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POPULATION GROWTH OF MONK PARAKEETS IN FLORIDA

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Abstract.—We summarize records of Monk Parakeets (*Myiopsitta monachus*) in Florida from Christmas Bird Counts (CBCs) from 1972 to 2003. On the 2002/2003 CBC a total of 2884 parakeets were counted at 22 localities in 16 counties, and over five broad geographical regions in Florida. On the 2002/2003 CBC the population of Monk Parakeets in Florida comprised 69.4% of the records of this species on CBCs nationwide, a percentage that has remained relatively stable over the last 15 years. The population of Monk Parakeets in Florida is growing at an exponential rate across the state generally, and within each of the four geographical regions where it is common. Across the entire state, the current intrinsic rate of population increase, r, equals 0.094 and is associated with a population doubling time of approximately 7.5 years. Given the apparently ideal conditions in Florida for a species such as the Monk Parakeet, and the observed exponential rate of population increase, this species will likely continue its range expansion and dramatic population increase in Florida for the foreseeable future. Problems associated with Monk Parakeet nests on electrical utility structures are also likely to increase.

In some regions of the United States, particularly in California and Florida, introduced parrots are an increasingly common part of the local avifauna. In southern California, for example, there are now 10 species of naturalized parrots (i.e., those that have established breeding populations) and population estimates put the number of individuals at 2,500 to 3,000 (all species combined; Garrett 1997). In Florida, the numbers are substantially larger. On the 2002/2003 Christmas Bird Count a total of 4,169 individuals of 22 species of parrots were reported for Florida. Florida's Breeding Bird Atlas (http://www.wildflor-

ida.org/bba/) provides species accounts for 22 species of parrots known to breed in Florida, plus an additional three species known to occur in Florida but for which breeding has not been established. Combining the data from California and Florida, at least 26 species of parrots are now naturalized (or suspected of being naturalized) in the contiguous United States. Compared with the known number of naturalized parrots in the United States just 17 years ago (nine species at that time; Lever 1987), it appears that approximately one new species of parrot becomes naturalized here each year.

The most abundant of these species is the Monk Parakeet (*Myiopsitta monachus*). When Monk Parakeets established breeding colonies in the United States is unclear because of the uncertainty over when and where birds were released or escaped. The first confirmed sighting was in 1967 in New York City (Lever 1987), and the species was breeding there shortly thereafter (Bull 1973). In Florida, the species was breeding in Miami by 1969 and possibly earlier (Owre 1973). Given multiple sightings of free-flying Monk Parakeets in the United States during the late 1960s (Bull 1973, Freeland 1973, Owre 1973, Simpson and Ruiz 1974), and the wide distribution of these sightings (from New York to Florida), it appears likely that the species became naturalized in multiple localities simultaneously as the result of multiple accidental or purposeful releases.

Although most species of naturalized parrots comprise relatively benign, if non-native, additions to local avifaunas, this is not the case with Monk Parakeets. There are several reasons for interest and concern in this species. First, the Monk Parakeet is the only species of parrot to build its own nest and it exhibits cooperative breeding (Sol et al. 1997, Eberhard 1998, Spreyer and Bucher 1998). Second, although most parrot species are locally restricted in distribution within the United States, Monk Parakeets are now widely distributed, from Oregon to New York in the north and from Florida to Texas in the south, and their population is growing exponentially (Van Bael and Pruett-Jones 1996, Pruett-Jones and Tarvin 1998). Third, there is concern that this species may become an agricultural pest, as it is reported to be in its native range (Bump 1971, Bucher and Bedano 1976; but see Bucher 1984). Perhaps most importantly, in several states, notably Connecticut, Florida, Texas, New York, and Illinois, the Monk Parakeet is causing electrical reliability problems and public safety issues because of its habit of building nests on electrical structures, causing power outages, electrical fires, and disruption of electrical service to customers.

