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Estimated population size of the Island Scrub-Jay*Aphelocoma insularis*

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Summary

As an island endemic, the Island Scrub-Jay's *Aphelocoma insularis* population status and conservation are of concern. In addition, because the Island Scrub-Jay is easily observed, it is an ideal candidate for monitoring the effects of management efforts on Santa Cruz Island, California. We used estimates of territory size in several different habitats occupied by the Island Scrub-Jay and the total area of these habitats on the island to develop an empirical estimate of the population size for this species. Our most conservative, and we feel most realistic, estimate for the Island Scrub-Jay breeding population is 7,000 individuals and for the non-breeding population 5,500 individuals, yielding a total population estimate of 12,500. Even though conservative, this estimate is larger than earlier estimates of 4,000 to 6,000 individuals. Even so, our data suggest no reason exists for immediate concern regarding the population viability of the Island Scrub-Jay and they provide a baseline for future estimates and comparisons. Most importantly, this population estimate can be used to monitor the influence on the Island Scrub-Jay of future island management efforts, especially regarding exotic tree species and feral pigs.

Introduction

Of the 176 bird species and subspecies that have gone extinct since 1600, 163 have lived on islands; island species also make up approximately one half of the world's currently endangered birds (King 1985). Numerous causes for this trend exist, but inherent to most is the fact that island populations are, by definition, limited in distribution and therefore are more susceptible to disturbances than are larger mainland populations. The conservation of island species is considered important for a number of practical reasons, as well as ethical ones. Island species play an important role in our understanding of biogeography and evolution. Islands also will likely be important in understanding the ecology and evolution of populations that have been restricted to continental wildlife reserves (King 1985).

In order to assess the viability of a population, it is helpful to develop a population estimate that will determine if that particular species is threatened and will establish a baseline with which future estimates can be compared. In addition, management efforts often require the detailed information that can come only from long-term ecological studies (Woolfenden and Fitzpatrick 1991). In this study we have developed the first empirical estimate of the population size for the Santa Cruz Island Scrub-Jay *Aphelocoma insularis*, an insular, endemic species for which long-term ecological and behavioural studies are ongoing.

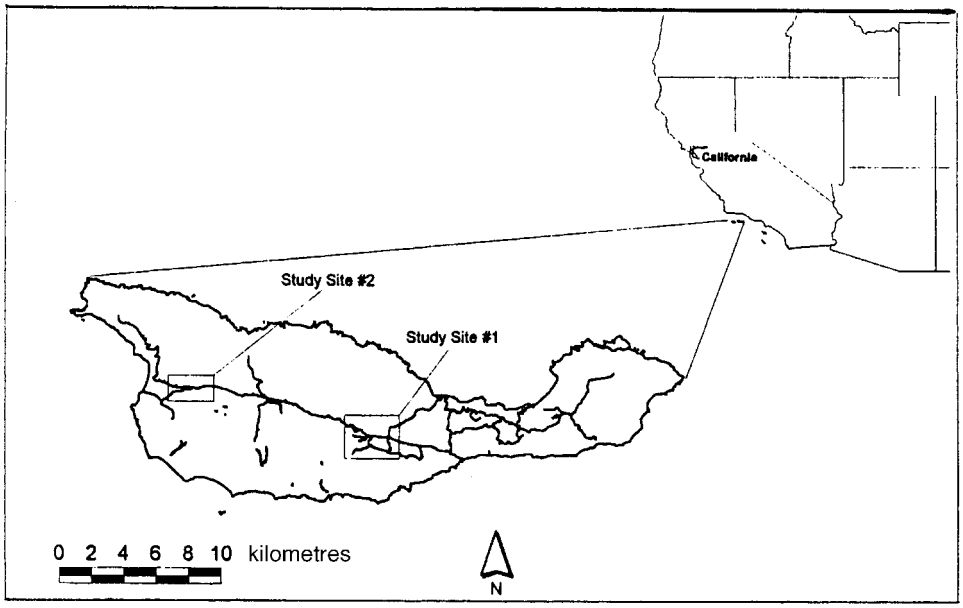

Figure 1. Santa Cruz Island and the study sites where Island Scrub-Jay territories were mapped.

