Fall 2007

Reproductive Success of Southeastern American Kestrels (Falco Sparverius Paulus) Nesting in 230Kv Transmission Towers and Alternative Nest Structures in South-Central Georgia

Hope Alyce Beasley

REPRODUCTIVE SUCCESS OF SOUTHEASTERN AMERICAN KESTRELS (*Falco sparverius paulus*) NESTING IN 230kV TRANSMISSION TOWERS AND ALTERNATIVE NEST STRUCTURES IN SOUTH-CENTRAL GEORGIA

by

HOPE A. BEASLEY

(Under the Direction of John W. Parrish)

ABSTRACT

This research involved a survey of the distribution and reproductive biology of the threatened southeastern subspecies of the American Kestrel (*Falco sparverius paulus*). Numbers of Southeastern American Kestrels are estimated to have declined by more than 80% over the last fifty years in the southeastern United States. In Georgia, populations have nearly disappeared below the Fall Line. The paucity of adequate nest sites is the major factor contributing to the decline of this obligate secondary cavity nester. The largest breeding population of this subspecies in Georgia is located in the south-central part of the state in the hollow cross-arms of a 230kV transmission line extending from the Offerman substation (Pierce County) in the east, to Plant Mitchell (Putney, Dougherty County, GA) in the west. Current data show this kestrel population remains stable in spite of high electromagnetic fields. Of the 373 usable transmission towers, 284 (76%) were used by breeding kestrel pairs in 2005 and 2006. The majority of the sites used for breeding occurred along the middle transect of the line where it is paralleled by an additional transmission line lacking hollow cross-arms. The study also indicated that kestrels will utilize human-made, alternative nest sites. Four of 17 (24%) and three of 17 (18%) PVC-tubes and nest boxes were used by kestrels in 2005 and 2006, respectively.

Additional data from a transmission line in central Georgia (near Butler, Taylor County, GA) support this finding by showing kestrel use of nest boxes placed on replacement towers lacking potential nest sites that were erected once the hollow cross-armed transmission towers were removed. Overall, this research continues the collection of data on *F.s. paulus* in Georgia, providing essential demographic and reproduction data of this subspecies of concern in Georgia.

INDEX WORDS: Southeastern American Kestrel, American Kestrel, *F.s paulus*, Electrical Transmission Towers, Reproduction, Demographics, Nesting, High Electromagnetic Field, Alternative Nest Structures, Nest Boxes

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HOPE A BEASLEY

B.S., Georgia Southern University, 2004

A Thesis Submitted to the Graduate Faculty of Georgia Southern University in Partial Fulfillment of the Requirements of the Degree

MASTER OF SCIENCE

STATESBORO, GEORGIA

2007

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HOPE A. BEASLEY

Major Professor: John W. Parrish

Committee: William S. Irby
Lance A. Durden

Electronic Version Approved:
December 2007

DEDICATION

I would like to dedicate this thesis to my two daughters C. Sky Beasley and J. Alyse Beasley. They are my pride and joy, the reason that I keep reaching for the stars. I can only hope to provide a good example for them. Also, I write this thesis in recognition of my parents, Walker and Teresa McLendon. Without their support and encouragement I would not have made it this far. They have been the motivation through my whole collegiate career and continue to encourage me to obtain and ultimately surpass my goals.

ACKNOWLEDGMENT

I would like to show my gratitude to Dr. John W. Parrish for his assistance in my data collection and analysis. His enthusiasm in his work has been an inspiration to me. His love of birds has inspired me to look beyond the obvious, at all the wonderful wildlife that can be found hidden anywhere and everywhere. Also, thanks to my committee members, Dr. William S. Irby and Dr. Lance A. Durden, for their suggestions on my thesis. I cannot find the words to express my appreciation of my family for their assistance and support during my data collection. Of course, I want to thank Jonathon Stober for collecting the data along the Butler line and Pam Maney for providing her data from 2003 and 2004 of the south-central Georgia population. I would also like to recognize Dr. C. Ray Chandler for his assistance with analyzing my data statistically. Finally, many thanks go to Georgia Power Co., Avian Power Line Interaction Committee, Georgia Department of Natural Resources, the Municipal Energy Authority of Georgia, and the GSU Research Committee for funding my research.

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CHAPTER 1

INTRODUCTION

Study Species

The American Kestrel (*Falco sparverius*) belongs in the avian family Falconidae and the order Falconiformes. It is the smallest falcon in North America and one of the smallest in the world, second in size only to the Seychelles Kestrel (*Falco araea*) (University of Minnesota 2004). At 19-21 cm in length, with an average wingspan of 50-60 cm, this raptor is approximately the size of a jay. Although the two sexes of the American Kestrel are sexually dimorphic, both have a rufous, or rusty-colored, back and tail along with a mustached black-and-white face pattern. Males of this species are distinguished by having a blue head with a rusty cap and blue-gray wings. The average male weighs 103 to 120 grams. Females, on average, weigh 126 to 166 grams and are not as brightly colored, with a more rusty brown color throughout their body (McCollough 2001, Peterson 1980).

The diet of an American Kestrels consists of a wide range of vertebrates and invertebrates. Their prey includes other small birds, rodents, lizards, large insects, and earthworms. Such a large selection of potential prey allows the kestrels to live in many types of environments. They are found mostly in open, rural areas, but have also been observed living in large, bustling cities that have spacious city parks nearby. However, dense woodlands are not a prime habitat for these open country birds. They require large open areas to fly over or perch near while hunting for their prey (Village 1990). This is supported by higher numbers of kestrels observed nesting in transmission towers of a power line in South-Central Georgia that ran parallel to a second power line doubling the clear-cut rights-of-way under the lines compared to that of the single line (Maney 2006, Maney and Parrish 2007).

During the nesting season, kestrels tend to be highly territorial. The monogamous breeding pairs typically require a separation of varying distances from other kestrel pairs but will occasionally breed in small colonies (Village 1990). Before a female settles with one mate she will copulate with two or three males, if available. When she finally makes her choice and until the eggs are laid, the pair will copulate frequently (McCollough 2001). An average egg is 35 mm x 29 mm, lightly streaked, and can be white, cream, or pale brown. The female kestrel will lay three to seven eggs at one time (University of Minnesota 2004), and she is the primary incubator. However, the male will feed her and occasionally relieve her of her duties. The incubation period lasts for approximately 30 days after which the chicks hatch. For the first 20 days of life, the female feeds the hatchlings. They then have to beg for food from the male and feed themselves (McCollough 2001). After two and a half weeks the young reach adult weight and will fledge from the nest about 30 days after hatching (Breen and Parrish 1997, Shuford 1997, University of Minnesota 2004). Under natural conditions the chicks have about a 50% chance of surviving. However, nest boxes built by humans provide better conditions, and in turn, increase survival rate (McCullough 2001). If the first attempt to nest fails, the breeding pair will try to re-nest. In some southern states, with the right conditions, kestrel pairs are able to raise two broods a year (Breen and Parrish 1996, University of Minnesota 2004).