Because of its potential to become an agricultural pest, the Monk Parakeet was the focus of an eradication program by the United States Fish and Wildlife Service (USFWS) in the 1970s. This program reduced the numbers of Monk Parakeets at that time by approximately one-

half (Neidermyer and Hickey 1977). Since 1975, the year that the USFWS removal program ended, numbers of Monk Parakeets have recovered and the species has exhibited a dramatic population expansion to levels far above the pre-control numbers in the early 1970s (Van Bael and Pruett-Jones 1996, Pruett-Jones and Tarvin 1998). Monk Parakeets have exhibited a similar population expansion and increase in Europe, where it is also a naturalized species (Sol et al. 1997).

Given that Florida is home to more than half of all Monk Parakeets presently breeding in the United States (Van Bael and Pruett-Jones 1996), an examination of the distribution and population growth of the species in Florida specifically seems warranted. Here we present such an analysis, summarizing population counts in Florida since 1972, for both the state as a whole and for specific geographic regions within the state. We also compare population growth of Monk Parakeets in Florida with trends nationwide, as well as in other states where the species is common.

METHODS

We summarized Christmas Bird Count records from every locality in the United States where Monk Parakeets have been recorded from 1972 to 2003 (the 2002/2003 count). These data were obtained from National Audubon Society's Christmas Bird Count web site: http://www.Audubon.org/bird/cbc/. Both total number of birds recorded and the number of "party hours" (the total number of person-hours spent counting birds in the count circle) were tabulated. Knowing the number of party hours on each count provides a method of adjusting counts for the relative effort involved.

Although some data from 1972 to 1975 are presented here, our statistical analyses focused on data collected during the period 1976 to 2003. Inclusion of data from 1972 to 1975 would have biased results because the population was being purposefully reduced during that time.

There are many methods of analyzing population data, but one of the most widely accepted is to determine what type of growth model the data fit. Two common models are the exponential growth model and logistic growth model. Populations experiencing exponential population growth are increasing in size rapidly, and at an increasing rate. Populations exhibiting logistic growth have reached or will soon reach an equilibrium population size (the carrying capacity of the environment) and then tend to fluctuate around this mean value over time.

The standard equation defining exponential growth is $N_{t+1} = N_t e^{rt}$ where N_{t+1} is the population size at time t+1, N_t is the population size at time t, r is the intrinsic rate of population growth, t is the time interval, and e is the natural logarithm base. To determine whether a population is growing exponentially, the standard procedure is to plot the natural logarithm (ln) of population size against time and to test whether this relationship is statistically significant. A significant regression suggests that the population growth fits an exponential model.

To calculate the intrinsic rate of population growth, r, the equation above defining exponential growth rate can be rewritten as $r = (\ln N_{t+1} - \ln Nt)/t$. To calculate the time interval for a population to double in size, the equation above defining r can be rewritten as $t = \ln 2/r$. We calculated r, and the population doubling time for each one-year interval beginning in 1976 for the United States, Florida, and various regions in Florida,

and then averaged the yearly values for the period 1976-2003 and for 1989-2003 (the last 15 years).

Monk Parakeets are not equally common across all areas of Florida, and we sought to examine population growth for each area separately. The Florida Counties Map (*http://www.floridacountiesmap.com*) defines eight broad geographic regions within the state as follows: Northwest, North Central, Northeast, Central West, Central, Central East, Southwest, and Southeast (Appendix 1). For each CBC locality reporting Monk Parakeets, we noted the county and the geographic region of that locality.

RESULTS

In Table 1 we summarize the numbers of Monk Parakeets recorded on CBCs from 1972 to 2003 for the United States as a whole, as well as for Florida, Connecticut, Texas, and Illinois, the four states where these parakeets are most common. Data for Connecticut, Texas, and Illinois are presented for comparison with Florida. Monk Parakeet numbers have steadily increased over time, although across states the timing of the initiation of the increase varied. In Florida the increase began in the 1970s. In Texas it began in the early 1980s, in Connecticut the late 1980s, and in Illinois the early 1990s.