The Island Scrub-Jay is restricted to Santa Cruz Island, the largest of the California Channel Islands (Figure 1), and is the most morphologically distinct member of the Channel Islands' avifauna (Atwood 1979, 1980a, Isitt 1989, Collins and Corey 1994). It was originally described as a distinct species based on morphology (Henshaw 1886), but was later designated a subspecies within the broad *A. californica* group. The Island Scrub-Jay was more recently re-elevated to full species status based on genetic evidence (Peterson 1992, American Ornithologists' Union 1995). Like its California mainland relative, the Western Scrub-Jay *A. californica*, the Island Scrub-Jay occupies oak woodland and chaparral habitats; it also defends territories in relict pine forest, riparian scrub and eucalyptus groves (Atwood 1980a). The Island Scrub-Jay has a unique social structure in that it shares features found in both its non-cooperative and cooperative breeding congeners. Like the Western Scrub-Jay, it is a permanently territorial, monogamous species that does not breed cooperatively (Atwood 1978, 1980a). On the other hand, acquisition of a breeding territory and the start of reproductive activity are delayed in young birds for an average of 3 to 4 years (Collins and Corey 1994, Corey 1994), which typifies the cooperatively breeding Florida Scrub-Jay (*A. coerulescens*; Woolfenden and Fitzpatrick 1984).

The objective of this study was to use measures of territory size and estimates of the total area of habitat available on the island to develop a population estimate for the Island Scrub-Jay. Because this species is isolated on a single island, its long-term viability is of some concern; a baseline estimate of its population size will be important in any future conservation efforts. Also, because the Island Scrub-Jay is relatively abundant and easily observed, it is an ideal candidate for

monitoring the effects of habitat conservation and management efforts on Santa Cruz Island.

Study Area

This study was carried out between March 1996 and September 1997 at two sites on Santa Cruz Island, which is located approximately 29 km south of Santa Barbara on the California coast. Santa Cruz Island is the largest and most topographically diverse of the California Channel Islands, with an area of approximately 250 km^2 (Figure 1; Raven 1967, Minnich 1980). The dominant vegetation classes on the island, in order of increasing abundance, include non-native grasslands, chaparral, oak woodlands, coastal sage scrub, riparian scrub, and pine forest (Jones *et al.* 1993). Scrub-oak habitat is included in the chaparral classification. Barren areas also make up a significant portion of the island, covering approximately 20% of the total land area.

Methods

The main study area, site 1 (Figure 1), encompassed a population of marked birds that have been the subject of demographic and breeding biology studies since 1974 (Atwood 1980a, Atwood *et al.* 1990, Corey 1994, Collins and Corey 1994). This study site included territories within oak woodland, scrub oak, chaparral, riparian scrub and eucalyptus. We also established a new marked population at site 2 (Figure 1) in order to include Island Scrub-Jay use of pine forest habitat in the analysis. We captured breeding and non-breeding birds at both study sites using a baited box trap and marked each bird with three coloured plastic leg bands and one numbered U.S. Fish and Wildlife Service aluminum band for individual identification. The new pine forest population required three days of acclimation to the baited traps before trapping was successful. Once a few individuals became acclimated, many others were readily trapped.

We spent a total of 45 days on Santa Cruz Island, during which 140 hours were devoted to mapping 23 territories on which male and female owners were known and identifiable by their colour band code. We selected territories for mapping based on the presence of known individuals and in order to represent as many habitats as possible (Table 1). Chaparral habitats on north-facing slopes and dense oak woodland habitats in canyons were excluded because of the difficulties in following individual birds and our inability to map their movements onto aerial photographs.

We mapped territory use by following the male owner of each territory for a minimum of five 1–2 hour sessions. During each mapping session we recorded the bird's position after each significant movement on large-scale infrared aerial photographs. These resulted in a continuous data set of point locations within each territory. Any movements that appeared to be in direct response to our presence were excluded. However, the continued foraging and territorial behaviour of the jays indicated that the birds paid little attention to us during these mapping sessions.

