Current Distribution and Abundance of O‘ahu ‘Elepaio (*Chasiempis ibidis*) in the Wai‘anae Mountains[1]

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Abstract: The O‘ahu ‘Elepaio (*Chasiempis ibidis*) is an endangered forest bird endemic to O‘ahu and has declined steadily during the past century. Current information on distribution and abundance is needed to help assess the species status and identify areas where recovery efforts can be focused. We used spot-mapping methods to census O‘ahu ‘Elepaio in all suitable forest habitat in the Wai‘anae Mountains from 2006 to 2010 and compared results with previous surveys from the 1990s. We detected a total of 300 O‘ahu ‘Elepaio, including 108 breeding pairs and 84 single males. The sex ratio was strongly male biased due to nest predation on females. Their distribution was extremely fragmented, and the only concentrations were in ‘Ēkahanui (38 pairs), Schofield Barracks West Range (40 pairs), and Pālehua (15 pairs). We failed to detect ‘Elepaio in many areas where they were observed in the 1990s. ‘Elepaio have become more sparse in other areas, indicating that they are continuing to decline. Nest predation by alien black rats (*Rattus rattus*) and mosquito-borne diseases are the greatest threats. Rat control programs have helped reduce nest predation and stop declines in several areas, but only a fraction of remaining ‘Elepaio benefit from active management and further declines can be expected unless rats are controlled on a larger scale. Alternative methods of rat control should be explored, and restoration of native trees that are less attractive to rats might provide safer nest sites and reduce the need for rat control.

‘Elepaio are territorial, nonmigratory monarch flycatchers (Monarchidae) endemic to the Hawaiian Islands of Kaua‘i, O‘ahu, and Hawai‘i (VanderWerf 1998). The forms on each island were treated as subspecies for many years, but morphological, behavioral, and genetic evidence indicate that ‘Elepaio on each island constitute separate species (Conant et al. 1998, VanderWerf 2007*a*, VanderWerf et al. 2009). In 2010, the American Ornithologists’ Union changed the taxonomy of ‘Elepaio so that each island form is again recognized as a species (Chesser et al. 2010). The Kaua‘i ‘Elepaio (*C. sclateri*) and Hawai‘i ‘Elepaio (*C. sandwichensis*) are fairly common and widespread (Scott et al. 1986, Gorresen et al. 2009), but the O‘ahu ‘Elepaio (*C. ibidis*) is rare and locally distributed and is listed as endangered under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2000) and by the State of Hawai‘i. The O‘ahu ‘Elepaio was abundant and widespread in forested habitat throughout the island early in the twentieth century (Seale 1900, Perkins 1903, Bryan 1905), but it has declined steadily and now occupies <4% of its presumed prehistoric range (VanderWerf et al. 2001). The islandwide population was estimated to be 1,980 birds based on surveys

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conducted during the 1990s (VanderWerf et al. 2001). Their distribution was highly fragmented, with six relatively large populations estimated at 100 or more birds and numerous small relicts with just a few birds. Roughly half of the total population and three of the six large populations were found in the Wai‘anae Mountains, including the second and third largest populations, which were located in The Nature Conservancy's Honouliuli Preserve and on U.S. Army Schofield Barracks West Range, respectively.

The most serious threats to the O‘ahu ‘Elepaio are nest predation by alien black rats (*Rattus rattus*) and introduced mosquito-borne diseases, particularly avian poxvirus (*Poxvirus avium*) and avian malaria (*Plasmodium relictum*). Prevalence of these diseases is high in O‘ahu ‘Elepaio (VanderWerf et al. 2006) and poxvirus causes some mortality, but the effects of nest predation by rats are generally more serious (VanderWerf 2009). Feral cats (*Felis cattus*) also may prey on ‘Elepaio occasionally, and newly fledged ‘Elepaio are vulnerable to a variety of predators, including feral cats, small Indian mongooses (*Herpestes auropunctatus*), and feral pigs (*Sus scrofa*), because they sometimes leave the nest before they can fly well and spend time on or near the ground (VanderWerf 1998).

Introduced predators are one of the most serious threats to island birds, and black rats have been particularly destructive, causing or contributing to the decline and extinction of many endemic species (Atkinson 1977, Steadman 1995, Blackburn et al. 2004). Several lines of evidence indicate that nest predation by black rats is the most serious threat to O‘ahu ‘Elepaio. Artificial nest experiments revealed that predation rates are high in O‘ahu ‘Elepaio habitat and that black rats are the most common nest predator (VanderWerf 2001). A rat control program using snap traps and rodenticide bait stations was begun in 1996 in an effort to stop ‘Elepaio population declines and begin recovery, and this proved to be an effective means of increasing nest success and survival of nesting females (VanderWerf and Smith 2002, VanderWerf 2009). Female ‘Elepaio are more vulnerable to nest predation than males because they alone incubate at night, when rats are most active, causing higher mortality among females and a skewed sex ratio (VanderWerf 2009). Rat control allowed the sex ratio to become more equal and also increased mate fidelity (VanderWerf and Smith 2002). Rat control programs have been implemented to protect ‘Elepaio in several areas on O‘ahu by multiple agencies and organizations (U.S. Fish and Wildlife Service 2006, VanderWerf 2007*b*, O‘ahu Army Natural Resource Program 2009). However, rat control efforts have been relatively small in scale thus far, and the majority of ‘Elepaio remaining on O‘ahu do not benefit from active management.