Florida has, from the beginning of the species expansion, had most of the individual birds present in the United States. Over the last 15 years (1989-2003), the proportion of the total number of birds in the contiguous United States recorded in Florida has ranged from 66.6% to 79.9%, with an average of 72.5%.

Both the actual numbers of parakeets recorded on CBCs (see Table 1) and the number of birds corrected for effort (party hours; Fig. 1) have increased in Florida. The regression of birds/party hour (ln) against time for Florida (Fig. 2) is statistically significant ($df = 1, 26$, $F = 190.865$, $P < 0.0001$), suggesting that the population of Monk Parakeets is growing at an exponential rate across the state as a whole. The population of Monk Parakeets across the United States as a whole is also increasing exponentially ($df = 1, 26$, $F = 299.393$, $P < 0.0001$)) but this is not just a consequence of the records from Florida. When we exclude the Florida data from other records of Monk Parakeets, we still observe an exponential rate of population growth for the United States generally ($df = 1, 26$, $F = 73.146$, $P < 0.0001$).

We examined the CBC records separately for each geographical region in Florida (Table 2). Monk Parakeets do not occur, or are rare, in the Northwest, North Central, Northeast, and Central East regions, but are common to abundant in the other four regions, the Central, Central West, Southwest, and Southeast regions (see Table 2). For each of these four regions where the species is now regularly recorded, the regression of birds/party hour (ln) by time is statistically significant (Central: $df = 1, 19$, $F = 17.229$, $P = 0.0005$; Central West: $df = 1, 25$, $F = 322.183$, $P < 0.0001$; Southeast: $df = 1, 26$, $F = 59.797$, $P < 0.0001$;

Table 1. Number of Monk Parakeets recorded on Christmas Bird Counts in the United States as a whole, Florida, and three other representative states where the parakeets are currently common.

	Region				
Year	United States combined	Florida	Connecticut	Texas	Illinois
1972	28	0	0	0	0
1973	67	0	0	0	0
1974	46	6	0	2	0
1975	23	5	3	2	1
1976	32	22	0	1	4
1977	22	12	0	0	0
1978	31	26	0	0	0
1979	16	10	0	0	0
1980	46	35	0	0	0
1981	59	56	0	0	0
1982	44	31	0	3	4
1983	83	60	0	5	0
1984	73	66	0	5	0
1985	165	149	0	12	0
1986	310	272	8	18	0
1987	257	210	0	18	0
1988	467	381	11	51	2
1989	442	308	40	60	0
1990	701	560	70	60	0
1991	871	610	195	60	4
1992	1219	933	174	74	1
1993	1343	1035	196	75	5
1994	1471	1079	122	131	35
1995	1816	1174	238	289	55
1996	2342	1815	308	134	31
1997	1782	1255	293	108	35
1998	2321	1634	454	135	16
1999	2681	1779	641	165	67
2000	3147	2252	569	124	105
2001	3205	2454	499	123	90
2002	4243	3041	908	121	66
2003	4158	2884	799	230	85

Southwest: df = 1, 6. $F = 12.234$, $P = 0.129$). The overall exponential growth rate of Monk Parakeet populations across Florida thus seems a consequence of exponential growth rates in each of the four regions where it has established large breeding populations.

We calculated the intrinsic rate of population growth and population doubling times for the United States as a whole, for Florida, and for each of the four regions in Florida where Monk Parakeets are currently common (Table 3). These data reveal several important points. First, despite the fact that Florida supports most of the Monk Para-

