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16 Monk and Rose-Ringed Parakeets

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INTRODUCTION

Worldwide, there are about 350 species of parrots and parakeets (order: Psittaciformes). According to the analyses of Cassey et al. (2004), 54 of these species have been introduced to areas outside their native ranges, and 38 species have become established in the nonnative range. Humans exhibit ambivalent feelings toward parrots and parakeets. Many of these birds are strikingly beautiful and highly prized as companion animals, while others are banned because of potential agricultural

damage or competition with native species. Many parrot species are afforded special protection because they are endangered in their native habitats, but often these same species are considered crop pests and persecuted by farmers (e.g., Tella et al. 2013).

The United States was once home to two species of native parrots, the Carolina parakeet (*Conuropsis carolinensis*) and the thick-billed parrot (*Rhynchopsitta pachyrhyncha*). Carolina parakeets were found throughout southeastern United States, as far north as New York and North Dakota, and as far west as Colorado and Texas (Snyder and Russell 2002). Thick-billed parrots occupied northern Mexico and portions of the bordering states of Arizona and New Mexico (Snyder et al. 1999). These two native parrots were lost during the twentieth century. The demise of the Carolina parakeet was probably due to combined effects of disease, shooting (for sport, crop protection, and millinery), and habitat loss (Snyder and Russell 2002). Extirpation of the thick-billed parrot from the southwestern United States was most likely due to hunting (Snyder et al. 1994). A reintroduction program that began in 1986 for the thick-billed parrots in Arizona did not result in a self-sustaining population, although the species persists in Mexico (Snyder et al. 1994).

While there is an absence of native parrots in the United States today, at least nine species of introduced parrots are currently recognized as being established in the United States by the American Ornithologists' Union (Chesser et al. 2015). Nineteen additional free-flying, introduced parrot species are recognized, but not considered established (Chesser et al. 2015). At least five species are established in the state of Hawaii (Runde et al. 2007; Pyle and Pyle 2009).

The monk parakeet (*Myiopsitta monachus*) and rose-ringed parakeet (*Psittacula krameri*) are undoubtedly the world's most successful introduced parrot species. Each species now enjoys a broad nonnative range where conflicts with human activity include crop damage (Conroy and Senar 2009; Gaudioso et al. 2012), competition with native species (Strubbe and Matthysen 2007), and property damage (Avery et al. 2006). Each species exemplifies invasiveness through its capacity to adapt to new conditions and to exploit opportunities created by human activity. Biologists and resource managers are challenged to develop and implement effective strategies that not only protect resources from these invasive species, but also account for public opinions which often favor the charismatic avian invaders.

MONK PARAKEET (FAMILY: PSITTACIDAE)

The monk parakeet, also known as Quaker parakeet, is a medium-sized parrot (110–130 g body mass, approximately 28 cm total length). On average, adult males are slightly larger than adult females except during the breeding season when body mass of females increases slightly. Adult males and females are identical in plumage. The plumage is green on the back and tail, and grayish on the underside. The wings are dull green with the outer wing feathers blue (Spreyer and Bucher 1998).

Monk parakeets primarily eat a variety of fruit, seeds, buds, and flowers. In its native range within South America, the species is regarded as a major pest to crops such as sorghum, sunflower, and rice. The monk parakeet inhabits open woodlands, savannah, agricultural areas, and disturbed habitats from southern Bolivia, through Paraguay, southern Brazil, Uruguay, to southern Argentina (Spreyer and Bucher 1998).

FIGURE 16.1 Electric utility facilities, including substations as pictured here, are favorite nest sites for monk parakeets in the United States. (USDA photo.)

Monk parakeets are monogamous. One clutch of four to eight eggs is produced annually during the well-defined spring breeding season. The female incubates the eggs and broods the nestlings while the male contributes nest materials and brings food to the female. Monk parakeets are unique among psittacines as they use sticks and twigs to construct bulky nests which house from one to many individual nesting chambers (Spreyer and Bucher 1998). The nest structure is the focus of the parakeets' social system as the birds live in their nests year round, not just during the breeding season (Figure 16.1).

Breeding adults and nonbreeding subadults defend and maintain their nests throughout the year, and instances of nonbreeding parakeets helping to feed nestlings or recent fledglings have been documented (Bucher et al. 1990; Eberhard 1998). Nesting season and molt cycle of the species in the United States are shifted six months with respect to the native range (Avery et al. 2012).

Origin in the United States

In 1966, the U.S. Bureau of Sport Fisheries and Wildlife implemented regulations requiring declarations (Form 3–177) of wildlife imported into the United States (Banks 1970). Psittacines, however, were initially exempted from this reporting requirement, so the first full tabulations of monk parakeet importations date from 1968. During the five-year period 1968–1972, over 63,000 monk parakeets were imported into the United States. Most, perhaps all, of these imports were from Paraguay. Importations from Paraguay were suspended in 1973 due to concern over Newcastle's disease. Imports resumed in 1974 when 608 birds were brought

in (Greenhall 1977). In 1978, Uruguay and Argentina became the main sources of monk parakeets imported into the United States. Since 1981, importation records have been maintained and compiled by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Data on exports and imports by species can be found online from the CITES trade database (http://trade.cites.org/). Importation of monk parakeets essentially ended with the passage of the Wild Bird Conservation Act of 1992, which ensures that exotic bird species are not harmed by international trade and encourages wild bird conservation in countries of origin. Monk parakeets continue to be available in the pet trade because they are readily bred and raised in captivity.

Establishment in the United States

Monk parakeets in New York/New Jersey. Free-flying parakeets were first reported from the New York/New Jersey metropolitan area in 1967, and nest construction was observed in 1970. These earliest populations in the New York/New Jersey area probably originated from escaped pet birds imported from Paraguay. The Audubon Christmas Bird Count (CBC) is the only long-term, structured source of survey data (http://netapp.audubon.org/CBCObservation/). Monk parakeets first appeared on the CBC for New York in 1970, and they appeared on the New York CBC every year thereafter, except 1983. Data from the CBC support the notion that many early populations in the New York/New Jersey area did not persist. One exception is Brooklyn, where parakeet numbers on the CBC were low, but consistent, throughout the 1970s and 1980s. Parakeet numbers in the New York/New Jersey area have increased slowly since then and are at their highest level ever, according to the 2014 CBC results.