As described by Kelsey (1998), the point maps that we generated in the field were transferred to geographically referenced digital versions of the same photo-

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graphs used in the field using the GIS program ArcView, produced by Environmental Systems Research Institute (ESRI). From these digital point maps of territory use we were able to calculate territory size and the total area of each vegetation type within each territory.

The program CALHOME (Zie *et al.* 1994) was used for generating 95% adaptive kernel (Worton 1989) territory size estimates. We chose this method based on the superior performance of kernel type estimators in evaluations of accuracy for the various methods available (Seaman and Powell 1996).

We classified each territory into one of five habitat types based on the dominant woody vegetation present on the territory. The accuracy and predictability of these classifications were tested using discriminate function analysis based on the mapped vegetation on each territory (Kelsey 1998).

We calculated the size of the total breeding population on the island by multiplying the average territory size for each habitat by the total area of that habitat available on Santa Cruz Island, as estimated by Jones *et al.* (1993). Three estimates of the non-breeding population were calculated. The first estimate was developed using a formula presented by Brown (1969) for calculating the number of surplus individuals per capita in a population. For this formula, we used the mean clutch size of the Island Scrub-Jay (Atwood 1980a), and the survival rates of breeders and non-breeders (Collins and Corey 1994). Our second estimate was based on Carmen's (1988) life-table calculations that estimated the non-breeding Island Scrub-Jay population to be 50% of the total population. Carmen based these calculations on the clutch size and survival rates proposed by Atwood (1980b) and other demographic measures that he had estimated for the Western Scrub-Jay. Our third estimate of the non-breeding population size was based on an assumption that Carmen's ratio of one non-breeder per breeder applies only to optimal habitats, in which it could be expected that individuals waiting for a territory opening would prefer to forage.

Results and discussion

Observation point independence

We mapped a total of 23 territories during this study. For each of these territories a minimum of five one hour mapping sessions was completed. The sample size of observation points for these territories varied considerably, depending on our ability to locate the individual birds while following their movements (Table 1). One of the assumptions associated with these types of analyses is that of the statistical independence of the observation points collected. We tested the independence of the points collected by using Schoener's ratio (Schoener 1981) as described in Swihart and Slade (1985a, 1986). Each test for independence was non-significant, supporting the null hypothesis that the points collected were autocorrelated ($P > 0.25$). Swihart and Slade (1985a, b) suggested that non-independence may result in biased estimates, warning that such points can result in underestimates of territory size. However, other studies have indicated that the use of autocorrelated data may not significantly influence estimates of territory size (Anderson and Rongstad 1989, Gese *et al.* 1990, Call *et al.* 1992). Anderson and Rongstad (1989) suggest that in highly mobile species the use of autocorrel-

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Table 1. The Island Scrub-Jay territories mapped during 1996 to 1997 including point sample size, dates visited, and the general habitat type for each territory