There are 17 subspecies of the American Kestrel, and only two of these are found in the Southeastern United States (White 1994). *F. sparverius sparverius*, the northern subspecies, is a migrant and winter resident of the Coastal Plain and Piedmont regions of Georgia and nests in the Cumberland Plateau region (Burleigh 1958, Parrish *et al.* 2006). The Southeastern American Kestrel, *F. sparverius paulus*, is non-migratory and a permanent resident of South Carolina, Georgia, Florida, Alabama, and Louisiana (Chapman 1928, Smallwood and Bird 2002). It can be found breeding in generally small areas throughout the Piedmont and Coastal Plain of Georgia (Burleigh 1958, Breen and Parrish 1997, Snow and Parrish 2002, Parrish *et al.* 2006).

American Kestrels are obligate secondary cavity nesters, depending upon natural cavities or on other animals as a source of nest cavities. Therefore, the requirements for successful breeding of this species are a cavity in a tree or other structure large enough for a nest, adequate numbers of prey, and an open habitat for hunting (Johnsgard 1990). For the past four decades the Breeding Bird Survey (BBS) data have recorded consistently low numbers of kestrels in Georgia (Fuller *et al.* 1987, Price *et al.* 1995). Loss of suitable nesting habitat and the paucity of nest sites are the major factors limiting the reproductive success of Southeastern American Kestrels in Georgia, South Carolina, and parts of Florida (Hoffman 1983, Stys 1993). Gault *et al.* (2004) discovered that the combination of the loss of longleaf pine (*Pinus palulstris*) habitat through development, degradation of the remaining habitat due to fire suppression, removal of old growth trees and snags, and the decline of the Red-cockaded Woodpecker (*Picoides borealis*), a primary cavity nester, may have had detrimental effects on the population of this subspecies of kestrel in Florida. The decline in numbers in the Southeast has resulted in the Southeastern Kestrel being listed as a threatened subspecies in Florida in 1978 (Stys 1993) and more recently in Georgia by the Georgia Department of Natural Resources.

230 kV Electrical Transmission Towers in South-Central Georgia

American Kestrels will readily nest in man-made structures. Evidence of this fact is shown by the success of nest box programs throughout the Southeast (Smallwood and Callopy 1991, Breen and Parrish 1997, Boyd *et al.* 2003). However, nest boxes are not the only human-provided cavities that kestrels utilize. Snow and Parrish (2002) discovered a significant kestrel population nesting in the hollow, tubular cross-arms of 230 kV electrical transmission towers of a power line in South-Central Georgia running between Pierce County in the east and Dougherty County in the west. Based on the paucity of kestrel reports from the BBS in recent years (Sauer *et al.* 2006) (Figure 1), this line of transmission towers is maintaining the largest known breeding population of kestrels, more than 250 documented nesting pairs (Maney 2006, Maney and Parrish 2007), in not only Georgia, but possibly in all of the Southeastern United States, with the exception of Florida. These towers, however, have been in place for more than 50 years. Some have already been removed because of rusting and have been replaced with non-tubular lattice cross-arms, which do not provide a potential nesting site. Maney (2006) observed that a pair of kestrels nested in a tubular PVC nest site, placed on a transmission tower that had its tubular cross-arms removed because of construction of a nearby power substation. More of these alternative nest sites have been erected since Maney (2006) concluded her survey in 2004.

A similar line also has been discovered in Taylor County, Georgia, near the town of Butler. It also had the tubular cross-arm towers, but many of those towers were replaced before a survey was made of the kestrel population. In the hope that there would not be a loss in population numbers, several wooden nest boxes were placed on the section of the line where the towers were taken down. Between breeding seasons, more boxes were added.

Power lines emit high electromagnetic fields (EMFs). Since many birds utilize power lines for perching, hunting, and nesting, they are regularly exposed to those fields. Fernie and Bird (2000) estimated that wild kestrels, on a 24-hour basis, were exposed to EMFs from 71% of the day during courtship to 90% of the day during incubation. It has been shown that in American Kestrels, these high EMFs affect melatonin levels of captive adults and fledglings (Fernie and Bird 1999a), body mass of the males (Fernie and Bird 1999b), adult behavior during breeding season (Fernie and Bird 2001), and reproductive success (Fernie and Bird 2000).

<u>Objectives</u>

The purpose of the present study was: 1) to collect demographic data on the population of kestrels in South-Central Georgia, 2) to document the use of alternative nest sites, 3) to estimate the effects of high EMFs on the reproductive success of this population of kestrels, and 4) to provide demographic data of the kestrel population utilizing nest boxes in Taylor County. The transmission towers in South-Central Georgia, including alternative nest sites, were monitored to document the extent of use by breeding pairs, supplementing a decade of demographic data on populations of *F. s. paulus* in Southeastern Georgia. Three types of alternative structures were established and monitored for kestrel use to determine the most suitable type of structure to use after replacement of the tubular, cross-armed towers. The nest boxes placed on the line of the newly discovered population of kestrels in Taylor County, Georgia, were inspected for egg and hatchling numbers. This research should demonstrate the ability of these unique, hollow cross-armed power lines to support sizeable kestrel populations despite their production of high EMFs, and the benefit of alternative nest sites as a substitute for the hollow cross-armed transmission towers when they are replaced.

CHAPTER 2

MATERIALS AND METHODS

Study Site

The study site consists of a 230kV power line that runs about 80 km from Offerman, in Pierce County, to Plant Mitchell near Putney in Dougherty County (Figure 2). The kestrels nest in the unique H-shaped transmission towers, which possess tubular cross-arms that are more than 30 m high (Figure 3). These cross-arms are around 12 m long and have an opening diameter of approximately 15.2 cm that expands to about 25 cm in the middle (Figure 3). There are approximately five transmission towers per kilometer, making the towers approximately 0.2 km apart.

These large 230kV power lines provide substantial areas underneath the line that are mowed every six years, called rights-of-ways (ROW). At both the eastern and western ends, the power line is a single 230kV line for about 15 km. Under this single line, the ROW is only about 30 m. The middle section (about 50 km) contains not only the line with tubular cross-arms, but also a second, parallel line that does not contain transmission towers with the tubular structures. This creates a wider ROW of 60 m and provides substantial numbers of additional poles for perching while prey-hunting by the kestrels.

