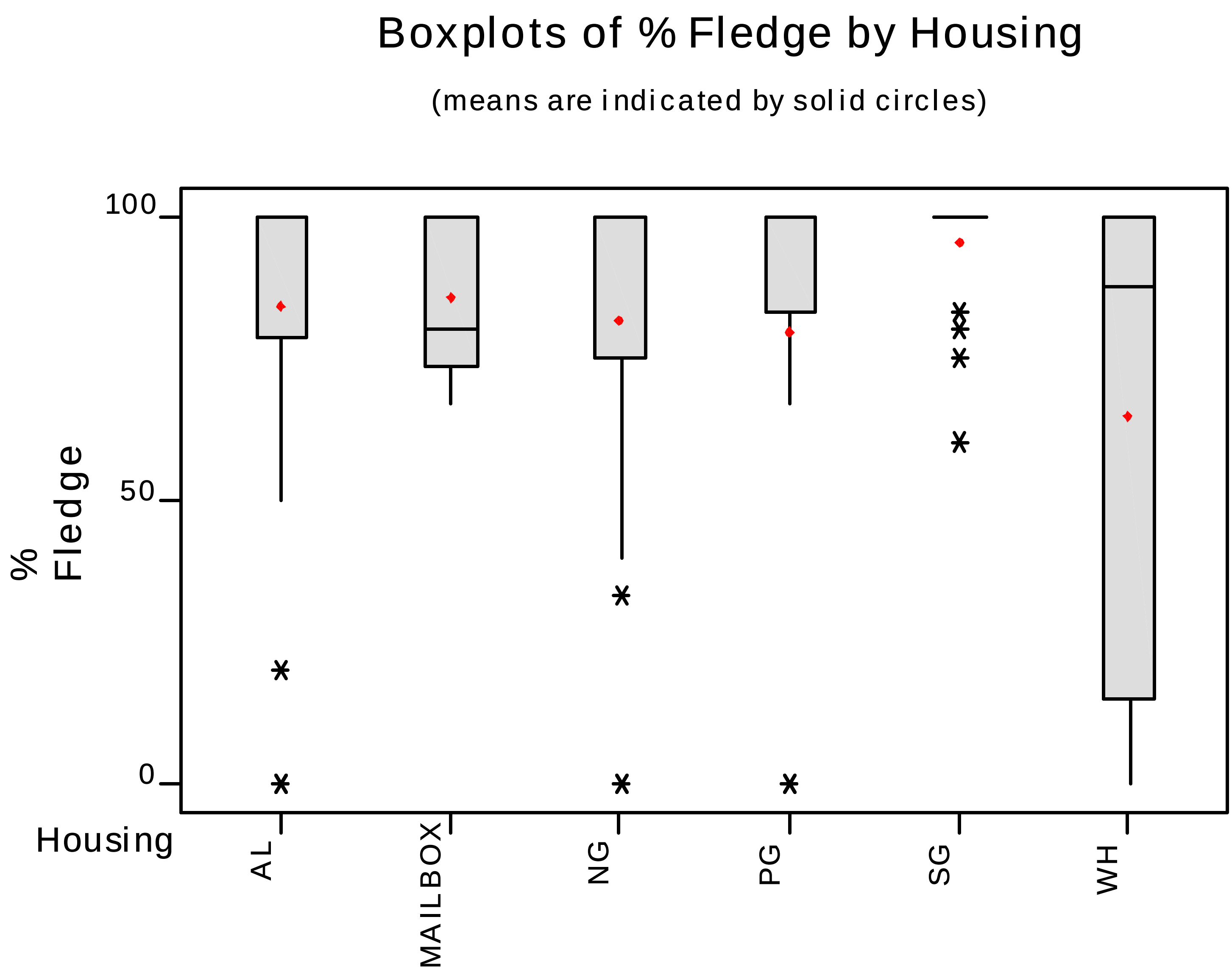


Figure 23. Boxplots of % Fledge by Housing

Based on 224 nests, this graph represents the percentage of eggs that led to young that fledged at each type of housing. The means are indicated by red dots, and asterisks represent data outliers.