Territory name	No. of points	Dates visited	Total hours	Habitat type
Big Oak West	51(48)[a]	4/2/96, 5/26/96, 7/6/96, 5/17/97, 5/25/97	8	Oak
Big Oak East	49(68)[a]	4/2/96, 4/5/96, 4/7/97, 5/17/97, 5/25/97	7	Scrub oak
Lower Big Oak	55	4/2/96, 5/25/96, 7/4/96, 3/23/97, 3/24/97, 4/7/97	9	Scrub oak
3 Fingers West	80	3/24/97, 5/24/97, 5/27/97, 6/2/97, 6/3/97, 6/5/97	7	Scrub oak
3 Fingers East	88	4/3/96, 5/25/96, 5/27/96, 3/24/97, 5/23/97, 5/27/97, 6/2/97	10	Scrub oak
3 Fingers Lower	67	5/24/97, 5/26/97, 6/1/97, 6/2/97, 6/3/97, 6/5/97	6	Scrub oak
Spring Canyon	74	4/3/96, 5/26/96, 5/27/96, 3/24/97, 3/27/97	8	Oak
Dry Canyon	80	4/3/96, 5/26/96, 3/24/97, 3/27/97, 5/23/97	7	Scrub oak
Coches Grove B	46	3/25/97, 3/27/97, 5/16/97, 5/25/97, 5/30/97, 6/2/97, 6/3/97	7	Eucalyptus
Coches Grove C	53	7/3/96, 3/25/97, 3/27/97, 4/5/97, 5/16/97, 5/25/97, 5/30/97, 6/3/97	8	Eucalyptus
Coches Grove D	40	3/25/97, 3/27/97, 4/5/97, 5/24/97, 5/27/97, 5/30/97	6	Eucalyptus
Pat's Ridge	52	3/26/97, 3/29/97, 5/24/97, 5/26/97, 6/3/97	5	Scrub oak
Two Oaks	63	3/26/97, 3/29/97, 4/5/97, 5/24/97, 5/26/97	5	Scrub oak
Islay Ridge Road	68	6/1/96, 3/23/97, 3/26/97, 5/24/97, 5/29/97, 6/5/97	6	Oak
Sherwood Wash	75	7/2/96, 3/26/97, 3/28/97, 5/25/97, 6/2/97	5	Riparian
Grape Canyon	74	7/2/96, 3/26/97, 3/28/97, 5/25/97, 5/28/97	5	Scrub oak
Two Forks Canyon	76	7/4/96, 3/267/97, 3/28/97, 5/25/97, 5/28/97, 6/5/97	7	Riparian
Pine Forest 2	70	3/25/97, 3/28/97, 4/6/97, 5/17/97, 5/18/97, 5/26/97	6	Pine
Pine Forest 3	76	5/29/97, 5/30/97, 5/31/97, 6/2/97, 6/3/97	5	Pine
Pine Forest 4	99	5/29/97, 5/30/97, 5/31/97, 6/2/97, 6/3/97	5	Pine
Pine Forest 5	79	5/29/97, 5/30/97, 5/31/97, 6/2/97, 6/3/97	5	Pine

[a] These territories have two size estimates because of territorial shifts. The second set of points is in parentheses.

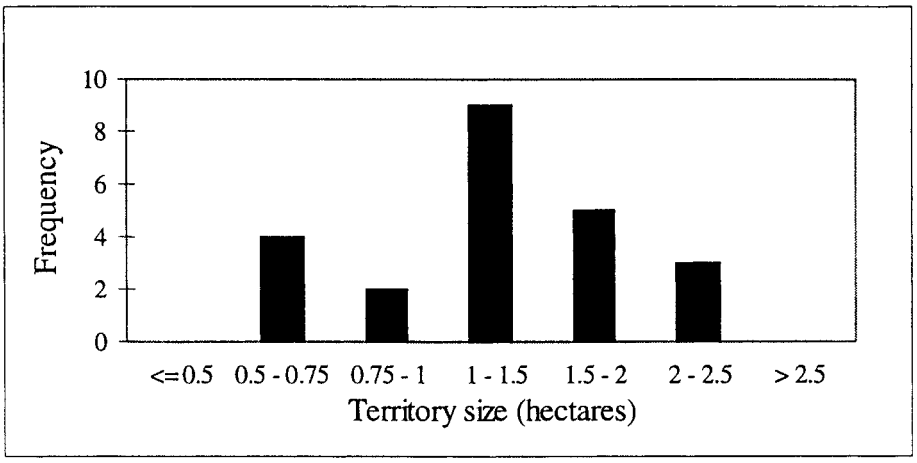

Figure 2. Frequency distribution of territory sizes for the Island Scrub-Jay. The overall mean territory size was 1.35 ha (n = 23).

ated bursts of relocations separated by long intervals between sampling sessions may not severely bias territory size estimates. This is the pattern found with the majority of the points collected in this study. The Island Scrub-Jay inhabits small territories within which it may spend long periods of time in localized areas, separated by movements of greater distance, often the entire length of the territory. Because of this activity pattern, we felt justified in using all of the observation points collected in our size estimates so that the sample size was maximized. Also, the calculated territory boundaries tended to be partially restricted by adjacent territorial pairs. While the patchy mosaic of vegetation types generally prevents territories from being so densely packed that they are entirely surrounded by other territories, in most cases, adjacent suitable woodland habitat was occupied. As a result, any expansion into these adjacent woodland areas would result in substantial overlap between adjacent pairs. This suggests expansion was not possible and thus underestimation of territory size was unlikely.

