

Short Communication

An update of the breeding population status of the critically endangered Mariana Crow *Corvus kubaryi* on Rota, Northern Mariana Islands 2013–2014

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Summary

The critically endangered Mariana Crow now exists in a single population on the island of Rota, Northern Mariana Islands. Targeted management requires an accurate measure of the population status of this species. In Mariana Crows the breeding population is both the easiest cohort to accurately survey and the most important segment of the population in terms of population recovery. The total number of Mariana Crow territorial pairs was estimated on the island of Rota using a direct count method, and total population size was calculated using a Chapman estimate. From September 2013 to April 2014, 46 crow pairs were found and up to an additional eight pairs were estimated in unsearched areas. The total population was estimated to be 178 individuals. This represents a 10–23% decline in pairs in the six years since 2007 and a 46–53% decline since 1998. This number is also considerably lower than the minimum 75 pairs recommended to maintain a viable population on Rota.

Introduction

The Mariana Crow or Aga *Corvus kubaryi*, is native to the islands of Guam and Rota, Mariana Islands. It was listed as an endangered species in 1984 (U.S. Fish and Wildlife Service 1984) and is currently considered 'Critically Endangered' (IUCN 2015). The introduction of the brown tree snake *Boiga irregularis* on Guam in the 1940s decimated the crow population, along with all other native forest birds and wild crows can no longer be found there (Savidge 1987).

The Mariana Crow population on Rota has also experienced significant declines since the 1980s. A 1982 estimate put the population at around 1,300 individuals (Engbring *et al.* 1986), and a second in 1995 set it at 600 individuals; both estimates used variable circular plot (VCP) methods (Fancy *et al.* 1999). A count conducted from 1996 to 1998 estimated 117 breeding pairs, based on direct count (85 pairs) and extrapolation (32 pairs) into unsearched, suitable habitat (Plentovich *et al.* 2005). Another count in 2007 revealed only 60 pairs, using only direct count methods (Zarones *et al.* 2015). In 2012, the population was estimated at between 30 and 202 individuals using VCP methods (Camp *et al.* 2015). In contrast to the situation on Guam, there is not a clear, single reason for the decline of crows on Rota. The cause could include one or more factors including habitat loss and degradation, human disturbance and direct persecution, habitat alteration by typhoon activity and introduced deer, introduced predators such as cats, rats and monitor lizards, as well as

the deleterious effects of inbreeding (Morton *et al.* 1999, Tarr and Fleischer 1999, U.S. Fish and Wildlife Service 2005). Endemic island species often lack antipredator behaviours and thus suffer from the introduction of non-native predators (Blackburn *et al.* 2004), which are one of the most prominent causes of the decline and extinction of island species worldwide (Vitousek *et al.* 1997, Salo *et al.* 2007).

A recent telemetry study suggests that predation by feral cats may be a significant cause of mortality (Ha *et al.* 2014). In response to these initial findings, a predator control programme was established on Rota in early 2012. In view of this step and other current and proposed population management efforts we aimed to update the island-wide pair count on Rota so that the efficacy of management efforts can be more accurately assessed in the coming years.

Methods

The study was conducted on the island of Rota, Commonwealth of the Northern Mariana Islands, situated in western Micronesia (14°09'N, 145°12'E). Rota is 86 km² in area and volcanic in origin with terraces of uplifted coral limestone. The climate is tropical with high humidity and warm year-round temperatures.

During the 2013–2014 breeding season we conducted a direct count of all territorial pairs. This method has been successfully used previously to estimate the population of Mariana Crows due to their high nest site fidelity (Plentovich *et al.* 2005, Zarones *et al.* 2015). We searched all territories identified during the September 2007–April 2008 pair survey (Zarones *et al.* 2015) as well as all new territories identified in the years since (Figure 1). The one exception was the lowest terrace of the Rail Trail area (Figure 1), which had difficult access and a sensitive bat colony, and was determined to have only one pair during the 2007 survey (Zarones *et al.* 2015). We excluded some areas of the island that were deemed unsuitable habitat for crows; these included the