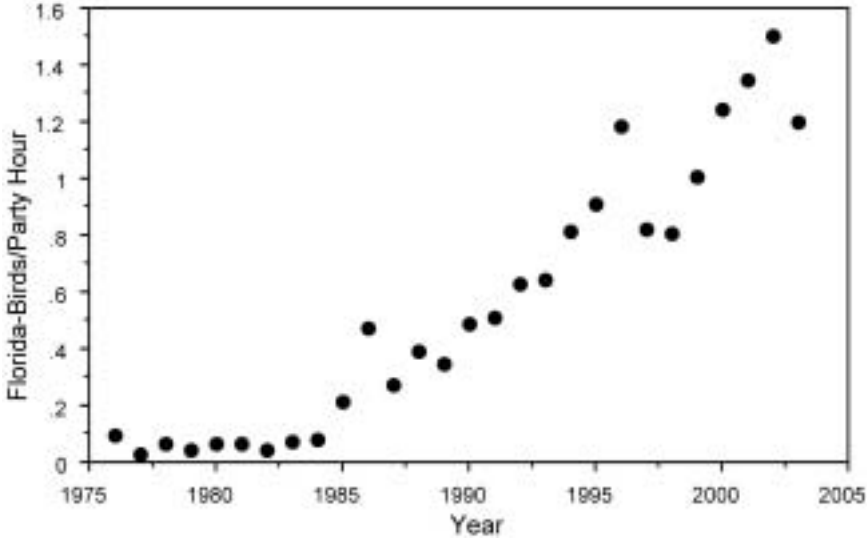

Figure 1. Plot of Birds/Party Hour for Florida since 1976.

keets in the United States, the populations in areas outside Florida are growing even faster than the population in Florida, leading to a higher intrinsic growth rate (0.119) in the United States generally than in Florida specifically (0.094). Second, across the four geographic regions of Florida, the intrinsic rate of population growth varies with overall population size in that region. If we rank regions by intrinsic rate of population growth, the Central West region is followed by the Southeast, Central, and lastly the Southwest regions. This is the same ranking if we rank these regions by population size (see Table 3), suggesting that the larger the population of Monk Parakeets becomes in a region, the faster the rate of population growth. This is further support of the finding that these populations are growing exponentially, as exponential growth is characterized by an ever-increasing rate of population growth. Third, and somewhat counter to the previous finding, for each of the areas considered in our analysis (see Table 3), rates of population growth have slowed slightly over the last 15 years relative to the entire period of 1976-2003. Despite the regional variation of population growth rates, across Florida as a whole, the population doubling time is between 7.37 and 7.79 years (depending on the time period considered; see Table 3) suggesting that, based on this analysis, the numbers of parakeets residing in Florida will double in less than eight years.

One of the difficulties of interpreting CBC data (see Discussion) is that it is often difficult to know what percentage of birds present in any area are counted on the CBC for that area. For Monk Parakeets in

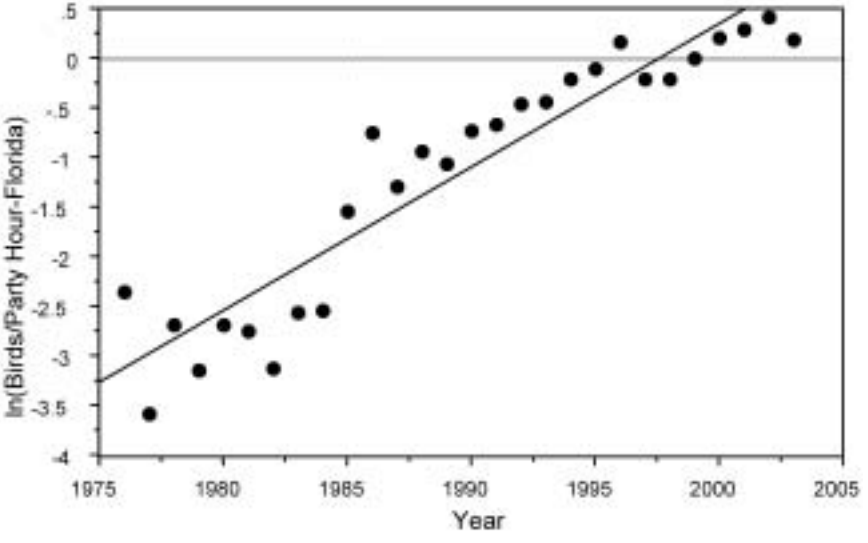

Figure 2. Regression of ln(Birds/Party Hour) for Florida since 1976. This regression is statistically significant, suggesting that the population of Monk Parakeets is growing exponentially in Florida.