AL=aluminum housing	WH=wooden housing	NG=natural gourd
PG=plastic gourd	SG=SuperGourd	Mailbox=mailbox

Table 5. Reproductive Success Based on Housing Type

This table represents 224 nests. The average number of eggs laid at each type of housing, percent of eggs that hatched, and percent of eggs that led to young that fledged are represented in this table.

AL=aluminum housing WH=wooden housing NG=natural gourd
PG=plastic gourd SG=SuperGourd Mailbox=mailbox

	AL	WH	NG	PG	SG	MB
Average number of eggs	4.76±. 14	5.20±. 29	5.32±. 12	4.42±. 35	5.03±. 16	4.20±.49
Percent eggs hatched	86.2	75.7	86.7	79.3	96.1	85.3
Percent eggs fledged	84.0	64.5	81.7	79.3	95.2	85.3

DISCUSSION

CHAPTER 4

Weak Points in Sampling Methods

A few factors concerning sampling methods must be taken into consideration before attempting to draw conclusions from the results obtained. This study was conducted in a single season. A more comprehensive study could have been conducted by taking data over a longer period of time incorporating more breeding seasons. Discarding the 105 nests from Tiptonville was undesirable. Perhaps a larger sample size would have provided a more informative analysis. In the analyses of reproductive success based upon parental age of the birds there was a sample size that was considerably smaller than the others. The sample size of 2 nests for subadult male paired with adult females was still included.

Part One: Reproductive Success Based on Parental Age

Nests

There were 119 nests available for analyses when considering observed parental age. Although past research by Allen and Nice (1952) presents analyses with 29 and 45 nests and Finlay (1971) with 55 nests, it would have been desirable to analyze more than 119 nests in this study. The small sample size (2 nests) of subadult males paired with adult females was also undesirable. However, these were included in analyses because a study by Hill (1997) revealed that 19% of 834 nesting pairs mated nonassortatively. Nonassortative mating was included in analyses for a fair representation of all nesting pairs. Even though the species exhibits positive assortative mating among age classes, nonassortative mating does represent a portion large enough to be biologically important. Most past research (Allen and Nice 1952; Johnston 1964; Lee 1967; Finlay 1971; Brown 1978) only considers assortative mating by adult and subadult age groups. In this study, 84.9% of the breeding pairs mated assortatively by age group and 15.1% were mixed pairs. Hill (1997) showed 81% pairing by age group and 19% mixed age pairs. Similar to other studies (Lee 1967; Finlay 1971; Brown 1978; Hill 1997), it is shown that there are more nests from adult pairs than any other age group. One explanation could be that some yearling birds do not get the opportunity to breed their first year. These young birds may lack social skills that are associated with successfully finding a mate and breeding (Morton and Derrickson 1990). Females are also more likely to select males that have acquired high-quality nest sites as territories (Brown 1997). Yearling birds arrive later in the breeding season, therefore they may not get an opportunity to breed because a large portion of high-quality nest sites that attract female have already been obtained.

Eggs

The mean number of eggs laid in this study, without consideration of parental age, was 4.9± .08. Results closely resemble the mean number of eggs reported by Allen and Nice (1952) of 4.9± .7, Johnston (1964) of 4.2, Finlay (1971) of 4.8± .6 eggs, and Brown (1978) found a mean of 4.6± .7.