Territory sizes

Among the 23 Island Scrub-Jay territories we mapped, territory size varied considerably, ranging between 0.594 and 2.243 hectares, with an overall mean size of 1.35 ± 0.52 hectares, with much of the variation occurring among the habitat types (Tables 2 and 3, Figure 2). This mean territory size is statistically similar to Atwood's (1978, 1980b) estimate for the Island Scrub-Jay of 1.5 hectares (t = −1.35, P = 0.19; Table 4) which was based on subjective analysis of a smaller sample located in fewer habitat types. The mean territory sizes in the five different habitat types (Table 3) proved to be significantly different (F = 5.82, P = 0.003).

Population estimate

We found that the Island Scrub-Jay breeds in a broader range of habitats and habitat combinations than had previously been observed. Island Scrub-Jays are

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Table 2. Island Scrub-Jay territory sizes for each territory mapped during this study. The territory size listed is that calculated using a 95% adaptive kernel estimate (Worton 1989)

Territory	No. of points	Territory size (ha)
Boeast 1	49	1.404
Boeast 2	68	1.151
Bolower	55	0.627
Bowest 1	51	1.576
Bowest 2	48	0.659
Dry	80	0.719
Spring	74	1.198
Sherwood	75	2.180
3 Finger W	80	1.405
3 Finger E	88	0.928
3 Finger L	67	1.385
Two Oaks	63	1.962
Pats Ridge	52	1.552
Coches D	40	0.594
Coches C	53	1.008
Coches B	46	1.051
Grape	74	0.895
Islay	68	1.227
Two forks	76	1.948
Pine 4	99	1.800
Pine 2	70	2.205
Pine 3	76	1.435
Pine 4	79	2.243
Mean		1.35 ± 0.52

Table 3. Mean Island Scrub-Jay territory sizes ± two standard deviations in each of the general habitat types surveyed in this study

Habitat	No. of territories	Mean size (ha)
Scrub oak	10	1.2 ± 0.42
Oak woodland	4	1.17 ± 0.38
Riparian scrub	2	2.06 ± 0.16
Eucalyptus	3	0.88 ± 0.25
Pine forest	4	1.92 ± 0.38

not limited to breeding and maintaining territories in scrub oak and oak woodland; they were found also to defend territories in riparian scrub-dominated habitat and in areas dominated by eucalyptus. Since the territory sizes in the different habitat types were significantly different, we used the mean territory size for each individual habitat separately for calculating the total population size. Using the mean territory size and the total area of each habitat type on the island (Jones *et al.* 1993), excluding eucalyptus groves, which constitute a very small fraction of area on the island, we calculated the mean breeding population to be approximately 8,940 individuals (Table 4). This is considerably higher than an early estimate by Pitelka (1951) who estimated the total population at 5,000 individuals.

As mentioned, this species exhibits a unique social system in which a subpop-

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Table 4. Population size estimates for Island Scrub-Jay breeders and non-breeders

Habitat type	Area (ha)	Mean territory size (ha)	Breeders[a]	Non-breeders (Brown 1969)	Non-breeders (Carmen 1988)	Non-breeders (unequal saturation)
Oak woodland	890	1.17 (± 0.38)	1,522 (1,148–2,253)[b]	3,044 (2,296–4,506)	1,522 (1,148–2,253)	1,522 (1,148–2,253)
Scrub oak/chaparral	3,600	1.2 (± 0.42)	6,000 (4,444–9,231)	12,000 (8,888–18,462)	6,000 (4,444–9,231)	6,000 (4,444–9,231)
Pine forest	130	(1.92 (± 0.38)	135 (113–169)	270 (229–338)	135 (113–169)	0
Riparian scrub	1,320	2.06 (± 0.16)	1,283 (1,189–1,389)	2,566 (2,378–2,778)	1,283 (1,189–1,389)	0
Total	5,940		8,940 (6,894–13,042)	17,880 (13,791–26,084)	8,940 (6,894–13,042)	7,522 (5,592–11,484)

Three separate estimates of the non-breeder population are listed based on Brown's (1969) formula for surplus individuals, Carmen's (1988) life-table calculations, and our proposal that only oak-dominated habitats are saturated and contain non-breeders.