Monk parakeets in Connecticut. In Connecticut, two monk parakeets were recorded in 1971 and again in 1972 (Neidermyer and Hickey 1977). In 1973, the Connecticut Department of Environmental Protection reported 34 monk parakeets in the state at three locations (Olivieri and Pearson 1992). Monk parakeets first appeared on the CBC in Connecticut in 1974 (three birds). As in New York/New Jersey, these first parakeets probably originated from Paraguay. Monk parakeets next appeared on the Connecticut CBC in 1985, and they have been in the count results ever since. The CBC counts peaked in 2005 and have slowly declined since.

Monk parakeets in Florida. The monk parakeet was first recorded breeding in Miami in 1969, and since the early 1970s, the species has been firmly established (Owre 1973). Florida monk parakeets have been on the CBC since 1974. The count numbers in Florida peaked in 2002, followed by a steady annual decline until 2014 when numbers recorded rose again. As judged by the CBC, Florida has the most monk parakeets of any state.

Expansion and Population Growth

The U.S. Fish and Wildlife Service initiated a nationwide monk parakeet control and removal program in the early 1970s because the species had a reputation as an agricultural pest in South America and there was concern for the impacts it might have on crops in the United States (Neidermyer and Hickey 1977). Other concerns

included possible transmission of psittacosis and interspecific competition with native wildlife. During 1970– 1975, participants in this removal program recorded 367 confirmed sightings of monk parakeets from 30 states (Neidermyer and Hickey 1977). As a result, 163 birds were removed from 16 states, mostly New York (88) and California (35). The removal program ended in 1975 and was considered a success in reducing the growth and spread of monk parakeet populations (Neidermyer and Hickey 1977).

The monk parakeet has thrived in the United States since 1975 and has become an urban/suburban species with no obvious factor limiting population growth. Nationwide, monk parakeets have exhibited exponential growth, buoyed principally by the Florida population (Van Bael and Pruett-Jones 1996). Declines in Florida and Connecticut populations since 2003 ended the exponential growth pattern, but monk parakeet populations are growing elsewhere, particularly in Texas (e.g., Reed et al. 2014), which now is second only to Florida in numbers recorded on the CBC (Figure 16.2). In Illinois, researchers hypothesize that actual parakeet numbers might not be decreasing, but instead their geographical distribution might be changing (Pruett-Jones et al. 2012).

Monk parakeets are well established outside of the United States. The first published records of escaped monk parakeets in Spain are from 1975, when the species established in Barcelona (Batllori and Nos 1985). Largely due to importation of thousands of birds from South America for the pet trade, the species quickly expanded to other cities in Spain and established populations in other countries such as Belgium, Italy, and England (Sol et al. 1997; Butler 2002; Strubbe and Matthysen 2009a). Monk parakeets appear to be spreading in Mexico where they were first reported in 1999 (MacGregor-Fors et al. 2011). In recent years (2010–2014), CBC records from Puerto Rico and Bahamas also have included monk parakeets.

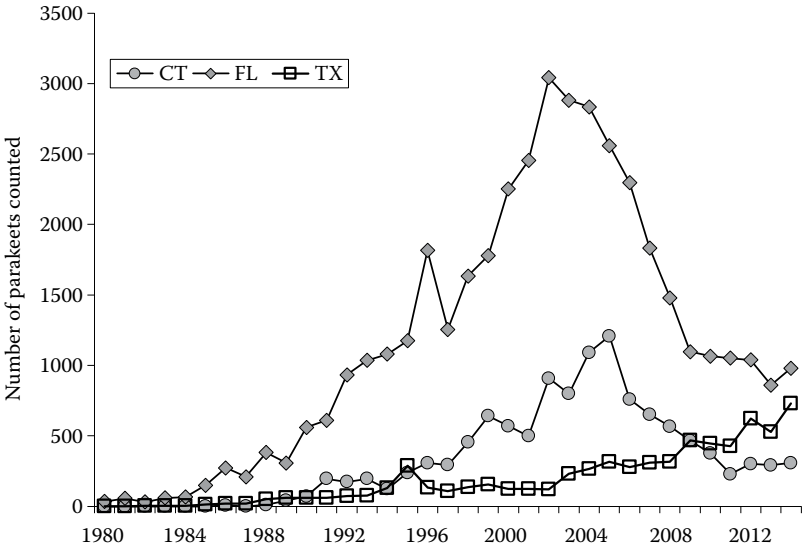

FIGURE 16.2 Monk parakeet population trends in Florida, Connecticut, and Texas, 1980–2014. (Data from Audubon CBC (http://netapp.audubon.org/CBCObservation/.)

Behavioral Shifts between Native and Introduced Range

The monk parakeet is considered a serious native crop pest in South America, where it inflicts damage to field crops such as sorghum, sunflower, rice, and corn (Aramburú 1995). The extent and severity of the damage varies across the region, but crop losses can be severe locally (Bucher 1992). The concerns regarding crop damage that were initially expressed when monk parakeets first appeared in the United States have yet to materialize. To date, these birds have demonstrated a propensity for life in urban and suburban areas, not rural or agricultural areas which they inhabit in their native range. Thus, monk parakeets in the United States have seldom been implicated in damage to crops (Tillman et al. 2001). However, if their population increases and habitat requirements are not met in urban environments, the birds could conceivably move into agricultural landscapes and cause crop damage, as has already occured in Spain (Senar et al. 2016).

Monk parakeets in south Florida build nests principally on man-made structures such as stadium light poles, cell towers, and electric utility facilities (Newman et al. 2008). Similar nest-site selection preference was documented in Texas, where 75% of monk parakeet nests were on electric utility structures (Reed et al. 2014). In Argentina, monk parakeets nest on electric utility poles in areas where there are no trees available for nesting (Bucher and Martín 1987).

In south Florida, crop contents of nestlings ($n = 26$) consisted mostly of sunflower (43%) and millet (32%) seeds (Tillman, unpublished data). These two seeds are the most common constituents in bird seed mixes sold for backyard feeders. The use of feeders exemplifies the behavioral flexibility of the monk parakeet. Such feeding opportunities are probably uncommon in the native range where monk parakeets are generally considered crop pests, rather than welcome additions to the local avifauna.