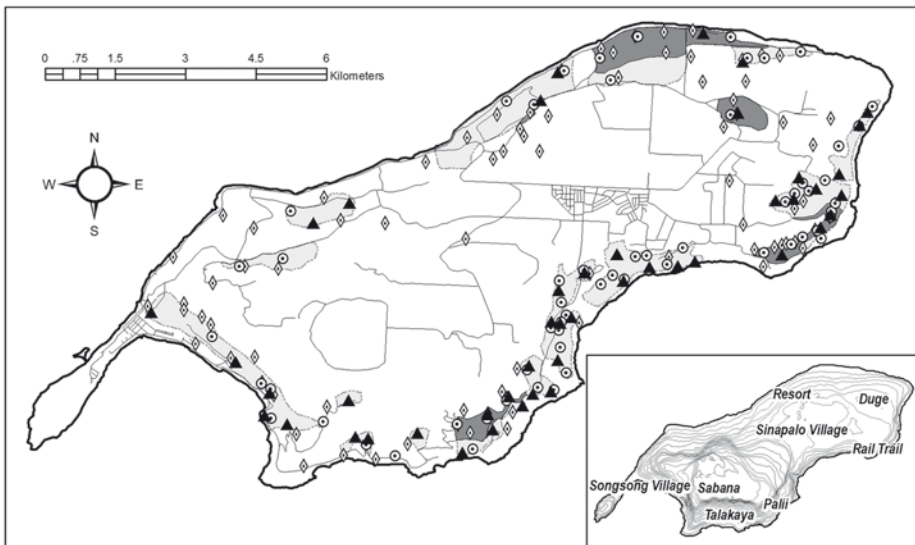


Figure 1. Locations of 2013 pairs represented as black triangles, 2007 pairs as circles and 1998 pairs as diamonds. Areas covered in the search effort are shaded light grey, while areas of overlap with the 1998 and 2007 surveys are dark grey. The location for each pair depicted was either the last nest location from the season, for nests that were found, or a point central to the observed locations of the pair, if no nest was found. Inset: Topographical map of Rota with location names.

residential and agricultural areas of the Songsong Peninsula, Sinapalo area and much of the Duge region (Figure 1). We did not survey the Sabana plateau because former surveys have established that crows rarely occur there (Fancy *et al.* 1999), nor did we survey some privately owned lands with restricted access. Finally, areas in which no pairs were found during the 2007 survey, were excluded due to manpower constraints and the low probability of finding pairs. In these unsearched areas we estimated the maximum number of pairs that could have been missed based on the density of pairs found in nearby, searched habitat.

We spent 845 person-hours searching and confirming pair locations and pair status from 8 September 2013 to 14 April 2014, not including time spent monitoring active nests. Search effort covered approximately 1,485 ha of forest, of which approximately 329 hectares overlapped with areas searched with similar methods in the 1996–1998 and 2007 surveys (Figure 1) (Plentovich *et al.* 2005; Zarones *et al.* 2015). The most intensive searching coincided with the peak period of the crow's breeding season from October to February (Zarones *et al.* 2015). During this time, each former territory was visited at least once every 4–6 weeks regardless of its occupancy status. We worked in a counter-clockwise manner around the island and attempted to visit multiple adjacent territories on the same day, with multiple searchers whenever possible, to reduce the chance that a pair straddling two formerly known territories would be double-counted.

Searchers covered each area on foot; the standard search was 1.5–2 hours or until crows were detected, whichever was shorter. Searches were not conducted during heavy rain or wind. Playbacks of crow location calls were used when there were no recent detections in an area. Searchers attempted to determine the status of each pair located during a visit (nesting, with fledgling, etc.), but if the status could not be determined, repeat visits were made to the territory to confirm status. If a pair behaved territorially (agitation, defensive calls, bill pounding, stick throwing, etc.), but was not actively nesting, the territory was visited again after 4–6 weeks. If a pair was found to be nesting, a nest monitoring protocol was used and that territory was not searched for additional occupancy until the nest was determined to have fledged or failed. After a nest attempt terminated, the area was placed back on the regular schedule of searches every 4–6 weeks, to reduce the chance of double counting if that pair later moved to a vacant neighbouring territory.

In the absence of detected nests or young fledglings, individual pairs were identified on the basis of multiple factors: the presence of colour-banded crows, family groups with older fledglings, consistency of sighting locations, observed territorial (defensive calls, bill pounding, stick throwing, etc.) or pair-like behaviour (mate feedings, carrying sticks, etc.) and timing of crow observations in neighbouring areas (Zarones *et al.* 2015).