[a] Calculated by dividing available area by territory size and multiplying this by two breeders per territory.

[b] This is the range of population size based on the mean territory size plus and minus one standard deviation.

ulation of non-breeding individuals exists that do not acquire a territory and begin breeding until the age of three or four on average. The very high survival (93%; Atwood *et al.* 1990) of this species after the age of two strongly indicates that these non-breeders may constitute a very large proportion of the total Island Scrub-Jay population. This is supported by our own observations of numerous non-breeders in and around our study territories. Because no data exist on the home ranges and overall density of non-breeders, or on the fledging success of pairs, the more difficult and speculative task has been to estimate the size of the non-breeding population. For this reason we have used several methods for comparative purposes. Using the equation proposed by Brown (1969) to estimate the number of surplus individuals in a population we calculated the non-breeding population to be two floaters per breeding adult or 17,880. This would suggest a mean total population of 26,820 individuals (Table 4). This number is extremely high, and based on yearly censuses conducted since the mid-1970s (C.T.C. pers. obs.) this estimate seems unrealistic. A life table analysis by Carmen (1988) using Atwood's (1978, 1980b) demographic data for the Island Scrub-Jay, supplemented by his own data for the Western Scrub-Jay, estimated the Island Scrub-Jay population to be composed of approximately 50% non-breeders. This suggests one floater per breeding adult or 8,940 floaters and a mean total population of 17,880 individuals (Table 4). We feel this is a more accurate estimate of the population because individual mortality, although much lower than on the mainland (Collins and Corey 1994), is still high prior to two years of age. Regardless, this estimate is still far higher than any previous estimates, including an earlier, informal estimate of 10,000 to 15,000 (C.T.C. and K.A. Corey pers. obs.) based on habitat availability (Minnich 1980) and Atwood's (1980b) territory size. One point to be considered is that this number assumes floaters exist for every territory on the island, including those in habitats considered marginal, such as riparian scrub and possibly pine forest. As suggested by Kelsey (1998), the degrees of saturation in these habitats may vary and the marginal habitats may not be saturated at all. In our final estimate we corrected for this possibility by assuming one floater per breeder in oak and oak/chaparral dominated habitats only. This assumption seems reasonable because these are the preferred habitats for the Island Scrub-Jays and because the marginal habitats appear to be less used by the Island Scrub-Jay. A mean total population estimate based on this proposal is slightly lower at 16,462 (Table 4). This population estimate also is higher than any previous estimates and probably represents a maximum estimate.

The estimates of total habitat availability on Santa Cruz Island (Jones *et al.* 1993) used in our calculations of population size are crude and likely included isolated fragments of habitat that are not used by the jays. If this is the case, these population size estimates may still be high and an extensive program of surveys in areas predicted to be occupied by jays will tell whether or not these estimates need to be revised downward and by how much. A better, more empirical estimate of the number of floaters per breeding adult also will be needed for a more accurate population estimate. With these limitations in mind, perhaps a more conservative estimate of the Island Scrub-Jay population size would be 7,000 breeding individuals and 5,500 non-breeders for a total of 12,500. Although lower than the means calculated with the average territory sizes, these estimates are within the statistical limits of our estimations (Table 4).

The Island Scrub-Jay is an endemic species and, as a result, its long-term stability and viability should be considered in decisions to manage the natural resources of Santa Cruz Island. For example, removal of the abundant feral pig (*Sus scrofa*) population certainly would increase the acorn resources available to the jays, because pigs have a significant detrimental impact on oak seedling recruitment (Peart *et al.* 1994). Future conservation efforts will depend on knowing the Island Scrub-Jay population size and our estimate is the first empirically derived, and therefore currently the most accurate, estimate that can be used for the purpose. In addition, this estimate provides a measure of population density that can be used in future analyses of habitat saturation and its influence on social structure on the island. These population estimates, crude though they may be, suggest that the conservation status of the Island Scrub-Jay should not be changed and that we may remain optimistic about its future survival.

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