To a much greater extent than in the native range, resource acquisitions by monk parakeets in the United States have become subsidized by human activities. Boarman (2003) observed that human activities provide wildlife with inadvertent sources of food, water, and other resources. Such resources tend to be more stable and predictable than a natural environment, and animals that take advantage of them are able to prosper and expand their range, often to the detriment of competitors and species they prey upon. His remarks were in the context of common raven (*Corvus corax*) management, but the same concept is applicable to invasive species such as the monk parakeet. That is, these invasives are thriving in the United States and in other countries in large part because they are able to adapt to human activities and exploit feeding and nesting opportunities provided by these activities.

Predators and Disease in Introduced Range

Adverse effects of predation, diseases, and parasites on monk parakeets have not been documented in the United States. Predation on eggs and nestlings is a substantial source of mortality for parakeets in their native range (Navarro et al. 1992), but there are no similar observations in the United States. On two occasions, one

of us (MLA) observed fish crows (*Corvus ossifragus*) at parakeet nest structures. One time, a crow stuck its head inside the nest entrance but emerged with nothing. The second time, a crow landed on the nest structure, pulled a stick from the outside of the nest, and flew off with it. Predation on adult parakeets most likely occurs in the United States, but we are not aware of any documented instances.

Millsap et al. (2002) reported the death of a fledgling bald eagle (*Haliaeetus leucocephalus*) in Pinellas County, Florida due to *Chlamydophilia psittaci* infection. Possible sources of this contamination were monk parakeets which had built a nest of their own at the base of the eagle nest. Monk parakeets also build nests at the base of osprey (*Pandion haliaetus*) nests (Pranty 2009; M.L. Avery, unpublished data), so if the parakeets in the area are carrying *C. psittaci*, then potential cross-species contamination exists there as well.

Range of Damage

Agricultural. The only documented agricultural damage that we are aware of in the United States is from south Florida, where monk parakeets and other bird species inflict localized damage to tropical fruit crops such as longans and lychee (Tillman et al. 2001). However, the potential for significant damage by monk parakeets to other fruit crops (citrus, blueberry, grapes, etc.) as well as to field crops such as sunflower, corn, rice, and sorghum remains great. Several states, including Hawaii, California (Dana et al. 1974), and Kansas (Buhler et al. 2001), have banned monk parakeets because of their reputation for causing agricultural damage in their native range (http://mrbeanva.tripod.com/legalq.htm).

Human health and safety. Parakeets and other psittacines are known to carry bacteria that can cause psittacosis in humans (Raso et al. 2014).

Natural resources. We are unaware of any damage to natural resources attributable to monk parakeets. Davis (1974) reported that, in New Jersey, parakeets killed blue jays (*Cyanocitta cristata*) and an American robin (*Turdus migratorius*), but this report could not be verified.

Property damage. Wherever monk parakeets occur in the United States, utility companies must cope with parakeets building nests on electrical utility facilities. Parakeets also build nests on stadium light poles and in trees, but utility structures are preferred in many locations (Newman et al. 2008; Reed et al. 2014). The utility facilities include distribution poles, which are familiar sights along neighborhood streets throughout the country; transmission line towers, which support high-voltage power lines traversing the countryside; and electrical substations, where power lines enter and the high voltages are decreased for distribution to residences and businesses (Avery and Lindsay 2016). The bulky nests of sticks and branches constructed by parakeets create hazards for safe, reliable electrical service on each of these types of facilities. When wet nest materials come in contact with energized components, a short circuit is created and results in a power outage. Such events cause a financial burden to customers who lose power, a health and safety concern, and the utility companies lose revenue and must replace or repair damaged equipment (Avery et al. 2002).

Methods Tested to Control Monk Parakeets

In the monk parakeet's native range, lethal control with toxic chemicals is the primary means of population management for crop damage reduction (Linz et al. 2015). Workers spread a paste containing carbofuran or other toxic pesticides around the entrance to the parakeets nest, and the birds succumb from ingesting the toxin as they preen the paste from their feathers.

For electric utility companies in the United States, the most common management approach is to remove nests from power poles or substations when the nests become large enough to constitute a threat to service reliability (Avery et al. 2006). Nest removal is a short-term strategy as the nest occupants almost immediately begin to rebuild at the same site. Further, it might be counterproductive because taking down a nest structure containing nest chambers of several pairs likely will cause the pairs to disperse, and if each pair initiates nest building at a new site, then the original single nest structure eventually becomes several.

Various control methods have been tested to determine their usefulness in keeping monk parakeets from nesting on utility facilities (Avery et al. 2006). Visual scare devices that were tested but were not effective include models of owls, rubber snakes, scare-eye balloons, and a taxidermic parakeet effigy suspended near nests of a substation (Avery et al. 2002). Loud noises were also ineffective and are not compatible with the residential location of most of the parakeet nesting locations. Parakeets were sensitive to a hand-held red laser; birds were repeatedly flushed from their nests at a substation, but the effect was only temporary. Even after a week of laser harassment, the birds still returned to the nest sites at the substation (Avery et al. 2002).

Attempts to remove parakeets from substations using the chemical irritant methyl anthranilate (MA) also proved unsuccessful. The MA was formulated to be dispensed as a fog, and although there were signs (head shaking and bill wiping) that the fog was irritating to the birds, the treatment did not dissuade them to leave the substation (Avery et al. 2006). Conceivably, a system of aerosol or fog dispensers could be devised and installed on a substation to deliver MA in an effective treatment, but currently this methodology remains unproven.

Monk parakeets can be trapped on distribution poles, particularly at night when the birds are in their nest. One successful technique involves use of a long-handled net to cover the nest opening and to catch the birds as they fly out of the nest (Martella et al. 1987). Netters can stand on the ground and use a long pole, or a bucket truck can be used to raise netters to the level of the nest. Once in place, the netters then employ long-handled nets and cover one or two openings to catch birds as they attempt to flee. If attempted during daylight, birds depart before the net can be properly placed. On distribution poles in south Florida, the nest was usually removed immediately or shortly after netting. Findings revealed that higher capture rates at the nest sites greatly retarded the rate at which those sites were reoccupied (Tillman et al. 2004).