Adult females lay more eggs, have a larger number of eggs hatch, and fledge more young than subadult females, regardless of male's age. There was a significant difference in the number of eggs laid when comparing these 2 age groups (Figure 11). Adult females laid 5.23± .11 eggs, and subadult females laid 4.39± .17 eggs. One explanation for smaller clutch sizes of subadult females is lack of physiological maturity. Curio (1983) and Hill (1997) suggest that first-time breeders may be constrained due to lack of breeding skills. Curio (1983) also suggests that subadults may possibly be restrained because reduced reproductive effort in initial breeding seasons increases lifetime reproductive success. Past researchers (Finlay 1971; Hill 1997) proposed that subadults lay fewer eggs because they breed later in the season. Laying a smaller clutch results in saving 1 or 2 days of the time needed for the reproductive cycle. By saving time the subadults are able to fledge their young sooner. This may enable subadults to better prepare their young for the journey south for the winter. A likely explanation for larger clutch sizes in adults is that they are better foragers than subadults (Lack 1968; Hill 1997). Older birds also have better ability to provision food among their nestlings. Subadult females require a greater effort to locate food resources, and thus may not produce as many eggs.

Adult males father more eggs than subadult males. There was a significant difference in the number of eggs fathered by adults versus subadults (Figure 12). Adult males father an average of 5.20 ± .10, whereas subadult males only father an average of 3.95± .22 eggs. Adult males may father significantly more eggs because females make assessments of their mates prior to laying eggs (Hill 1997). The females may take into consideration how well their mate will be able to forage and care for young. The experience that older birds have may make a difference in ability to provision a greater number of young.

Adult pairs laid the most eggs, followed by adult males paired with subadult females, adult females paired with subadult males, and finally subadult pairs. The only pairs that revealed significant differences in the numbers of eggs were adult pairs versus subadult pairs and adult males paired with subadult females versus subadult pairs (Figure 13). The general linear model revealed that it is the age of the male that makes a difference in the number of eggs laid by the female, regardless of her age. This provides additional evidence in support of the hypothesis that females take into consideration how well their mate will contribute to nestling care. Adult males also take part in more extra-pair copulations to increase chances of paternity (Morton et al. 1990). Subadult males' parental efforts are lower than adult males, and smaller numbers of eggs fathered by subadult males are the result. Hill (1997) found similar results with a larger sample size of 834 pairs.

Hatchlings

From the time eggs are laid until they hatch, many factors can affect on hatchling rates. Parental care plays a large role in the percent of eggs from the clutch that hatch. The female is the incubator most of the time, with the male's help when she is out of the nest. He will also sit on the eggs when he is in the nest (McEwen and Hill 1992). Eggs that do not hatch are often sterile, neglected, broken in the nest, chilled after a long spell of adverse weather, or lost to predators.

Results shown in Table 1, which includes all 224 nests, and Table 3 which includes 119 nests according to parental age, reveal that the total percentage of hatchlings is fairly high. Similar results were found in Allen and Nice's (1952) comparison of 3 different colonies. The percent of eggs that hatched was 83.2% in Michigan, 58.2% in Missouri, and 80.0% in Pennsylvania. Brown (1978) and Hill (1997) also report a high percentage of eggs that hatched. In contrast, Lee (1967) states that the most common cause of reproductive failure is the failure of the clutch to hatch. Finlay (1971) also reported that 24% of eggs failed to hatch.

The trend shown in the average number of eggs according to pair differs from the trend of percent of those eggs that hatched. When comparing the number of eggs laid on average by pair, subadult pairs laid the least. Although there were no significant differences when comparing percent of eggs that hatched, subadult pairs had the second highest percentage of eggs hatching, falling second to adult pairs. Adult males paired with subadult females did better than subadult males paired with adult females. The evidence that subadult pairs hatch the second highest percentage of eggs differs from the results shown by Hill (1997). Hill (1997) found that subadult pairs had the fewest number of young hatch of all the 4 pairs.

There was no significant difference in the percent of hatchlings (Figures 15 and 16) when only considering one sex of the pair. This suggests that both ages and sexes are incubating and protecting their eggs almost equally. Although no significance in difference in hatchling percentages occurred, a general linear model analysis including the age of the female, the age of the male, and the age of the pair revealed that the age of the pair was the largest determining factor in hatchling rates. The analysis also revealed that age of the male was a larger determining factor than age of the female in percentages of eggs that hatched. It was expected that the age of the female would be a larger contributing factor to the percent of eggs that hatched. If males are helping incubate when their mate is foraging and not on the nest, this may have a positive effect on the success of the eggs. A superior mate will allow the female to incubate most of the time, only helping when she is off of the nest, but females often have to push their mates off of the nest or nudge under them so they can take care of the eggs (McEwen and Hill 1992). This could also affect the number of eggs that hatch successfully.