Of the 471 towers along this transmission line, 373 possess tubular structures that permit kestrel use for nesting. The remaining towers are lattice-framed structures that contain no cavities for nesting birds (Figure 4). Only 66 of the 93 towers on the eastern end of the single line and 82 of the 94 towers on the western end provide nesting cavities for the kestrels. Nest site usage in the middle section is restricted to 220 usable poles out of 284. Only 80% of all the transmission towers possess tubular cross-armed structures.

There are a total of 334 electrical transmission towers between Offerman and Alma (334E – 1E) and 137 towers from Tifton to Plant Mitchell, in Putney (137W – 1W).

The second study site consists of a single line of a similar set of tubular, cross-armed towers that extend about 55 km from the Warner Robins (Houston Co.) power substation, westward to Butler (Taylor Co.), Georgia (Figure 5). Prior to the spring of 2004, the towers extended farther west to Talbotton (Talbot Co.), Georgia (about 28 km), but those tubular, cross-armed towers were removed that spring and replaced with towers that cannot be used as nest sites for kestrels. In mid-March, 2004, nest boxes were placed at 4.5 m above the ground on six of the new replacement towers in the vicinity of the Butler power substation (about 5 km west of Butler). An additional nest box also was available, which had gone unused for over a decade. It had been placed near that substation in 1993. Another 15 nest boxes were subsequently placed on the Butler-line replacement towers in the same vicinity in 2005. All nest boxes were lined with several cm of pine straw, or wood chips, to facilitate use of the nest boxes by nearby kestrels.

<u>Alternative Nest Site Structures</u>

In July of 2003, the tubular cross-arms on transmission tower number 87E in Irwin County near Ocilla, Georgia, were removed due to construction requirements by the electrical company that maintains the lines. In previous years, a pair of kestrels successfully nested at this site. To make up for this nest site loss, a tubular PVC nest site was constructed and placed at the top of pole number 87E after the kestrels fledged their young. The alternative nest site was made of UV-resistant PVC 30 cm in diameter, cut to 91 cm long (Figure 6A). Caps were placed on both ends with one end containing a 7.6 cm hole for nest access. To enhance kestrel use in subsequent breeding seasons, a several cm thick layer of pine straw was placed in the bottom of the PVC tube. In the spring of 2004, a similar sized PVC tube was mounted on pole number 111E, which is a lattice-framed tower.

Six PVC tubes were placed on various transmission towers lacking tubular cross-arms during the early spring of 2005. Three of the alternative nest sites were constructed with a vertical axis (Figure 6B), whereas the remaining three were constructed in the original design of the horizontal axis (Figure 6A). These were positioned at a height of about 4.5 m, adding to nine nest boxes already in place at that height, to investigate possible use by kestrels in the following years and allow future hatchlings to be banded.

Data Collection

Each transmission tower was visited at least once each month during the breeding season from March to August of 2005 and 2006. In April, May, and June of 2006, visits were made twice a month. The towers were observed using either a 30X, 60mm or 15-30X, 50mm spotting scope. Transmission towers where kestrels were sighted were used to determine the nesting locations. A record was kept for each visit on the sex of each kestrel along with the total number of individuals observed perched on or near a transmission tower. Notes were made indicating when adult kestrels were seen copulating, when males were seen carrying food to females, when adults were observed entering the ends of the tubular cross-arms with food for hatchlings, and when after-hatching year (AHY) juveniles were observed near the towers after fledging. The amount of time at each observation point ranged from 20 to 30 minutes, depending on the amount of kestrel activity.

Statistical Analyses

Statistical analyses were completed using JMP IN 5.1 (SAS Institute Inc. 2003). A G-test was used to compare the use of the single transmission power line with that of towers running parallel to a second line. To analyze the difference in the numbers of males and females throughout the year, an analysis of covariance (ANCOVA) was completed. If a probability (*P*) value of 0.05 or less was obtained, the result was considered significant.

CHAPTER 3

RESULTS

Nesting Activity in Transmission Towers

In both 2005 and 2006, kestrels were seen utilizing 284 of the 471 (60%) tubular, cross-armed, potential nesting sites (Table 1). Records indicated that, in 2003 and 2004, kestrels were observed more than once nesting in 274 poles and 296 poles, respectively. The lowest use of the towers occurred at the eastern end, between Offerman and Alma, along the solitary line, where an average of 41 (61%) of the usable towers had nesting kestrels during the study. A similar situation transpired at the solitary line on the western end, between Sumner and Putney, where kestrels were observed nesting in 56 (68%) of the usable towers. The area of highest usage for nest sites by the kestrels occurred along the middle portion ($3/5^{ths}$) of the transect, where the tubular, cross-armed line is paralleled by a second, non-tubular line. The eastern end of this portion, from Alma to Tifton, consisted of 185 possible nest sites, and throughout the study, kestrels were observed at an average of 149 (81%) of these towers. Although only 38 towers were used by kestrels along the western end of the middle transect, between Tifton and Sumner, that total represented all (100%) of the usable tubular, cross-armed transmission towers in each of the four years of the study (Table 1).

Kestrel use of the single-line poles was significantly lower than that of the double line in all four years of data collection (in 2003: G=27.8, d.f.=1, $P<0.0001$; in 2004: G=21.8, d.f.=1, $P<0.0001$; in 2005: G=20.1, d.f.=1, $P<0.0001$; in 2006: G=6.31, d.f.=1, $P=0.012$) (Figure 7). The single-line of poles located along the eastern and western ends of the transect was the location of the majority of transmission towers that were used less frequently, or not at all (Appendix 1). Throughout the four-year study, only 28 (7%) of the 389 potential nest sites (a tower with hollow cross-arms, a nest box, or a PVC tube) were never used as nest sites by Southeastern American Kestrels. Kestrels pairs did utilized 169 (44%) of the towers all four of the years, 94 (24%) were used three of the years, 59 (15%) were used only two years, and 39 (10%) were used by at least once (Figure 8).

The average number of female kestrels observed during the study was significantly higher than the average number of males (F=9.78, d.f.=1,5, P=0.0122). However, as the year proceeded the averages of both sexes dropped at the same rate (F=0.138, d.f.=1,5, P=0.7202). In the month of April, sightings of male kestrels increased, while that of females decreased, but throughout the remainder of the year females were observed near the nest sites more often (Figure 9).

Nesting Activity in Alternative Nest Sites

The horizontal, 30m-high PVC-tube on towers 87E and 111E were used by kestrels as nesting sites each of the years they were available. In 2005, a kestrel pair nested in the horizontal, 4.5m PVC-tube on pole 137W. Wooden nest boxes were utilized by the kestrels in 2005 on a telephone pole near McCarthen Lane (near tower 14W) and in 2006 on tower 134W (Appendix 1). Several of the PVC and wood nest boxes were used by passerine cavity-nesters. Of the total alternative nest sites, kestrels nested in 1/10 (10%) in 2004, 4/17 (24%) in 2005, and 3/17 (18%) in 2006 (Table 2).