Trapping at the nest is generally not appropriate at substations where access to nests is very difficult due to large amounts of high-voltage equipment. Also, substation nests are quite close together, so the disturbance at the first nest where netting is attempted causes the other birds at the site to leave their nests prematurely and

avoid capture. Monk parakeets are wary of traps and not easily captured, even with extensive prebaiting and the use of decoy birds (Avery et al. 2002; Tillman et al. 2004). A passive, unattended trap is not sufficient to capture the parakeets occupying a substation. It is possible to lure birds into a very spacious, open trap with end doors that can be slammed shut via remote control. Also, remotely triggered traps mounted on platform feeders within a substation have been used successfully to capture small groups of parakeets attracted to the food placed there (Avery and Lindsay 2016).

Methods Untested

To our knowledge, there has been minimal evaluation of aural deterrents for dispersing parakeets and keeping them from nesting on utility structures. In particular, sound deterrents that mimic or reproduce parakeet alarm or distress calls should be investigated, singly and in combination with lasers or other visual scare tactics.

Feasibility of Eradication

The nationwide monk parakeet "retrieval" program initiated by the U.S. Fish and Wildlife Service in the early 1970s failed to eradicate the species. Due to public opposition, a similar broadscale eradication effort has not been attempted because in states where parakeets are now established, the goal of management efforts is not to eradicate monk parakeets, but rather to ensure reliable delivery of electric service. To this end, methods development is focused on the problem of minimizing parakeet nesting on utility structures. This approach not only offers the best chance for achieving the management objective, but also helps to assuage concerns raised by parties interested in the welfare of the parakeet population. When incipient populations arise in states where parakeets are not tolerated, the birds can be readily removed by shooting or trapping.

Future Tools and Techniques Being Developed or Needed

Reproductive control. Considerable efforts have been expended in the development of a safe, effective contraceptive approach for monk parakeet population management (Yoder et al. 2007; Avery et al. 2008). The technique using diazacon as the active ingredient has been tested in cage and field studies, and the approach has been shown effective in reducing parakeet productivity and safe for nontarget species (Yoder 2011). Lack of Environmental Protection Agency (EPA) registration currently prevents diazacon fertility control to be implemented as a population management technique. It is not known at this time whether the necessary funding to perform the remaining EPA-mandated studies will be forthcoming.

Structural modifications. For nesting, monk parakeets display definite preferences for types of electric utility structures and for specific locations on the structures (Avery et al. 2006; Newman et al. 2008; Reed et al. 2014). The actual design will vary, but the objective is to eliminate structural features which allow parakeets to obtain a firm base from which to begin their nest construction. One example of the effects of structural design involves two types of transmission line supports. The

FIGURE 16.3 Example of an electric utility pole with many angles and surfaces suitable for monk parakeet nests. (USDA photo.)

older, multicircuit design consists of two vertical supports connected by horizontal and diagonal cross pieces which provide parakeets with numerous nesting opportunities (Figure 16.3). The updated standard design is now a single vertical pole with narrow cross members supporting insulators (Figure 16.4). This structure design eliminates the substrates suitable for the parakeets to initiate nest building.

FIGURE 16.4 Example of an electric utility pole affording no opportunity for monk parakeets to establish and maintain a nest. (USDA photo.)

Another option is to eliminate the acute angles that occur on transmission line support structures and in substations. The angles are formed where a horizontal beam is intersected by a diagonal support piece. Inserting a triangular block in the acute angle would create a right angle that presumably the birds would find less appealing as a nest site. Another approach is to eliminate the flat surfaces upon which the parakeets begin nest-building activity. This could be accomplished through installation of rounded, semicircular covers on the flat surfaces of beams. The more smooth and slippery the surface, the more effective a nesting deterrent it will be. The challenge to implementing structural modifications is that so many angles need to be eliminated and so many surfaces need to be rounded that it is unrealistic to expect they could all be done. But perhaps certain key parts could be retrofitted or replaced to help reduce nesting activity.

ROSE-RINGED PARAKEET (FAMILY: PSITTACULIDAE)

Rose-ringed parakeets (*Psittacula krameri*) are medium to large parakeets (40+ cm, 110–182 g; Butler 2003) that are native to Asia and Africa. These birds have tails approximately equal in length to their bodies, and are of bright green plumage with red bills. The adult males have a dark ring (sometimes reddish) around their neck, which justifies the naming of this species as the rose-ringed, or ring-necked, parakeet (Figure 16.5).

Juvenile males cannot be readily distinguished from adult or juvenile females. These cavity-nesting birds are highly social, foraging, roosting, and loosely nesting in the same areas.

FIGURE 16.5 Male rose-ringed parakeet. (Photo by Dick Daniels.)

In their introduced range, rose-ringed parakeets generally establish night roosts on tree branches or on palm fronds (Gaudioso et al. 2012; Sheehey and Mansfield 2015). They rarely excavate a new cavity for nesting, but instead often widen the opening of an already established cavity, and they can displace other cavity nesters during this process (Strubbe and Matthysen 2007). Large-diameter trees with ample surrounding shrub and tree cover appear to be the preferred nesting conditions in both the United Kingdom (Butler 2003) and Hawaii (Gaudioso et al. 2012). The median clutch size is four eggs, yet two eggs are generally fertile, and two fledglings per nest are common (Butler 2003; Lambert et al. 2009).

Rose-ringed parakeets are opportunistic granivores-frugivores, largely consuming dry and fleshy fruits and seeds, but they are also known to consume nectar and flower buds (Ali and Ripley 1969; Clergeau and Vergnes 2011). In their native range, they are well-known pests of agricultural crops, particularly corn (*Zea mays*) and sorghum (*Sorghum bicolour*) (Ali and Ripley 1969). Crop damage in the United States has not been well documented aside from damage to corn (Gaudioso et al. 2012) and tropical fruit (Bukoski, pers. comm.) on Kauai in Hawaii.

Introduced Range

Due to their large popularity as pets (caged birds), rose-ringed parakeets have established feral populations in at least 35 countries (Butler 2003), which makes this species the most widely introduced parrot in the world. In fact, the Invasive Species Compendium (2012) reports that 76 countries currently have rose-ringed parakeets or had them in the past. Of the four recognized subspecies of *Psittacula krameri* (two are from sub-Saharan Africa, including Senegal, Uganda, Sudan, Somalia, and Ethiopia; and two are from Asia, including India, Sri Lanka, Nepal, and Pakistan), the majority of the invasive rose-ringed parakeets are from northern India and Pakistan (*P. k. borealis*; Jackson et al. 2015). Temperature apparently provides some limitation to where they can become established (Roscoe et al. 1976; Butler 2005), yet they have successfully colonized tropical, subtropical, and temperate environments. In Europe, the main established populations are in the United Kingdom (ca. 10,000 individuals in 2004), Belgium (ca. 7000 in 2005), the Netherlands (5400 in 2004), and Germany (5700 in 2003) (Butler 2005; Strubbe and Matthysen 2007).