Fledglings

The overall percentage of young that fledged was high (Table 1). Considering all birds, regardless of age, 84.9% of the eggs laid led to young that fledged. Table 3, which separates fledgling rates into parental age groups, also exhibits high fledgling percentages. These results compare to 84.3% of young that fledged from Brown's (1978) study, and 70.7% from Finlay's (1971) study. Allen and Nice (1952) found that 31.5% of young fledged in a Michigan study, 50.0% in Missouri, and approximately 61.6% in Pennsylvania. Some possible factors involved in fledgling failure are young that leave the nest too early, young that fall out of the nest, nest abandonment by parents, predators, and weather.

The percentage of fledglings for each pairs follows the same pattern as the percentage of hatchlings. Although differences between pairs were not statistically significant, adults had the largest percentage of their young fledge, followed by subadults, and both mixed pairs did slightly worse (Figure 17). Just as hatchling rates by pair differed from Hill (1997), so do fledgling rates by pair. Hill (1997) found that subadult pairs fledge the lowest percentage of young when compared to the other 3 age pairs. A general linear model that compared age of the female, age of the male, and age of both birds that make up the parental pair to see if there was a difference in contribution to fledge rates among those 3 factors. Although none were significant, the age of both birds in a pair was the largest determining factor of the percent of a clutch that fledged.

When considering the age of the male and the age of the female without their mates, there were no significant differences in fledgling percentages. Subadults fledge percentages were not as high as for adults, but the lack of a significant difference leads to the conclusion that regardless of the difference in effort between the sexes, the analysis was not able to detect it.

An additional consideration is that nest monitoring has also gained popularity over the years. Often when nestlings fall out of nests, landlords replace them. The desire to perform nest checks and provide suitable nesting is a large contributing factor to the currently high fledgling rates of martins at monitored colonies. Each site in this study was properly monitored, which could be a reason for high reproductive success rate.

Part Two: Reproductive Success Based on Housing

Nests

The type of housing, housing location, color of housing, compartment sizes, and protection on the houses from predators is of growing interest in the landlord community. This has stemmed from the declines of Purple Martin populations in the recent past. The Purple Martin's nest selection process is not a hasty one. Both males and females visit many sites prior to settling down (Brown 1997). After they have chosen a nesting site, martins often prefer compartments that are located higher in birdhouses (Morton and Derrickson 1990). This is important to escape predation, especially from climbing predators. Females that are unpaired while choosing a nesting site will look for cues from unpaired males in their assessment of colonies. Purple Martins also prefer light colored housing, and houses that are mostly white have the highest occupancy rate (Perry and Bloch 1987). Location is an important factor when erecting a Purple Martin colony, and having the colony in an open area is important when trying to attract martins (Jackson and Tate 1974; Perry and Bloch 1987; Hill and Wade 1990). Nest compartment size has also been debated, and there is evidence that the larger the nest compartment dimensions the better the martins reproduce. Proper colony monitoring is also an extremely important element in success rates.

When considering the Purple Martin's preference in housing, it would be desirable to obtain equal sample sizes of different types of housing for an accurate account of true preference. The percentages of occupancy in the different types of housing can be observed to get an idea of what housing martins prefer. Although without statistical evidence, SuperGourds had the highest occupancy rate. They have large compartments, which may be attractive to the birds. The housing type with the second highest occupancy was the natural gourd. The high level of occupancy in natural gourds was not surprising because (Hill 1999) provided strong results and evidence that martins reproduce at their highest levels in gourds. The percentage of occupancy for wooden housing was lowest of all 6 housing types compared. Brown (1981) revealed that Purple Martins are highly successful in wooden houses, and Jackson and Tate (1974) found that 44.1% of occupied martin housing was in wooden compartments. The results in this study were considerably lower. The type of housing the Purple Martin prefers may be based on the type of housing they imprinted upon as young. It may also be possible that birds make an assessment of housing conditions, such as size, available resources, or if the colony is near water.