Florida, there are data for one year that allow us to examine this issue. The Monk Parakeet Survey (Bill Pranty, http://www.monkparakeet.com/index2.htm) completed a survey of all known nests in Florida and counted birds in the areas of those nests. The survey results for eight counties (the counties for which it was believed that all nests present were known) in Florida in 1999 are presented in Table 4, along with the numbers of parakeets recorded from these counties on the 100th CBC (1999/2000). Overall, 256 parakeets were recorded in the surveys and 203 (79.3%) parakeets were reported on the CBCs. For most counties, as expected, the number of birds reported on the CBCs is less than the number recorded on the field survey. We do not know the explanation for the large discrepancy in this trend that exists for Kissimmee Valley. On the 99th CBC, just seven birds were reported from Kissimmee Valley, and on the 101st CBC, 52 birds were reported. If we exclude Osceola County (and the Kissimmee Valley CBC) from our comparison, then 238 birds were recorded on the field survey and 99 (41.6%) birds were reported on the CBCs for those areas. Another comparison that can be made is the total number of birds recorded on all of the field surveys in 1999 from the Monk Parakeet Survey versus the total number of birds reported on the CBCs from Florida. Bill Pranty (http://www.monkparakeet.com/index2.htm) reports that a total of 3300 Monk Parakeets were recorded in 1999. For the 100th CBC (1999/

Table 2. Number of Monk Parakeets recorded on Christmas Bird Counts in each geographical region of Florida during the last 15 years. See Appendix 1 for tabulation of counties in each region.

	Region in Florida							
Year	North-west	North Central	North-east	Central West	Central	Central East	South-west	South-east
1989	0	0	0	139	4	0	0	165
1990	0	1	0	149	4	0	0	406
1991	0	0	5	212	5	0	0	388
1992	0	0	6	503	10	0	0	414
1993	0	0	0	636	15	0	1	383
1994	0	0	0	753	1	0	0	325
1995	0	0	5	744	0	0	0	425
1996	0	0	0	1272	6	0	0	537
1997	0	0	0	839	13	0	57	346
1998	0	0	0	947	19	0	55	613
1999	0	0	2	1362	9	0	67	339
2000	0	0	0	1520	202	1	24	505
2001	0	0	0	1832	90	0	72	460
2002	0	0	8	1833	166	0	96	938
2003	0	0	9	2038	152	0	68	617

2000) a total of 2252 (68.2%) Monk Parakeets were reported on the CBCs for all of Florida.

Another difficulty in using population estimates from CBCs to calculate total population size is that it is often difficult to know what proportion of a species distribution is encompassed by the CBC count circles. For the year 2001, we have one estimate of this parameter from Dade and Broward counties. During 2001, staff of Florida Power and Light counted a total of 1069 nests on utility structures in these counties. We overlaid the CBC count circles for Dade and Broward counties on a map of those counties and found that 220 (20.6%) of the nests were included in the area counted.

Discussion

Records from Christmas Bird Counts provide estimates of winter population size of a particular species, but interpretation of such records must be made with caution. Such records are relatively poor at estimating a species total population size, but much better at tracking long-term trends in population numbers of a species. Our use of CBC records follows the latter of these two objectives, specifically to ask whether the population of Monk Parakeets is expanding, contracting, or remaining stable. Based on our analysis here, there seems only one reasonable conclusion. Monk Parakeets are expanding their distribu-

Table 3. Mean values of intrinsic growth rates (*r*) of Monk Parakeet populations calculated for the periods 1976-2003 and 1989-2003 (last 15 years) for various regions, and the 'population doubling time' associated with these values of *r*.