While both the 1996–1998 and the 2007 counts included pairs located outside the former study plots, uncertainty about the comparability of search methods used in these outer areas spurred us to compare areas that were known, based on the available literature, to be searched using the most similar methods. To compare pair estimates across years we overlaid the study plots searched in the two former pair surveys (Plentovich *et al.* 2005, Zarones *et al.* 2015) with the area searched during this survey, then counted pairs occurring in the areas of overlap (Figure 1). Because the Plentovich *et al.* (2005) study included pairs found over the course of three years within their study plots, we choose to use the number of pairs found only during the latest year, 1998, as a snapshot to compare both this survey and the 2007 survey which were each conducted in one season. Pair density was calculated across years by dividing the number of pairs that occurred in a region (north or south) by the hectares searched in that region that year. For these purposes the north is considered the entire north or northwest-facing shoreline from Songsong Village to the easternmost point of the island, including the Duge homestead area.

To provide an estimate of the population size of Mariana Crows on Rota that was inclusive of non-breeding subadult and adult birds, we recorded all subadult and adult banded and unbanded birds seen throughout the island during the 845 person-hour search. We used the Chapman estimator analysis on these data to acquire a total population size that was unbiased due to small sample size (Chapman 1951).

Table 1. Summary of 46 crow pairs and their status during the period September 2013–April 2014. Shows the highest achieved nesting status of all crow pairs found (i.e. non-breeding pairs, pairs with failed breeding attempts, or pairs that fledged young). *Two fledglings taken into captivity due to poor condition at time of fledging.

Pair status	Number of pairs
Not detected with nests	9
Nested, but failed	21
Fledged 1 young	12*
Fledged 2 young	4
Total pairs	46

Results

We identified a total of 46 Mariana Crow pairs on Rota during the 2013–2014 breeding season (Figure 1). In addition, there were nine unpaired banded crows (six adults, three subadults) resighted on separate occasions, at least once during the season. Thirty-three pairs were detected actively engaged in a nesting attempt (any nest stage from building through fledge) and four pairs were found with young fledglings although the actual nest had not been found in time. A total of 20 fledglings from 16 pairs were confirmed (Table 1).

In a comparison of pair loss across the three surveys (1998, 2007 and 2013) and between north and south regions of the island we found that the three surveys all searched somewhat different, but overlapping areas (Figure 1). If we limit comparisons to direct counts in those areas searched by the same methods, the number of pairs in the North decreased across the survey years from 16 to eight (Table 2). Given that 77% more hectares were surveyed in 2013, the decline in density of pairs is even more dramatic. In the south, the number of pairs counted increased between 1998 and 2013, but, because the number of hectares searched was four times greater, the density still declined (Table 2). Furthermore, in those areas of overlap that were searched in all three surveys using the same methods, the density of pairs has been consistently higher in the south than in the north (Table 3; Figure 1). The sample sizes are too small to conclude that losses from 1998 to 2013 were any greater in the north than in the south (Table 3).

We saw 129 total subadult and adult banded ($n = 23$) and unbanded crows ($n = 106$) during the 845 person-hour search. Based on banding records and resightings from May 2012–May 2015 of birds banded prior to 8 September 2013, we determined that there were 32 banded subadult and adult birds that were available to be seen from 8 September 2013 to 14 April 2014, of which we detected 23/32, or 71.86%. Based on the Chapman estimator analysis, the total population size of subadult and adult Mariana Crows on Rota is thus 178 (Chapman 1951).

Discussion

A number of different methods have been used to estimate the Mariana Crow population on Rota. Estimates in 1982, 1995, 1998 and 2012 used variable circular plot (VCP) surveys island-wide to

Table 2. Pair counts and density of pairs found in 1998 and 2007 within the former study plots (see Plentovich *et al.* 2005) and all area intensively searched in 2013.

Survey Year	Region						Total		
	North			South			Pairs	Hectares	Pair/ha
Pairs	Hectare	Pair/ha	Pairs	Hectares	Pair/ha				
1998	16	384.9	0.042	12	195.3	0.061	28	580.2	0.048
2007	5	384.9	0.013	10	195.3	0.051	15	580.2	0.026
2013	8	682.9	0.012	38	802.1	0.047	46	1485	0.031

Table 3. Pair counts and densities limited to geographically overlapping areas searched in all surveys 1998–2013.