Establishment in the United States

In the United States, rose-ringed parakeets have become well established in parts of Florida, Hawaii, and southern California, and additional, more temporary populations have been reported in Virginia, Texas, Louisiana, and Alabama (Invasive Species Compendium 2012; Sheehey and Mansfield 2015). Escapees from the pet trade probably account for most of these established populations in the United States, and intentional releases or large storm events such as hurricanes that damage aviaries are additional pathways that facilitated some rose-ringed parakeet establishment in the United States (Gaudioso et al. 2012; Sheehey and Mansfield 2015). According to the CITES trade database (http://trade.cites.org/), there have been approximately 60,000 live rose-ringed parakeets imported into the United States for the period of

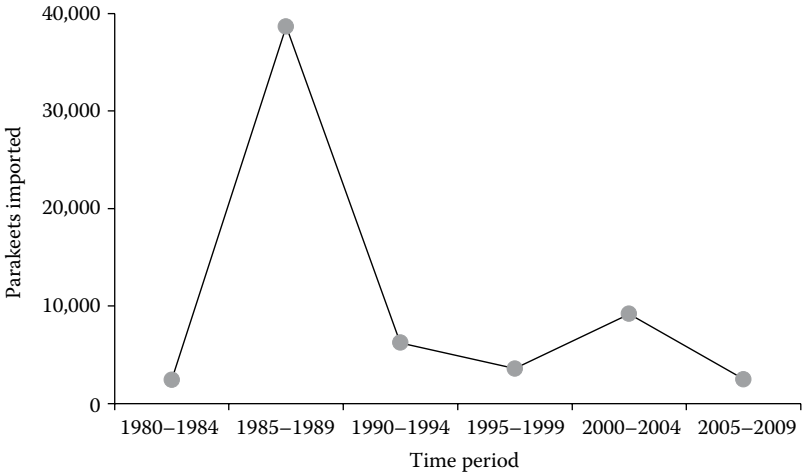

FIGURE 16.6 Rose-ringed parakeets imported to the United States, 1980–2009. (The data are from http://trade.cites.org/.)

1980–2007, and the majority of these (>40,000) were imported during 1985–1990 (Figure 16.6). Apparently, the majority of the rose-ringed parakeets imported into the United States were wild-caught because a very small portion (approximately 3%) of the CITES-listed imports stated they had originated from stocks bred in captivity.

When introduced to New York City, rose-ringed parakeets did not establish, possibly due to insufferably cold winter weather (Roscoe et al. 1976). According to the Florida Fish and Wildlife Conservation Commission, rose-ringed parakeets were introduced as early as the 1930s in Florida, and populations at various times occupied 15 counties presumably through repeated introductions or escapees rather than by breeding in the wild (http://myfwc.com/wildlifehabitats/nonnatives/birds/rose-ringed-parakeet/). The species has declined in the state during recent years and currently is restricted to the Naples area in southwestern Florida where a small population persists (Pranty and Garrett 2011). There are several discrete populations of rose-ringed parakeets in southern California. With introductions as early as 1977, the estimated population in the greater Bakersfield area was approximately 3000 individuals in 2012, and additional smaller populations have been reported in San Diego, Anaheim, Santa Cruz, Malibu, and Pasadena (Sheehey and Mansfield 2015). The state of Hawaii also has rose-ringed parakeets established on at least two islands, with over 2000 individuals on Kauai (Gaudioso et al. 2012) and at least 500–1000 on Oahu (Kalodimos, unpublished data).

Expansion and Population Growth

It took 130 years for rose-ringed parakeets in the United Kingdom to establish a self-sustaining population (Lever 1987; Tayleur 2010). In Kauai, rose-ringed parakeets were first released in the 1960s in the south part of the island. By 1982, the population had grown to 50 birds, and a second pair of rose-ringed parakeets had been released

after Hurricane Iwa. By 1994, late 2000s, and 2011, the population was estimated at 150–200 birds, 500–1000 birds, and over 2000 birds, respectively (Gaudioso et al. 2012; U.S. Department of Agriculture [USDA], Wildlife Services [WS], National Wildlife Research Center [NWRC], unpublished data). The size of the current rose-ringed parakeet population on Kauai is unknown, but USDA staff estimated the population in 2015 to be at least threefold greater than the 2011 estimate even after accounting for removal of 100–200 birds each year around agricultural fields.

In southern California, there was a self-sustaining population estimated at 60 individuals in 1997 (Garrett 1997; Butler 2005), and yet by 2012 there were 3000 individuals in Bakersfield alone (Sheehey and Mansfield 2015). Population growth of introduced rose-ringed parakeet in the United Kingdom varied from 15% per year on the Isle of Thanet to approximately 30% per year in the Greater London area (Butler 2003). Rose-ringed parakeet populations are relatively sedentary, and they expand their range slowly as evidenced by just 400 m/year expansion in the United Kingdom (Butler 2003). Although no formal measurements of geographical expansions are available for the United States, the rose-ringed parakeet populations appear to spread slowly and probably at comparable rates as those reported for populations in the United Kingdom. The relatively slow geographic expansion of rose-ringed parakeets is probably partly attributable to their release near human habitations, which offer an abundance of resources and few predators, and that the original birds released were often pets and therefore habituated to humans. Additionally, Strubbe and Matthysen (2007) suggest that dispersal may be limited because of the species' communal roosting behavior.

Behavioral Shifts between Native and Introduced Range

The habitats where rose-ringed parakeets reside in their native range are largely woodlands and grasslands. In their introduced range, they thrive in a wider range of habitats, including highly disturbed urban areas to natural or seminatural areas. In Belgium, the greatest densities of rose-ringed parakeets are in forested areas where there is an abundance of cavities for nest sites (Strubbe and Matthysen 2011); however, in Kauai, nearly 1000 birds roost outside of administrative buildings in downtown Lihue (Gaudioso et al. 2012). Behavior of male rose-ringed parakeets may differ between their native and introduced range; in India, males were found tending the young at the nest sites (Hossain et al. 1993), whereas observations of nests in the United Kingdom and Belgium revealed that the breeding males left the nest to return to the communal roost just after sunset (Butler 2003; Strubbe and Matthysen 2011). Further observations of male rose-ringed parakeets in Brussels, Belgium, revealed that males would feed their female mate and young at the nest site during the day, then briefly stop to forage on the way from the nest to the roost just before dark (Strubbe and Matthysen 2011). Another difference between rose-ringed parakeets in their native (India) range and in their introduced range is that nesting in India can occur in rock crevices and buildings (Ali and Ripley 1969; Roberts 1991; Juniper and Parr 1998), whereas in the United Kingdom, they only nest in tree cavities (Pithon and Dytham 1999; Butler 2003).