	1976-2003		1989-2003	
Region	*r*	Time for population to double in size	*r*	Time for population to double in size
United States (including Florida)	0.119	5.82	0.104	6.66
United States (excluding Florida)	0.132	5.25	0.116	5.97
Florida	0.094	7.37	0.089	7.79
Central Florida	0.056	12.38	0.040	17.33
Central West Florida	0.168	4.13	0.127	5.56
Southeast Florida	0.124	5.59	0.083	8.35
Southwest Florida	0.043	16.12	0.043	16.12

tion in Florida, their population size is growing exponentially, and the population is currently doubling every seven to eight years.

Although our efforts here are not focused on estimating the total population size of Monk Parakeets in Florida, this is obviously an important issue. The total size of the population of Monk Parakeets in Florida is obviously much larger than the numbers counted on CBCs. To estimate total population size, we need values for two parameters: the proportion of the total parakeet population that is covered by the CBC count circles and the proportion of birds resident in the area covered by the count circle that is actually counted. We do not have precise data on either parameter. Based on comparisons detailed in our Results, we can use as a first approximation the value of 20.6% as the pro-

Table 4. Comparison of Monk Parakeets counted on the 100th Christmas Bird Count (1999/2000) with field surveys in which all nests in eight counties were mapped.

County	Number of nests[a]	Number of birds[a]	Birds recorded on 100th CBC
Brevard	8	18	1
Citrus	2	27	19
Lee	21	78	24
Orange	1	2	0
Osceola	9	18	104
Pasco	43	104	55
Seminole	1	6	0
St. Johns	2	3	0
Totals	87	256	203

[a]Data from the Monk Parakeet Survey (http://www.monkparakeet.com/index2.htm).

portion of the parakeet population that is covered by the CBC count circles. With respect to the proportion of birds resident in an area that is actually counted on the CBCs, we had three estimates: 41.6%, 68.2%, and 79.3% (see Results). These values lead us to the following calculations. On the 2002/2003 CBC a total of 2,884 Monk Parakeets were counted. If the CBC count circles cover 20.6% of the total population of parakeets in Florida, and if 79.3%% of the parakeets resident in the count circles are actually counted, we can estimate the total population size of Monk Parakeets in Florida as $2{,}884/(0.206 \times 0.793) = 18{,}025$ birds total. In contrast, if the CBCs count is just 41.6% of the parakeets resident in an area, we can estimate the total population size of Monk Parakeets in Florida as $2{,}884/(0.206 \times 0.416) = 32{,}044$ birds total. The range of these two values, 18,025 and 32,044, illustrates the need for additional data before we can accurately estimate total population size. Nevertheless, these two values also estimate approximate minimum and maximum values for the current population size.

The Monk Parakeet has a number of characteristics that appear to be related to, or have facilitated, its rapid population expansion in Florida and elsewhere. First, it builds its own nest, unlike other parrots, and is thus not dependent on large tree hollows or other similar nesting sites. Monk Parakeets appear to be able to construct a nest on virtually any surface, from trees, to man-made towers, utility poles, the frame of a basketball hoop, and hollow steel tubes supporting lights. Second, the species also has an extremely diverse diet, and an ability to adapt to new foraging situations. Monk Parakeets appear to be able to eat any vegetative matter, from fruits, grains, and seeds, to other plant parts. In Illinois, the species diet changed dramatically over the year as various food items became available (South and Pruett-Jones 2000). During the coldest winter months in Chicago, January and February, Monk Parakeets were able to subsist on a diet comprised entirely of birdseed obtained at backyard bird feeders. In Connecticut, Monk Parakeets have been observed feeding on mud flats along the coast during winter. Although perhaps less important in Florida than elsewhere, this variable and adaptable diet appears directly related to the fact that Monk Parakeets can thrive in areas with a cold winter climate. Finally, the species is highly gregarious and appears to have developed and adapted to an association with humans, which appears unlike their behavior in the wild. The association with humans has both a positive and negative result. The positive result is that such an association may make it less likely that the species will expand into rural, agricultural areas where it could lead to agricultural damage. The negative result is that this association will likely permit the species to continue its population expansion. Also, this association is contributing to the current situation of Monk Parakeets causing economic damage in areas where the birds nest on electrical utility structures.