In Taylor County, GA in 2004, of the eight wooden nest boxes available, seven had a successful nesting season with three to five chicks per nest. Eight more boxes were placed on poles in that area before the breeding season in 2005, for a total of 16 boxes.

Kestrels nested in nine of the boxes that year. By 2006, twenty boxes were available, but only ten were utilized by nesting kestrel pairs (Table 3). Each of those nests had three to five eggs, except one that only had one egg.

Numbers of Hatching Year Kestrels

Surveys conducted after the young fledged in July and August provided frequent sightings of immature (HY) kestrels. Thirty-nine HY male and 48 HY female Southeastern American Kestrels were observed, at 43 different transmission towers in 2006, often accompanied by adults perched on the power lines or in trees adjacent to the towers. Not surprisingly, those immature kestrels occupied the areas near transmission towers documented to have nesting kestrels earlier in the year.

CHAPTER 4

DISCUSSION

The present study, along with previous data presented by Maney (2006) and Parrish (2007), clearly confirmed that the transect of power lines between Offerman, Georgia and Putney, Georgia houses the largest population of breeding kestrels in the entire state of Georgia. The number of kestrel nests occurred at an average of 284 (60%) of the poles with the hollow, tubular cross-arms, throughout the four years of data collection from 2003 to 2006 (Table 1). In contrast, there were no more that about three dozen pairs of kestrels nesting in more than 350 established nest boxes across other areas of the southern Coastal Plain of Georgia (Parrish 2007).

Data analysis indicated that nesting activity was lowest along the eastern and western ends of the transect, where the power lines ran in a solitary line through the middle of pine forests and near human habitation, which is less desirable kestrel habitat. The solitary line provides a ROW of only about 30 m in width. Consequently, there likely is not enough hunting space to provide adequate prey items for the kestrels along this portion of the line. Even though 67% of the towers along this transect did support a pair of breeding kestrels sometime during the four-years of study, most of those towers were found in areas of open pastures or farmlands. Successful kestrel nesting significantly increased to more than 90% of the usable poles once the tubular, cross-armed line joined with a second, parallel electrical transmission line that did not provide additional nesting sites, but did provide the kestrels with a large number of additional perching sites for hunting. This non-tubular parallel line, however, increased the width of the ROW to approximately 60 m, giving the kestrels a much larger space to hunt and perch.

More females were observed at the beginning of the nesting season, presumably because they were the ones to make the final choice for nest location and to protect the nesting sites at the transmission towers, while the males hunted for food to maintain pair bonds with the females (Figure 9). As the breeding season proceeded, females retreated to the nests for the requisite 30-day incubation period. Males were still observed providing food for the females during the incubation period, and were often seen perched on the power lines near the nest. As the hatchlings started to emerge, both male and female kestrels provided the food for the HY birds. However, since males more commonly hunt vertebrate prey to feed the hatchlings (Parrish, unpublished), males were not seen as frequently near the nest sites as the females after the young fledged.

The condition of the tubular transmission towers is rapidly deteriorating because they have been in place for more than a half-century. As expected, without knowledge of the importance of these transmission towers to kestrels in Georgia, and because they have rusted beyond repair, some of the hollow cross-arms have been replaced with non-tubular structures with no potential nest site. The option of placing an alternative nest site at a non-tubular replacement tower is rectifying this situation. The PVC-tubes placed at 80 m high on poles 87E and 111E (Figure 6A) were used by kestrels each year since their installation (Table 2). However, most of the other variously-shaped PVC-tubes were not used for nesting with the exception of the 4.5m-high PVC-tube placed with a horizontal axis on tower 137W, which was used in 2005, and a vertical, 4.5m-high PVC-tube placed on pole 121W, that was used in 2007 (Parrish 2007). Unfortunately, kestrel use of the wooden nest boxes placed on some of the non-tubular towers along the transmission line was very low, probably due to the availability of the high number of preferred nest sites in the transmission towers with the hollow, tubular cross-arms. In contrast, nest boxes in Taylor County (near Butler, GA) were utilized more frequently in order to sustain population sizes once a 20-mile stretch of similar, tubular, cross-armed transmission towers were recently removed. The data showed kestrel use of nest boxes increased each year with the availability of more nest sites (Table 3). Further research is needed to determine the extent of the Southeastern American Kestrel population in this central area of Georgia.

Clearly kestrels are able to maintain a high level of successful reproduction due to the number of observations of HY kestrels in late June and July in 2006. It was not uncommon to see three to four HY kestrels in close proximity to transmission towers with high electromagnetic fields (EMF), which is near the average number of kestrels that has been shown to be fledged from nest boxes in the Coastal Plain (Breen and Parrish 1997). The stability of the breeding population over the four years of data collection, with an average number of 284 pairs of nesting kestrels per year, further suggests that high EMF exposure may have minimal effects on kestrel reproduction, although high levels of EMF have been shown to have adverse effects on reproductive success and other physiological functions of captive American Kestrels (Fernie and Bird 1999, 2000, 2001). Further studies of kestrels nesting in or near 230kV transmission towers will need to be conducted in order to determine the possible effects of high EMF associated with these transmission towers on kestrel reproduction in the wild.

Table 1. Southeastern American Kestrel use of tubular, cross-armed transmission towers as nest sites along an 80 km transect from Offerman to Putney, Georgia, in the summer of 2003, 2004, 2005, and 2006. The tower transects consist of a single line on both the eastern (Offerman to Alma) and western ends of the transect (Sumner to Putney), but has a second parallel (non-tubular) line between Alma and Sumner, Georgia.

Location	Usable Poles / Total Poles	2003 No. Poles (%)	2004 No. Poles (%)	2005 No. Poles (%)	2006 No. Poles (%)
Offerman to Alma	67 / 93	32 (48)	38 (56)	44 (67)	50 (76)
Alma to Tifton	185 / 240	148 (80)	157 (85)	150 (82)	142 (78)
Tifton to Sumner	38 / 44	38 (100)	38 (100)	38 (100)	38 (100)
Sumner to Putney	83 / 94	56 (67)	63 (76)	52 (63)	54 (65)
TOTALS:	373 / 471	274 (73)	296 (79)	284 (76)	284 (76)

Table 2. Southeastern American Kestrel use of alternative nesting structures mounted on or near a transect of transmission towers from Offerman to Putney, Georgia. The structures consist of three different types mounted at different heights on the poles: horizontal PVC tubes at 30 m, horizontal PVC tubes at 4.5 m, vertical PVC tubes at 4.5 m, and wooden nest boxes at 4.5 m.