Individuals travel more than 6 km a day in the United Kingdom, presumably for forage (Butler 2003); foraging distances in native India are several kilometers a day

(Chakravarthy 1998). Rose-ringed parakeets in Kauai have home ranges that vary widely (0.11–6437 ha), and the average home range (1771 ha; n = 16) of rose-ringed parakeets on Kauai was almost 13–24 times greater (average 75–86 ha; n = 5) than rose-ringed parakeets in Brussels (Strubbe and Matthysen 2011). In Brussels, orchards, parks, and gardens were the most preferred habitats of rose-ringed parakeets, probably a result of the abundance of high-quality food in those environments relative to the less favored and visited habitats of deciduous forests, coniferous forests, and (nonorchard) agricultural lands (Strubbe and Matthysen 2011). In fact, Strubbe and Matthysen (2011) concluded that, at least in Brussels, rose-ringed parakeets do not forage in agricultural areas.

Frequent activity and foraging in suburban areas by the rose-ringed parakeets may also be influenced by backyard bird feeders. Clergeau and Vergnes (2011) studied four radio-collared rose-ringed parakeets in Paris, France, and observed that half of the parakeets' feeding time was at backyard bird feeders. Possibly backyard feeders, which can be reliable food sources, assist rose-ringed parakeet survival through the winter (Butler 2003; Clergeau and Vergnes 2011).

Predators and Disease in Introduced Range

Predation of rose-ringed parakeets has not been well documented in their introduced range, though rodents represent the most-likely threats when the parakeets are nesting in cavities, while raptors would be able predators of parakeets when they are flying or roosting. Predation of rose-ringed parakeets in their native range of India is generally attributed to owls, crows, and snakes (Lamba 1966; Shivanarayan et al. 1981; Hossain et al. 1993; Dhanda and Dhindsa 1998). In their introduced range, the only available records of rose-ringed parakeet predation are those by rodents, and such predation events seem relatively uncommon. In Italy, the native red squirrel (*Sciurus vulgaris italicus*) was documented entering a tree hole and emerging 10–15 seconds later with a living featherless rose-ringed parakeet in its mouth. While the squirrel was inside the nest cavity, adult parakeets stayed outside and vocalized loudly until the squirrel had exited the cavity and made off with the chick (Mori et al. 2013a). In the United Kingdom, introduced grey squirrels (*Sciurus carolinensis*) are the only reported predators of rose-ringed parakeets (Schwartz et al. 2009).

Diseases that psittacines can contract, and are known to negatively affect these birds, include beak and feather disease, avian bornavirus, Newcastle disease virus, avian pox virus, avian influenza, avian psittacosis, and pulmonary disease (England 1974; Tozer 1974). It is also possible for some of these diseases to transfer from the parakeets to poultry or wild birds, as well as humans (see below). In Kauai, all 15 rose-ringed parakeet individuals tested were negative for avian influenza virus and avian psittacosis (Gaudioso et al. 2012).

Range of Damage

Agriculture. In their native range, many farmers consider rose-ringed parakeets to be the most serious avian pest because of the heavy damage they cause to agricultural crops (e.g., corn, sorghum, rice, safflower, sunflower, fleshy fruit) and stored grains

(Shivanarayan et al. 1981; Dhindsa and Saina 1994; Mukherjee et al. 2000). In fact, rose-ringed parakeet reduced crop yields of corn and sorghum in India by 74%–81% (Reddy 1998, 1999). Gizzard and crop contents of nestlings and adults in India consisted primarily of sorghum, corn, and sunflower (Shivanarayan et al. 1981; Sani et al. 1994). In Pakistan, rose-ringed parakeets are a serious pest of corn, sunflower, rape seed, as well as fruit crops such as mangos, citrus, and guava (Bashir 1979). Bashir (1979) reported that the estimated annual loss in corn seed from rose-ringed parakeets in Pakistan was 97,000 tons, which was equivalent at the time to US$15 million.

In their introduced range, crop damage is much less common than in their native range, aside from the extensive damage to both corn and tropical fruit crops on the island of Kauai (Gaudioso et al. 2012). Seasonal availability of cereal and fruit crops in north temperate latitudes (northern United Kingdom and United States) does not coincide with the early breeding season of the rose-ringed parakeet (e.g., February; Lambert et al. 2009; Strubbe and Matthysen 2011). In Kauai, rose-ringed parakeets leave their roost after sunrise and begin feeding in corn fields. These birds "sample" the corn as it is ripening by clipping at the tassels, before feeding in a particular corn field; this type of damage is unique to the rose-ringed parakeets on Kauai, as other (native and nonnative) birds may also feed on the corn in Kauai (Gaudioso et al. 2012). When rose-ringed parakeets feed on the corn, they feed on the kernels of the corncobs just prior to the harvest stage (Gaudioso et al. 2012).

Human health and safety. Presence and expansion of rose-ringed parakeet populations around airports in the United Kingdom (Fletcher and Askew 2007) and Hawaii (W. Bukoski, pers. comm.) have caused concern for human safety associated with potential aircraft strikes with these birds. At Heathrow Airport, Fletcher and Askew (2007) reported that one of the 54 bird strikes in 2005, and two of the 44 bird strikes in 2006, involved rose-ringed parakeets. Although no airstrikes with rose-ringed parakeets have yet been reported on Kauai, scare techniques and occasional removal are practiced by USDA WS (W. Bukoski, pers. comm.). As rose-ringed parakeet populations grow around urban and suburban areas, including airports, concerns for air traffic and human safety may become more pressing. Additionally, airstrikes with birds are costly, and have been reported to be UK£20,000 per bird strike (Tayleur 2010).