The mild climate in Florida and the seemingly unlimited potential nesting sites in Florida might suggest that Monk Parakeets should do better there than elsewhere, and to be sure Florida is home to approximately 60% of all Monk Parakeets in the United States. Nevertheless, the populations of this species outside of Florida are expanding at a rate that is comparable to that observed in Florida (see Table 3), suggesting to us that it is possible that other states will eventually have the number of Monk Parakeets that are currently seen in Florida.

The Monk Parakeet is an invasive species, and its success as such led to its designation of the "Invasive Species of the Month" for February 2000 by the Institute for Biological Invasions (see http://invasions.bio.utk.edu/invaders/monk.html). Although the initial threat of the Monk Parakeet, that it would become a serious agricultural pest, has not yet materialized (and some would say never will), the species is causing considerable economic damage through nesting on electrical structures. Electrical fires and power outages directly attributable to Monk Parakeets have been reported in Connecticut, Florida, Texas, Illinois, and New York. The view that the Monk Parakeet should be considered "innocent until proven guilty" (see http://www.monkparakeet.com/spreyer.htm) may be justified, at least at present, with respect to agricultural damage. However, when it comes to the damage the species is causing through disruption of electrical coverage, the proof is in hand that this species is guilty.

In summary, Monk Parakeets are widely distributed in Florida and abundant in at least two geographical regions, the Central West and Southeast regions. In all areas in Florida where it occurs, the species is experiencing exponential population growth and populations sizes in each area will likely increase. The population in Florida is likely to double within the next eight years, and with this increase, the economic damage that the species causes through electrical disruption is also likely to double.

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Appendix 1. Geographical regions of Florida, the counties encompassed by these regions, and the specific Christmas Bird Counts in these counties on which Monk Parakeets have been recorded at least once since 1972.

Region in Florida	Counties in this region	Christmas bird counts in these counties on which parakeets have been recorded
Northwest	Escambia	
	Santa Rosa	
	Okaloosa	
	Walton	
	Holmes	
	Washington	
	Jackson	
	Calhoun	
	Bay	
	Gulf	
	Liberty	
	Franklin	
North Central	Gadsen	
	Leon	
	Wakulla	
	Jefferson	
	Madison	
	Tarlor	
	Hamilton	
	Suwannee	
	Lafayette	
	Dixie	
	Columbia	
	Gilchrist	
	Union	
	Bradford	
	Alachua	Gainesville
	Levy	
Northeast	Baker	
	Nassau	
	Duval	Jacksonville
	Clay	
	St. Johns	St. Augustine
	Putnam	
	Flagler	
Central West	Citrus	Crystal River
	Hernando	
	Pasco	New Port Richey
	Pinellas	North Pinellas
		St. Petersburg
	Hillsborough	Alafia Banks
		Tampa
	Manatee	Bradenton
		Gulf Circle, Manatee

Appendix 1. (Continued) Geographical regions of Florida, the counties encompassed by these regions, and the specific Christmas Bird Counts in these counties on which Monk Parakeets have been recorded at least once since 1972.

Region in Florida	Counties in this region	Christmas bird counts in these counties on which parakeets have been recorded
Central West	Sarasota	Sarasota
		Venice-Englewood
	DeSoto	
Central	Marion	
	Sumter	
	Lake	
	Seminole	
	Orange	Wekiva River
	Osceola	Kissimmee Valley
	Polk	Lakeland
		Lake Wales
	Hardee	
	Highlands	
Central East	Volusia	
	Brevard	Cocoa
	Okeechobee	
	Indian River	
	St. Lucie	
Southwest	Glades	
	Charlotte	Peace River
	Lee	Fort Myers
	Hendry	
	Collier	Naples
Southeast	Martin	Jonathon Dickinson State Park
		Stuart
	Palm Beach	West Palm Beach
	Broward	Ft. Lauderdale
	Monroe	Key Largo Plantation
	Dade	Dade County
		Royal Palm-Homestead
		Kendall Area