Type of Alternative Nesting Structure	2004 Used/Available	2005 Used/Available	2006 Used/Available
Horizontal PVC Tube (30m)	1/1	2/2	2/2
Horizontal PVC Tube (4.5m)	0/0	1/3	0/3
Vertical PVC Tube (4.5m)	0/0	0/3	0/3
Wooden Nest Box (4.5m)	0/9	1/9	1/9
TOTALS:	1/10 (10%)	4/17 (24%)	3/17 (18%)

Table 3. Southeastern American Kestrel use of alternative nesting structures mounted on or near the power substation in Taylor County, Georgia. The structures consist of wooden nest boxes mounted at 4.5 m from the ground.

Year	Number of Boxes Available for Nests	Number of Boxes with Nests
2004	8	7
2005	16	9
2006	20	10

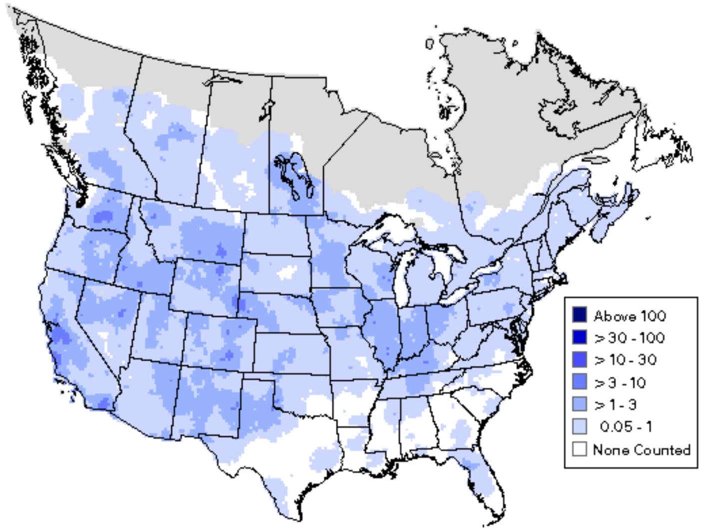

Figure 1. A detailed Breeding Bird Survey map of the distribution of the American Kestrel in the United States and Canada from 1994 to 2003 (Sauer *et al.* 2006).

Figure 2. A detailed map of the 230kV transmission line running from Offerman, GA, to Putney, GA (denoted by arrows). The eastern side of the single line begins in Offerman and ends in Alma when another power line (denoted by flags) begins to run parallel to the study line until it reaches Tifton, where it becomes single again until the end in Putney.

Figure 3. H-shaped transmission tower with tubular, cross-arms, in south-central Georgia, which provide a suitable nesting site for Southeastern American Kestrels. Right view is a close-up view of the entrance (white arrows) to the cross-arms. Only one pair of kestrels can nest at each transmission tower. The towers are about 0.2 km apart.

Figure 4. An example of the replacement lattice frame transmission tower containing no potential nest sites for American Kestrels.

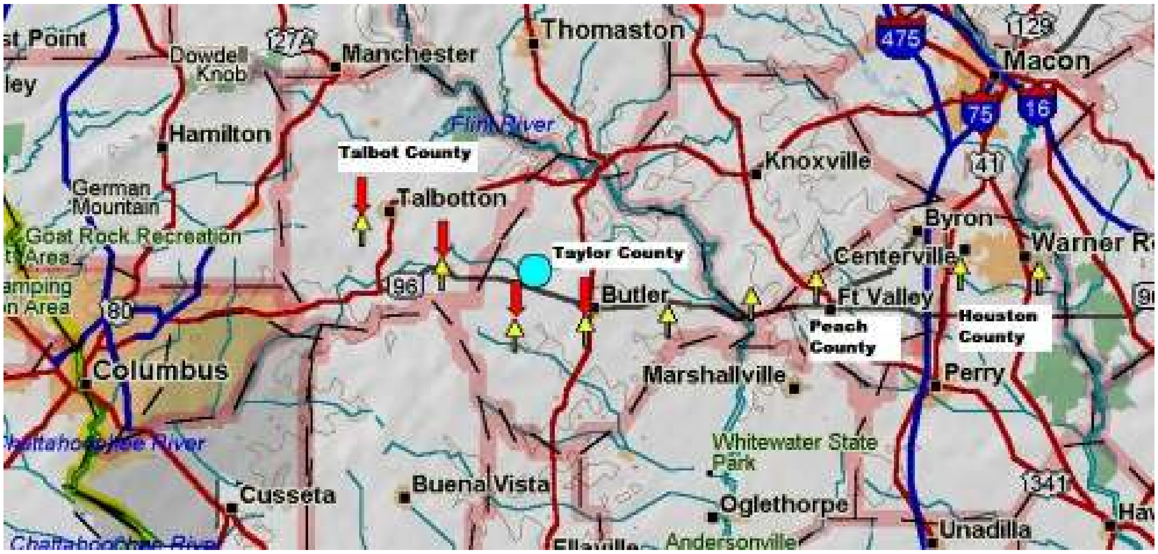

Figure 5. A detailed map of the 230kV transmission line (denoted by arrows pointing up) beginning in Warner Robins, GA and ending in Talbotton, GA. In the spring of 2004, the line extending west from Butler, GA was replaced with non-tubular cross-armed towers (denoted by arrows pointing down).

A B C

Figure 6. Examples of alternative nesting structures made with wood or UV-resistant PVC pipes, placed on transmission towers that do not provide a cavity for American Kestrels to nest.

(A) Horizontal PVC-tube structure placed at 4.5m on transmission towers 5W, 105W and 137W, and at 30m on transmission towers 87W and 111W.

(B) Vertical PVC-tube structure placed at 4.5m on transmission towers 15W, 121W, and 125W in the spring of 2005.

(C) Wooden nest box placed at 4.5m on transmission towers 122E, 123E, and on a power pole by the railroad near tower 10E along Douglas line, and on towers 1W, 8W, 46W, 48W, 134W, and on a pole on McCarthen Lane near tower 14W along the Tifton line, and on towers along the Taylor County line.