Survey Year	Region								
	North			South			Total		
	Pairs	Hectare	Pair/ha	Pairs	Hectares	Pair/ha	Pairs	Hectares	Pair/ha
1998	10	220.4	0.045	12	108.4	0.111	23	328.8	0.070
2007	5	220.4	0.023	10	108.4	0.092	15	328.8	0.046
2013	3	220.4	0.016	5	108.4	0.046	8	328.8	0.024

estimate the total number of individuals (Engbring *et al.* 1986, Fancy *et al.* 1999, U.S. Fish and Wildlife Service 2005, Camp *et al.* 2015). Comparisons of VCP surveys have shown an estimated population decline of 84–97% from 1982 to 2012 (Engbring *et al.* 1986, Camp *et al.* 2012). A comparison of the population estimates based on direct count methods shows a decline of approximately 49% from 1998 to 2007, and an additional reduction of around 10–23% from 60 pairs in 2007 to 46–54 pairs in 2013 (Zarones *et al.* 2015). When all three direct count surveys are compared there is an approximately 46–53% decline from 1998 to 2013.

The 2007 survey observed substantial pair losses in the northern study areas when compared to the 1998 study, but relatively stable pair numbers in the Rail Trail and Palii study areas (Zarones *et al.* 2015). Mariana Crow studies on Rota in the 1990s restricted most search effort to six study plots, four of which were on the north side of Rota, and pairs were located outside these plots somewhat opportunistically over the course of 10 years (Plentovich *et al.* 2005). Searches in more recent years have included much more of the south side of the island (Table 2). Our comparisons of pair densities across the three direct-count surveys suggests that the crow population has typically been denser in the south than the north. However, even the 1998 survey occurred after Rota population declines had been detected, and may not fully represent the natural density and distribution of the population across the island prior to the decline. The apparently greater decline in the north between 1998 and 2007, was not seen between 2007 and 2013. In fact, the declines between the north and south are very similar for 2007–2013.

These density differences could be due to a number of factors, including habitat loss from development or degradation by typhoons, reduced habitat connectivity, and persecution by humans in the more accessible northern parts of the island. The north and north-eastern portions of the island consist largely of privately owned land, or have been slated for homestead development. Although there has been limited direct evidence of persecution, when the Mariana Crow was listed as endangered in 1984 much of the homestead development was halted, and this is still a contentious issue with some residents (Morton *et al.* 1999, Sussman *et al.* 2015). Further, recent estimates of forest loss only account for broad scale changes for the island as a whole and no studies have investigated differences in predator abundance across the island (U.S. Fish and Wildlife Service 2005, Camp *et al.* 2015).

Despite efforts to locate all pairs, crows are not always detectable, particularly when they are not calling, and they are not always responsive to playbacks. An established pair with a known territory can wander up to 1 km away even during the breeding season, meaning that pair would have gone undetected if the area was searched only once (pers. obs.). This is why we conducted multiple searches in each area in order to consider it sufficiently searched. In addition, due to limitations in manpower, some areas where pairs were identified in 1998 were not searched sufficiently, or at all, during this survey. Some areas were not searched due to the presence of sensitive fruit bat colonies, such as the upper reaches of the Palii area (Figure 1). Others had minimal or no detections during the 2007 survey, such as the Resort area and the eastern half of the Duge area, and still others were not searched at all in 2007 with the exception of the coverage provided by the quarterly road survey (Berry *et al.* 2008). Given limited manpower, exploratory searches into these areas were left at a minimum. Therefore, it is possible that additional pairs occur there. Based on the densities found in the surrounding areas, no more than an additional eight pairs

could be added to the total of 46 detected pairs. This estimate is consistent with a follow-up survey done during the 2015 breeding season in which 50 pairs were found in an expanded search effort with a 55% increase in person-hours and 425 more hectares covered. Forty-seven of the 50 pairs were found in areas that had also been searched in 2013 (Faegre *et al.* 2016).

The 2013 pair survey estimated a population of up to 54 pairs of crows, or 108 adults. Our mark-resight population estimate using the Chapman index is 178 birds. Given the low end of the pair estimate and not counting sub-adult or fledgling birds, the adult population is between 92 and 108 individuals based on the pair survey. Subtracting the median of that range, or 100, from the Chapman estimate (178), gives an additional 78 individuals that may not have been directly detected in the pair survey. Many of these are likely to be subadult individuals (floaters), as well as some unobserved pairs.

Conclusions

Even at the upper limit of this range of 46–54 pairs, the pair count is still much lower than the 75 pairs needed to maintain a viable population on Rota (U.S. Fish and Wildlife 2005), and the total population size is below 180. We therefore recommend that predator control continue on the island of Rota and that a pair count be repeated with greater frequency to better determine the effectiveness of these management efforts. An increase in colour banding efforts, so that pairs can be more individually identifiable, would also aid in monitoring demographics of the population as a whole. Those conducting pair counts should keep track of search effort in terms of person-hours, hectares searched and frequency of visits to allow better comparisons between years.

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