Eggs

Conclusions can be drawn concerning the number of eggs that were laid in each type of housing by assessing general housing recommendations for landlords. The most eggs were laid in natural gourds, and the least eggs were laid in mailbox housing. Aside from parental age and their ability to provision young, the type of housing is also a determining factor in clutch size. Natural gourds had an average clutch size of 5.32± .12, and this could be the result of larger floor areas for eggs. Diameters of natural gourds in this study range from 8 inches to 12 inches. Hill (1999) provides evidence that females increase clutch size significantly when eggs are laid in nesting compartments larger than 6X6X6. In Hill's (1999) studies, he found that 6 and 7 egg clutches were more likely to take place in natural gourds than in aluminum or wooden housing.

There were significant differences in average clutch size when comparing natural gourds to aluminum housing and comparing natural gourds to plastic gourds. The plastic gourds in this study had diameters of 6 inches, and the majority of aluminum housing had 6X6X6 compartments. This also supports the conclusion that larger clutch sizes prevail in larger compartments.

Hatchlings

Considering the percentage of eggs that hatch, one must take into consideration many relevant factors exist from the time the eggs are laid until they hatch. Incubation may last from 12-20 days (Bent 1942), but usually lasts from 15-18 days (Allen and Nice 1952; Finlay 1971). Different types of housing provide an array of advantages and disadvantages. These differences may affect the percent of the clutch that hatches. Aside from parental care, location, and predation; weather greatly affects hatchling rates in different housing types. Because weather conditions have an effect on the hatching success rates of the Purple Martin, insulation of the housing is also an important factor (Hill 1999). Natural gourds and wooden housing are good insulators, whereas metal compartments are conductors of both heat and cold. All variations of gourds keep eggs drier than other types of housing (Hill 1998). If eggs get wet and chilled, they may not hatch. Wooden houses also stay dry during wet weather, and it has been documented that aluminum housing becomes nearly saturated with water after strong rains (Hill 1999). Hatchling rates suffer in aluminum housing because of their shallow 6X6X6 compartments. Brown (1978) revealed that when parents are leaving the nest, they are likely to brush out one of their eggs in the aluminum compartments. Shallow compartments also make the nest easily accessible to predation as well as nest site competitors that may steal or knock out eggs. Natural gourds, plastic gourds, and SuperGourds prevent predation and nest-site competitors from entering because they swing in the wind, and visitors have trouble landing on them (Hill and Wade 1990).

Even though there were no statistical differences in any comparisons, SuperGourds had the highest hatchling rates followed by natural gourds. Aluminum housing had 86.2% of eggs hatch and mailbox housing had 85.3% of eggs hatch. Hill (1999) states that Purple Martins had an average of 1.22 more eggs hatch in natural gourds than in aluminum housing. When Hill (1999) compared wooden housing to natural gourds and aluminum housing, he found that wooden housing did second best in the number of eggs that hatched. Contrary to those results, wooden housing in this study did considerably worse than aluminum housing and natural gourds, with only 75.7% of the $5.20 \pm .29$ eggs hatching. The number of eggs laid in wooden housing was second highest, but the percentage of hatchlings in wooden housing was the lowest. This indicates that a large number of eggs in wooden housing were not successfully hatching. One contributing factor could be that the sample size of 10 nests in wooden housing is extremely small. A larger sample size may have increased hatchling percentages. Other types of housing do not display such dramatic drops in the number of eggs that hatched from the ones that were originally laid (Table 5). There were not significant differences in the number of eggs that hatched when comparing any of the housing types.