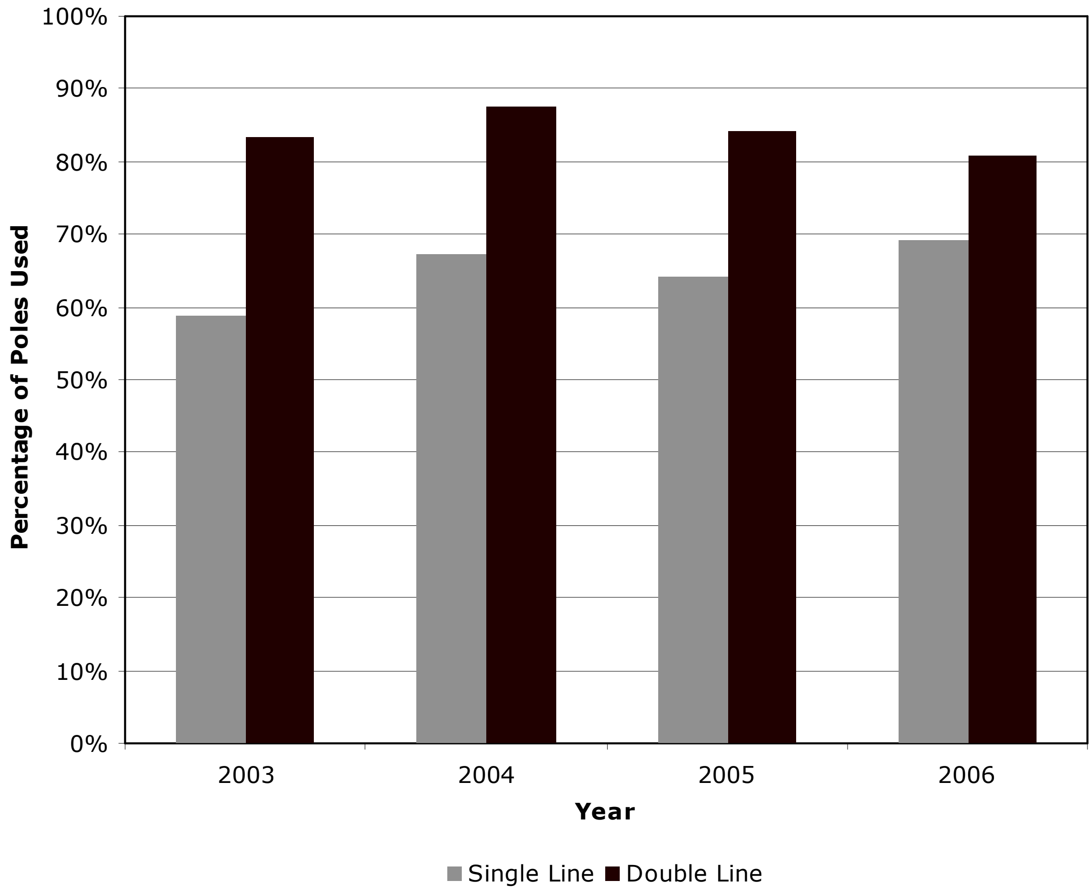

Figure 7. A comparison of transmission tower use by Southeastern American Kestrels from 2003 to 2006. Breeding kestrel pairs preferred towers on the transect in south-central Georgia that ran parallel to a second, non-tubular line over towers that ran in a solitary line (in 2003: G=27.8, d.f.=1, $P<0.0001$; in 2004: G=21.8, d.f.=1, $P<0.0001$; in 2005: G=20.1, d.f.=1, $P<0.0001$; in 2006: G=6.31, d.f.=1, $P=0.012$).

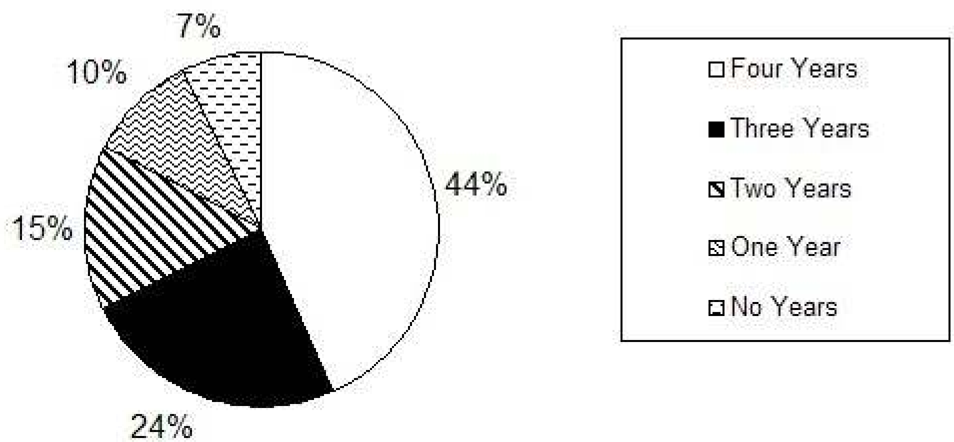

Figure 8. The percentage of usable transmission towers utilized by Southeastern American Kestrels for nest sites in hollow cross-arms, nest boxes, or PVC tubes during the four-year study in south-central Georgia. Ninety three percent of the usable towers hosted a nesting pair of kestrels at least once between 2003 and 2006.