Rose-ringed parakeets are potential vectors of diseases that can negatively affect both poultry and humans. These diseases include Newcastle disease (Butler 2003), cryptosporidium (Morgan et al. 2000), and psittacosis (Fletcher and Askew 2007; Raso et al. 2014). Exposure to disease from bird droppings deposited below roosting sites, which can be in public places, is a human health concern that does not require direct contact with the birds. Although less severe for humans than contracting a disease from rose-ringed parakeets, residents and tourists in Hawaii have complained about the loud, shrill calls commonly made by these birds (Gaudioso et al. 2012).

Natural resources. The growing number and sizes of introduced rose-ringed parakeet populations has raised concern for their potential involvement in loss of native biodiversity. Rose-ringed parakeets feed on both native and nonnative plants (Cramp 1985; Strubbe and Matthysen 2007; Clergeau and Vergnes 2011), and by doing so they probably destroy the majority of the seeds that they consume. In the United

Kingdom, they are known to feed on berries of native holly (*Ilex* spp.) and elder (*Sambucus* spp.), and seeds of native hornbean (*Carpinus betulus*) and ash (*Fraxinus excelsior*) (Cramp 1985). Additional native plants were consumed by rose-ringed parakeets that had colonized Paris (Clergeau and Vergnes 2011). Despite their consumption of native plants in Europe, no reports yet exist indicating that rose-ringed parakeets are altering the natural or seminatural environment through their feeding ecology (Tayleur 2010). In Australia, however, rose-ringed parakeets are known to strip bark, which has killed some trees and possibly shifted the local tree community composition and structure (Fletcher and Askew 2007). Reports of damage to native species in the United States are lacking, though they have been observed feeding on some native plants in Hawaii, including endemic palms (*Pritchardia* spp.) (W. Bukoski, pers. comm.). Additionally, there is potential for rose-ringed parakeets to spread nonnative or invasive plants if seeds are small enough or otherwise remain viable after passing through the bird. Partially intact seeds of the nonnative invasive plant *Passiflora edulis* were removed from the crop/gizzard of an individual captured in Kauai (Gaudioso et al. 2012). If parakeets continue to grow in numbers and locations throughout the United States, they have the potential to alter natural areas through their feeding behavior.

Because of their cavity-nesting behavior, rose-ringed parakeets may threaten or otherwise competitively exclude native birds and bats that rely upon cavities. This has been a serious concern in the United Kingdom and other parts of Europe, as rose-ringed parakeets are thought to have a competitive advantage over several native breeding birds, including kestrel (*Falco tinnunculus*), stock dove (*Columa oenas*), jackdaw (*Corvus monedula*), Eurasian nuthatch (*Sitta europaea*), and common starling (*Sturnus vulgaris*) (Butler 2003; Fletcher and Askew 2007; Strubbe and Matthysen 2007). Newson et al. (2011) evaluated the potential for population-level impacts of rose-ringed parakeets on all native cavity-nesting species in the parakeet's current range in the United Kingdom and found no evidence for a significant impact through competition. In contrast, and through a series of correlative analyses that included six native cavity-nesting birds (stock dove, jackdaw, Eurasian nuthatch, common starling, and two primary-cavity nesting woodpeckers) in Belgium, Strubbe and Matthysen (2007) found the nuthatch was negatively associated with rose-ringed parakeet abundance. Through further experimental study where rose-ringed parakeets were blocked from nest cavities, Strubbe and Matthysen (2009b) demonstrated that indeed rose-ringed parakeets competitively exclude some Eurasian nuthatches from nesting cavities. Furthermore, rose-ringed parakeets apparently begin to breed earlier in the season than nuthatches, which may enable them to claim the best cavities before the nuthatches (Strubbe and Matthysen 2007). Based on modeling geographic spread and the potential for rose-ringed parakeets to usurp nests, Strubbe et al. (2010) concluded that, at most, one-third of the Eurasian nuthatch population would be at risk to the ill effects of the rose-ringed parakeet.

Rose-ringed parakeets also reportedly attack and kill little owls (*Athene noctua*) and red squirrels (*Sciurus vulgaris*) in Europe (Mori et al. 2013b; Menchetti and Mori 2014). In possible defense of their nest, three rose-ringed parakeets killed an adult red squirrel (Japiot 2005). Additionally, rose-ringed parakeets were reported injuring and killing a small bat (*Nyctalus leisleri*) that was roosting or possibly

hibernating in a tree cavity in Italy (Menchetti et al. 2014). There have been no reports in the United States involving the effects of rose-ringed parakeets on native fauna. However, due to the diversity of native cavity nesters that appear to be vulnerable to the negative effects of rose-ringed parakeets, future studies should prioritize investigation of the interactions between local native cavity nesters and rose-ringed parakeets.

Property damage. Unlike other parrots that cause frequent damage to vehicles and dwellings (e.g., native kea, *Nestor notabilis*, in New Zealand; Brejaart 1994) or electrical outages from their nest-building behavior (e.g., introduced monk parakeets in Florida; Avery et al. 2002), there is little property damage associated with rose-ringed parakeets other than crop damage and airplane collisions. A more subtle example of property damage induced by rose-ringed parakeets is the large amounts of droppings produced at high-density roosts. Populations of rose-ringed parakeets in both Kauai and California form such high-density roosts in public areas, such as in palms lining shopping malls and public buildings (Gaudioso et al. 2012; Sheehey and Mansfield 2015). As with many of the negative impacts caused by parrots, we expect those attributable to the rose-ringed parakeet to become more common as more populations become established and the sizes of established populations increase.

Methods Tested to Control Rose-Ringed Parakeets

For rose-ringed parakeets, a suite of scare tactics have been used historically to reduce the negative impacts on crops. Auditory scare tactics have included shooting of guns and propane-gas cannons, and the use of loudspeakers. Additionally, rose-ring parakeets are shot or netted in agricultural settings (Koopman and Pitt 2007; Gaudioso et al. 2012). These methods have been largely unsuccessful because the birds become accustomed to the tactic, and the methods are costly and can require humans patrolling the sites multiple times a day (Bashir 1979; Gaudioso et al. 2012). Incorporating scare and lethal methods in cornfields of Hawaii has been estimated to cost corn companies hundreds of thousands of dollars each year (Koopman and Pitt 2007). Live-trapping rose-ringed parakeets has been tried with variable success. Large box traps baited with fruit or seed, or a live conspecific parakeet as a lure, were used in Pakistan to reduce rose-ringed parakeet damage to sunflower crop (Bashir 1979). When this method was replicated in Kauai, the traps were never visited by any parakeets despite their frequent flights over the trap and roosting above the trap (Gaudioso et al. 2012).