<u>Fledglings</u>

Many of the same factors that affect the hatchling rates also affect the percent of eggs that successfully fledge from the nest. A successful fledgling is one that does not disappear or leave the nest earlier than 24 days of age Hill (1999). Parental care, predation, and proper monitoring are important elements, but housing type introduces additional elements affecting success. Effective housing insulation during bad weather is as important in fledgling success rates as in egg and hatchling success. Gourds and wooden housing stay warm during cold spells and cool when it is hot outside. The nestlings may become stressed in smaller nesting compartments during periods of hot weather and die from hyperthermia (Van Balen 1984; Hill and Wade 1990). Houses with smaller compartment sizes often have lower fledgling rates because of overcrowding, where nestlings may get pushed out of the nest early (Allen and Nice 1952; Brown 1978; Perry and Bloch 1987; Hill 1999). Before the young fledge, they often sit on the porches of houses (Brown 1978). In houses with porches, older nestlings will often wander out of compartments and fall or occasionally get lost. This may result in starvation, consequently lowering reproductive success in housing types with porches. Nest predation is also increased in houses that have porches but not predator guards. Natural gourds, plastic gourds, and SuperGourds do not have porches that welcome predators or that nestlings can fall from. Diseases and parasites are more likely to spread in aluminum and wooden houses with compartments close to each another (Hill 1999). Gourds provide nesting in a less crowded arrangement, and this may contribute to the high fledgling rates in gourds. Although there are advantages to gourds, and their high fledgling rates are evident, they do suffer from storm damage (Hill and Wade 1990). This causes mortality among nestlings as well as adult Purple Martins.

The percentage of eggs that fledge according to housing type does not differ greatly from percentages found in previous studies (Brown 1978, Perry and Bloch 1987, Hill 1999). Table 5 displays fledgling percentages for the 6 different types of housing. Differing from past studies, it was determined in this study that the percent of eggs that fledge from wooden housing was notably lower. Hill (1999) found that natural gourds had the highest fledge rates with 62.6%, followed by wooden houses with 58.2%, and aluminum houses with 42.6%. Brown (1981) compared aluminum housing to wooden housing and found that 85.67% of eggs led to fledged young in wooden housing and 82.25% of eggs led to fledged young in aluminum housing. In this study, aluminum housing, natural gourds, SuperGourds, and the mailbox housing all fledged over 80% of the young in the housing. Housing types that have larger clutch sizes still fledge about the same percent of young than housing types with small clutches. Natural gourds, which had the largest average clutch size of 5.32± .12, fledged fewer young than 3 of the other 5 housing types with smaller clutch sizes. Parents with small clutches may take exceptionally good care of their clutch and hatchlings to assure the highest reproductive rates possible. A large clutch that loses nestlings could be attributed to the overcrowding that can occur in nests with many young. Birds with a larger clutch to feed may have trouble provisioning food equally to the young, and the weaker nestlings that do not get enough food die.

Conclusions

The Purple Martin's reproductive success and its breeding habits are of great interest to landlords and researchers. This bird depends on humans for nesting; therefore, scientific studies providing information concerning reproductive success by age group and housing will continue to be important. The Purple Martin nests colonially because it does not have a choice. Nest-site competitors and the lack of natural nesting sites make human intervention essential. Further study on nonassortative mating may provide new insight into the consequences of this behavior. It is suggested in this study that mating assortatively by age is beneficial. Although there were no significant differences, birds paired with others of the same age fledged a higher percentage of young than those that did not pair with a bird of the same age.

Landlords and the manufacturers of martin housing need to follow current research to determine what type of housing is most beneficial. Previous studies (Brown 1978; Hill 1999) also show that housing types that are most used by landlords, such as aluminum housing and wooden housing, are not the most beneficial to the martins. The reproductive success in SuperGourds was superior to the other types of housing. Based on these results, it is suggested that a large area for nesting, predation deterrence by the swinging motion, and favorable insulation may make reproductive success in the SuperGourd superior to other housing types. Unquestionably, proper colony monitoring is one of the greatest factors in the reproductive success of the Purple Martin.

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