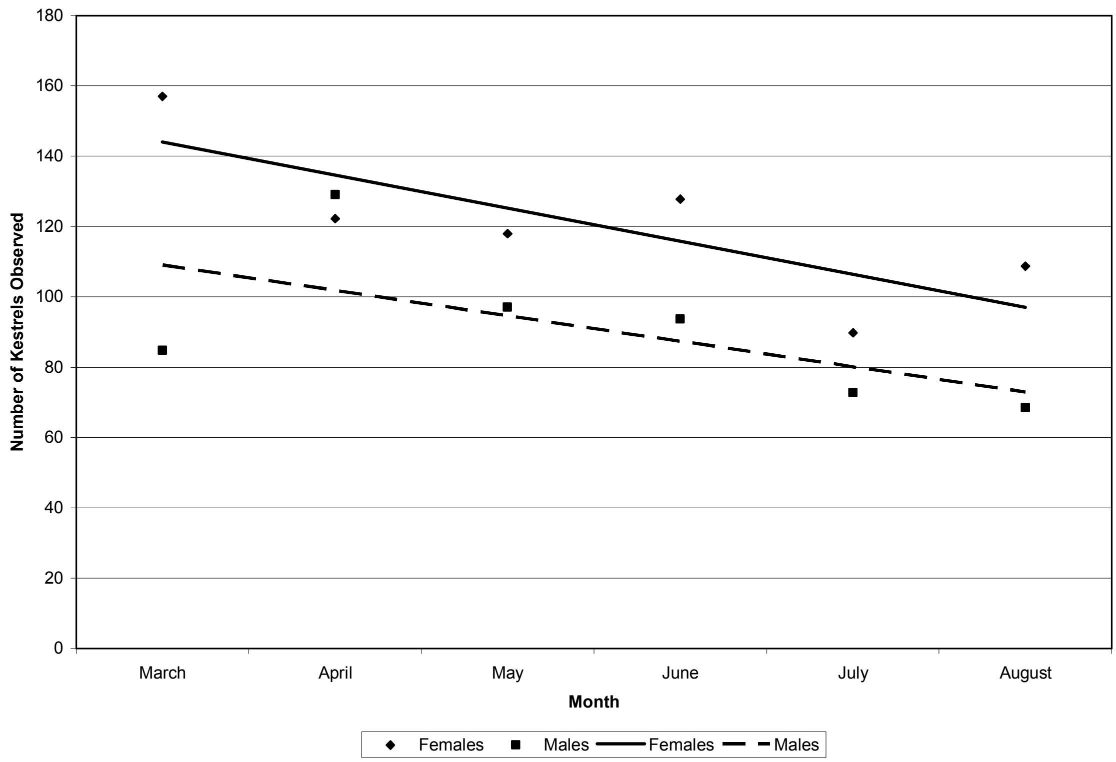

Figure 9. The average monthly totals from spring to summer of male and female Southeastern American Kestrels observed at individual transmission towers in south-central Georgia from 2003 to 2006. Observations of both sexes declined at equal rates from March to August (F=0.138, d.f.=1,5, P=0.7202). Females were sighted more often that males throughout the year (F=9.78, d.f.=1,5, P=0.0122).

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APPENDIX 1

LIST OF TRANSMISSION TOWERS

The numbers (3, 4 ,5, 6, and 7) in the column adjacent to the tower numbers (**in bold**) represent the years kestrels nested in a tower, nest box, or PVC tube in 2003, 2004, 2005, 2006, or 2007, respectively. Abbreviations: hpvc (horizontal PVC at 4.5m), vpvc (vertical PVC at 4.5m), hPVC (horizontal PVC at 100m), box (nest box), non-tubular (no hollow cross-arms), E (towers east of Tifton), W (towers west of Tifton).

Pole #	Yr. Used	Pole #	Yr. Used	Pole #	Yr. Used	Pole #	Yr. Used	Pole #	Yr. Used
334-Single	3.4,5	**287**	5,6	**240**	4,5,6	**193**	4,5	**146**	nontubular
333E	nontubular	**286**	nontubular	**239**	3,4,5,6	**192**	3,4,5,6	**145**	nontubular
332	3,6	**285**		**238**	3,4,5,6	**191**	3,4,5,6	**144**	3,4,5,6
331	5,6	**284**	6	**237**	4,5,6	**190**	3,4,5,6	**143**	5,6
330	4,5,6	**283**	5	**236**	3,4,5,6	**189**	3,4,5,6	**142**	4,6
329	3,4,5,6	**282**	nontubular	**235**	4,5,6	**188**	3,4,5,6	**141**	nontubular
328	4,6	**281**	nontubular	**234**	3,4,5,6	**187**	nontubular	**140**	3,4,5,6
327	3,4,5,6	**280**	4,5,6	**233**	3,4,5,6	**186**	nontubular	**139**	nontubular
326	3,4,5,6	**279**	nontubular	**232**	nontubular	**185**	3,4,5	**138**	nontubular
325	3,5,6	**278**	nontubular	**231**	5,6	**184**	3,4,5,6	**137**	3,4,5,6
324	4,5,6	**277**	nontubular	**230**	3,4,6	**183**	nontubular	**136**	3,4,5,6,
323	nontubular	**276**	4,5,6	**229**	4,5,6	**182**	3,4,5,6	**135**	3,4,5,6
322	3,4,5,6	**275**	4,5,6	**228**	3,4,6	**181**	3,4,5,6	**134**	3,4,5,6
321		**274**	6	**227**	3,4,5,6	**180**	3,4,5,6	**133**	nontubular
320	nontubular	**273**	nontubular	**226**	nontubular	**179**	3,4,5,6	**132**	3,4,6
319	4	**272**		**225**	nontubular	**178**	3,4,6	**131**	3,4,5,6
318		**271**	nontubular	**224**	nontubular	**177**	nontubular	**130**	3,4,5,6
317	Bristol	**270**	3,5	**223**	3,4,5,6	**176**	3,4,5,6	**129**	3,4,5,6
316	nontubular	**269**	3,4,5,6	**222**	3,4,5,6	**175**	nontubular	**128**	nontubular
315	5	**268**	3,4,5,6	**221**	3,4,5,6	**174**	3,4	**127**	3,4,5,6
314	3,4,6	**267**	nontubular	**220**	3,4,5,6	**173**	nontubular	**126**	4,5,6
313	6	**266**	nontubular	**219**	3,4,5,6	**172**	3,4,5,6	**125**	3,4,6
312	nontubular	**265**	nontubular	**218**	3,4,5,6	**171**	4,5,6	**124**	3,4,6
311	4,5,6	**264**	6	**217**	3,5,6	**170**Doug	3,4,5,6	**123**	box
310	3,5,6	**263**	5,6	**216**	3,4,5,6	**169**	3,4,5	**122**	box
309	3,4,5,6	**262**	3,4,5,6	**215**	3,4,5	**168**		**121**	nontubular
308	nontubular	**261**	3,4,5,6	**214**	3,4,5,6	**167**	nontubular	**120**	3,4,5,6
307	3,4,5,6	**260**	5	**213**	4,5,6	**166**shorty	5	**119**	3,5,6
306	3,6	**259**	3,4	**212**	3,4,5,6	**165**	3,5	**118**	3,4,5,6
305	3,5,6	**258**	nontubular	**211**	5,6	**164**	nontubular	**117**	3,4,5,6
304	4,5,6	**257**	5	**210**	3,4,5,6	**163**	nontubular	**116**	3,4,5,6
303	6	**256**	3,4,5,6	**209**	3,4,5,6	**162**	nontubular	**115**	nontubular
302	3,4,6	**255**	3,4,6	**208**	3,4,5,6,	**161**	3,4,5,6	**114**	3,4,6
301	nontubular	**254**	4,5,6	**207**	3,4,5,6	**160**	3,5	**113**	3,4,6
300	5,6	**253**	nontubular	**206**	3,4,5,6	**159**	3,4,6	**112**	4,5,6
299	nontubular	**252(251)**	4,5,6	**205**	3,4,5	**158**	4,5	**111hPVC**	4,5,6
298	3,4,5	**251**	3,4,5,6	**204**	4,5,6	**157**	nontubular	**110**	4,5,6
297	3,4,5,6	**250**	nontubular	**203**	3,5,6	**156**	nontubular	**109**	4,6
296	4,5,6	**249**	3,4,5,6	**202**		**155**	nontubular	**108**	4,5,6
295	nontubular	**248**	3,5,6	**201**	nontubular	**154**	3,4,5,6	**107**	nontubular
294		**247**	3,4,5,6	**200**	5	**153**		**106**	
293	3,4,5,6	**246**	4	**199**	5,6	**152**	3,4	**105**	nontubular
292	3,4,5,6	**245**	4,5,6	**198**	4,5,6	**151**	3,4,5	**104**	nontubular
291	nontubular	**244**	6	**197**	3,4,5,6	**150**	3,4,5,6	**103**	3,4,5
290	nontubular	**243**	5,6	**196**	3,4,5,6	**149**	3,4,5,6	**102**	nontubular
289	5,6	**242**-Single	nontubular	**195**	nontubular	**148**	3,4	**101**	3,4,5,6
288	6	**241**-double	3,4,5	**194**	nontubular	**147**	nontubular	**100**	3,4,5,6