Shooting of rose-ringed parakeets, both for harassment and harvest at roost or in fields when foraging, has been the dominant control method continued in Kauai, where these parakeets cause persistent damage to seed corn crops. Crop damage appears less severe when shooters patrol the cornfields, but the rose-ringed parakeet population has not noticeably declined on Kauai (Gaudioso et al. 2012; W. Bukoski, pers. comm.). Although rose-ringed parakeet control methods have historically been practiced to combat parakeet damage to crops (e.g., in native range, Bashir 1979; in introduced range of Kauai, Gaudioso et al. 2012), licenses have been issued since 2010 in the United Kingdom to harvest rose-ringed parakeets in order to prevent

serious damage or disease, preserve air safety, preserve public health and safety, and to conserve native flora and fauna (Tayleur 2010).

Fertility control is a nonlethal technique that is often more appealing to the public for long-term population management. In the United Kingdom, the fertility control agent diazacon has been tested and proven effective against captive rose-ringed parakeets (Lambert et al. 2010). Diazacon reduces blood cholesterol and cholesterol-dependent hormones, and has therefore proven useful for reducing reproductive output in birds (Lambert et al. 2010). A suitable formulation and delivery system is needed before diazacon can be an effective method for rose-ringed parakeet population control. A challenge for rose-ringed parakeet control in Kauai has been a difficulty in successfully drawing the parakeets to bait (Gaudioso et al. 2012); therefore, if diazacon is formulated in palatable bait, it may still be difficult to deliver to the birds in such areas where alternative food sources are abundant or more desirable. Effects on nontarget species and potential secondary toxicity to predators feeding on dosed parakeets also must be evaluated.

Methods Untested

Effectively reducing rose-ringed parakeet populations would appear easiest at their roosts because they are stationary (sleeping), accessible, and generally in large numbers. However, most of the roosts are located in urban or suburban areas (e.g., rugby club, cemetery, shopping mall, residential area), which means the high visibility of such an effort, even practiced at night, would have to be considered (Butler 2003). In urban and suburban areas of Kauai, rose-ringed parakeet flocks departing their roosts often number 175 individuals (Gaudioso et al. 2012). Therefore, the use of mist nets to capture a large number of birds leaving the roost may be worth investigating. Long poles, or a bucket truck, could be used to raise nets after sundown to the level of the roosting birds, and the nets could easily be lowered to collect entangled individuals immediately after the birds leave the roost (typically sunrise).

Because there are no remaining native parrots in the United States, it would seem a parrot-specific disease may be considered as a method of biological control; however, we know of no such diseases currently available, and even psittacosis can be passed to nonpsittacine birds. One type of control effort that seems to be lacking in rose-ringed parakeet management is the use of toxicants. Although avian toxicants are field tested as a means of controlling agricultural pests in the United States (Linz 2013), their use is generally unwelcome by the public. Additionally, testing appropriate delivery devices would be critical to ensure that nontargets, such as native birds, would not be negatively affected by toxicants targeted for rose-ringed parakeets. Furthermore, in Kauai, where rose-ringed parakeets are damaging agricultural crops, there has been low success in luring individuals into traps (Gaudioso et al. 2012).

Future Challenges to Eradication/Control

A prominent barrier to rose-ringed parakeet eradication or control efforts is human fondness for this and other parrot species. In addition to humans having rose-ringed

parakeets as pets, many people enjoy seeing the birds in the wild, including at parks and backyard bird feeders. Lambert et al. (2010) stated that eradication of established rose-ringed parakeets in the United Kingdom is unlikely, largely because a substantial portion of the human population welcomes the colorful addition to the avifauna. The amount of effort required to curtail the population would be considerable, and Butler (2003) suggested that a 30% reduction in rose-ringed parakeet population would be needed to prevent further increase in the Greater London population. Population control and local eradication of rose-ringed parakeets are controversial, but the very destructive nature of these birds to a diversity of cereal and fruit crops, their potential to spread disease and to outcompete native birds, and to adversely affect native plant communities warrant consideration of suppression of existing rose-ringed parakeet populations and prevention of expansions.

SYNTHESIS OF FUTURE CHALLENGES (BOTH SPECIES)

The impacts of invasive monk parakeets and rose-ringed parakeets are undeniable, but often there is little empathy for wildlife managers when they are up against charismatic birds which otherwise seem a pleasant addition to the local avifauna. Many residents may not care or are unaware that a parakeet is nonnative or not. Thus, one challenge is to increase education and public awareness with regard to the potential negative consequences of invasive wildlife. This could be difficult to achieve because, in some cases, the invasive species is part of the local culture. For example, the monk parakeet is the only species of parrot successfully established in the northern United States, where it is a colorful subtropical curiosity and a particularly welcome sight where winters can be long and cold. In some cities, such as Brooklyn and Chicago, monk parakeets have for many years been the subject of study by college students and amateur birders, so any disruption of the birds will be readily noticed and widely publicized in local media. Social controversies surrounding monk parakeet management are often fomented by organized animal rights advocacy groups. Leery of adverse publicity, utility companies adversely affected by the parakeets are reluctant to initiate management programs in the face of such opposition.

Availability of resources, especially funding, for development and implementation of new management tools represents a major challenge. Often the information needed for cost-benefit analysis is not available, so it can be difficult to justify the expense required to develop a new technology, such as a contraceptive for parakeet population management or a repellent for crop protection. Time is on the side of the invader, so while the necessary background information is collected, populations increase, disperse to new areas, and the problems they cause become that much more difficult to address.

Another challenge is to remain vigilant to impacts of the invasive species. Just because impacts are not readily apparent does not mean they are not occurring or will not occur eventually. For example, to date, there is no evidence that monk parakeets compete with native species for essential resources. Nor have monk parakeets lived up to their South American reputation as serious crop depredators. Rose-ringed parakeets have demonstrated no adverse impact on native species in the United

States. We suggest, however, that a complacent attitude regarding management of the monk parakeet or rose-ringed parakeet is not appropriate. Instead, aggressive, science-based management strategies are needed to address specific current problems and to minimize future negative impacts that stem from these birds.

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