Appendix 1. (Continued)

Pole #	Yr. Used	Pole #	Yr. Used	Pole #	Yr. Used	Pole #	Yr. Used	Pole #	Yr. Used
99	4	**51**	3,5	**3**	nontubular	**93**Sumner	3,4	**45**	3,4
98	3,5,6	**50**	3	**2**	nontubular	**92**	3,4,5,6	**44**	6
97	3,5,6	**49**	nontubular	**1E**	nontubular	**91**	3,4,5,6	**43**	4
96	nontubular	**48**	nontubular	**Tift Subst**	3,4,5,6	**90**	3,4,5	**42**	
95	3,4,5,6	**47**	4,5	**137hpvc**	5	**89**	3,4,5,6	**41**	nontubular
94	3,5	**46**	4,6	**136W**	3,4,5,6	**88**	3,4,5,6	**40**	4
93	3,4,5,6	**45**	3,4,5,6	**135**	3,4,5,6	**87**	3,4,5,6	**39**	
92	3,4,5,6	**44**	3	**134box**	6	**86**	4,5,6	**38**	4,6
91	3,5,6	**43**	3	**133**	3,4,5,6,	**85**	3,4,5,6	**37**	5
90	3,4,5,6	**42**	5,6	**132**	3,4,5,6	**84**	4,5,6	**36**	4,5
89	nontubular	**41**	nontubular	**131**	3,4,5,6	**83**	5,6	**35**	3,4,6
88	3,4,5,6	**40**	nontubular	**130**	3,4,5,6	**82**	5,6	**34**	6
87hPVC	3,4,5,6	**39**	3,4	**129**	3,4,5,6	**81**	3,4	**33**	5,6
86	3,4,5,6	**38**	3,4,5,6	**128**	3,4,5,6	**80**	4,6	**32**	3,4,5,6
85	3,4,5,6	**37**	nontubular	**127**	3,4,5,6	**79**	4,56	**31**	3,4,6
84	3,4,5,6	**36**	3,4,5,6	**126**	3,4,5,6	**78**	3,4,5,6	**30**	3,4,5,6
83	3,4,5,6	**35**	nontubular	**125vpvc**		**77**	4,5,6	**29**	3,4,5.6
82	3,4,5	**34**	3,4,5,6	**124**	3,4,5,6	**76**	3,4,5,6	**28**	3,4,5,6
81	3,4,5,6	**33**	3,4	**123**	3,4,5,6	**75**	3,4,5,6	**27**	3,4,5,6
80	nontubular	**32**	3,4,5	**122**	3,4,5,6	**74**	3,4,5,6	**26**	4,5
79	3,4,5,6	**31**	3,4,5,6	**121vpvc**	7	**73**	5,6	**25**	3
78	3,4,5,6	**30**	3,4,5,6	**120**	3,4,5,6	**72**	3,5,6	**24**	nontubular
77	3,4,5	**29**	nontubular	**119**	3,4,5,6	**71**	4,5,6	**23**	3,4,5
76	3,4,5	**28**	4,5,6	**118**	3,4,5,6	**70**		**22**	3,4
75	3,4,5,6	**27**	4,5,6	**117**	3,4,5,6	**69**		**21**	3,4
74	3,4,5,6	**26**	4	**116**	3,4,5,6	**68**	3	**20**	3,6
73	4,5,6	**25**	3	**115**	3,4,5,6	**67**		**19**	
72	4,5,6	**24**	3,4,5,6	**114**	3,4,5,6	**66**	4,5,6	**18**	3,4
71	4,5,6	**23**	3,4,5,6	**113**	3,4,5,6	**65**	3,4,5,6	**17**	3,4,5,6
70	4,5,6	**22**	4,5,6	**112**	3,4,5,6	**64**	nontubular	**16**	3,4,5
69	3,4,5,6	**21**	3,4,5	**111**	3,4,5,6	**63**	3,4,5,6	**15 vpvc**	
68	3,5,6	**20**	3,4,6	**110**	3,4,5,6	**62**	3,4,5,6	**McCarthenBox**	5
67	3,4,5,6	**19**	nontubular	**109**	3,4,5,6	**61**	3,4,5,6	**14**	3,5
66	4,5,6	**18**	3,4,5,6	**108**	3,4,5,6	**60**	3,4,5,6	**13**	3,4,6
65	3	**17**	3,4,5,6	**107**	3,4,5,6	**59**	3,4,6	**12**	3,4,5,6
64	3,4	**16**	4,5,6	**106**	3,4,5,6	**58**	3,4,5,6	**11**	3,4,5,6
63	4,5,6	**15**	3,4,5,6	**105 hpvc**		**57**	3,5	**10**	3,4,6
62	3,4,5	**14**	nontubular	**104**	3,4,5,6	**56**	3,6	**9**	3,4,6
61	3,4,6	**13**	3,4,5,6	**103**	3,4,5,6	**55**	5,6	**8 box**	
60	3,4	**12**	nontubular	**102**	3,4,5,6	**54**	5,6	**7**	nontubular
59	nontubular	**11**	3,4,5,6	**101**	3,4,5,6	**53**	3,4	**6**	3,4
58	3,4,5	**10 RR box**		**100**	3,4,5,6	**52**	3,4,5,6	**5 hpvc**	
57	nontubular	**9**	nontubular	**99**	3,4,5,6	**51**	4,5,6	**4**	nontubular
56	3,4,5,6	**8**	3,4,5,6	**98**	3,4,5,6	**50**	3,4,5	**3**	3,4
55	nontubular	**7**	4,5	**97**	3,4,5,6	**49**	3,4,5,6	**2**-not there	Plant Mitchell
54	3,4,5,6	**6**	3,4,5,6	**96**	3,4,5,6	**48 box**		**1W box**	
53	3,4,5	**5**	nontubular	**95**-Double	3,4,5,6	**47**	3,4,5,6		
52	3,5,6	**4**	3,4,5,6	**94**-Single	3,5	**46 box**			