Current information about distribution and abundance of O‘ahu ‘Elepaio is needed to help assess status of the species and identify areas where recovery efforts can be focused. In this paper, we provide an update on status of O‘ahu ‘Elepaio in the Wai‘anae Mountains based on a thorough census of all suitable habitat from 2006 to 2010. We also compare these results with previous population estimates and discuss causes of the apparent decline. Additional surveys have been conducted in portions of the Ko‘olau Mountains, but more effort is needed before the population estimate for the eastern half of O‘ahu can be updated.

MATERIALS AND METHODS

We used spot-mapping survey methods to conduct a census of O‘ahu ‘Elepaio in all areas of the Wai‘anae Mountains that contain potentially suitable forest habitat. Surveys consisted of walking up or down a gulch or ridge or traversing an area of forest and stopping to play recorded ‘Elepaio songs at approximately 100 m intervals. ‘Elepaio defend territories year-round, and song playbacks are an efficient method of locating birds and determining the extent of their territory (Falls 1981, VanderWerf 2004). ‘Elepaio often respond more strongly to local song dialects (VanderWerf 2007*a*), so recordings used during playbacks were from the area being surveyed or a nearby area. After each playback observers listened and watched for ‘Elepaio for several minutes. Most ‘Elepaio respond to recorded

songs within 1 min (VanderWerf 2007*a*), but some birds approach quietly and must be searched for visually. We recorded the age and sex of each ‘Elepaio observed, any behaviors or association with other ‘Elepaio, and whether each territory contained a pair or a single male. The location of each detection was determined by GPS if possible, or with an altimeter and topographic map. Consecutive detections were counted as different individuals if the birds could be distinguished by color bands or distinctive plumage, or if the detections occurred more than 150 m apart, making it unlikely that they were from the same territory. ‘Elepaio territory size varies with habitat structure and population density (VanderWerf 2004), but the width of a territory is usually 75–150 m. ‘Elepaio may move farther and follow an observer for longer distances in areas with sparse populations. If it appeared that a bird was following us, we used additional playbacks to ascertain the extent of individual territories to avoid counting birds twice. We estimated the total current population of ‘Elepaio in the Wai‘anae Mountains by adding the numbers of birds found in all areas. Not all areas were visited in the same year; surveys began in 2006 (VanderWerf 2006, Mosher 2007), and it took several years to complete surveys in all areas. Some areas were visited only once, but others were surveyed annually as part of recovery efforts for the species, in which case numbers from the latest year were used for the purposes of this study.

RESULTS

During spot-mapping surveys from 2006 to 2010, we detected 300 O‘ahu ‘Elepaio in the Wai‘anae Mountains, including 108 breeding pairs and 84 single males (Table 1). Their distribution was extremely fragmented (Figure 1). The only concentrations of ‘Elepaio were found in ‘Ēkahanui (38 pairs), Schofield Barracks West Range (42 pairs), and Pālehua (15 pairs), and these three sites now comprise 88% of the breeding population in the Wai‘anae Mountains. Mākaha also contained several ‘Elepaio, but most were single males. There were two pairs in Mākua Valley, but no other areas were found to support more than a single breeding pair. The sex ratio was male-biased in all areas, the bias was more severe in smaller populations, and some population remnants consisted entirely of males. The sex ratio was least skewed in areas where rats have been controlled, including ‘Ēkahanui, Pālehua, and portions of Schofield Barracks. We failed to detect ‘Elepaio in many parts of the Wai‘anae Mountains where they were observed in the 1990s, including Lualualei, Kuaokalā, Mokulē‘ia, and Pahole (Figure 1). ‘Elepaio now appear to be absent from the entire northern end of the Wai‘anae Range. In other areas some territories have been vacated and ‘Elepaio have become more sparsely distributed.

DISCUSSION

The number of O‘ahu ‘Elepaio estimated to occur in the Wai‘anae Mountains is low, their range is small, and their distribution is fragmented. Moreover, the long-term decline in number and range of ‘Elepaio has continued since the 1990s (VanderWerf et al. 2001). The larger populations in ‘Ēkahanui and vicinity, Schofield Barracks, and Mākaha all have declined during the past 20 yr, though numbers have stabilized recently in response to rat control (VanderWerf et al. 2011). Several smaller populations have disappeared completely, including those in Kuaokalā, Mokulē‘ia, Pahole, Lualualei, and Schofield Barracks South Range (Table 1). The population at Pālehua was not known in the 1990s and was rediscovered in 2006 (VanderWerf 2007*b*), and though small, it now represents the third largest population in the Wai‘anae Mountains. The remaining populations are now even more isolated from each other, further reducing the effective total population size. Observed natal dispersal distances in ‘Elepaio have been less than a kilometer, and rare instances of breeding dispersal are even shorter (VanderWerf 2008), making it unlikely that the remaining fragments are connected via dispersal or will be rescued from decline by immigration.

The distribution and abundance of O‘ahu ‘Elepaio reported in this study are likely to be

TABLE 1

Oʻahu ʻElepaio Abundance in the Waiʻanae Mountains

Code	Location	No. of Pairs	No. of Single Males	Latest Survey	Comments
1	Kuaokalā GMA (Kaluakauila)	0	0	2007	Single male last observed in 1999
2	Kuaokalā FR	0	0	2004	Last observed pair and single male in 2001
3	Mokulēʻia FR	0	0	2007	Single male last observed in 1991
4	Pahole NAR	0	0	2009	Pair last observed in 1999, single male in 2000
5	Kaʻala NAR	1	1	2010	
6	Mākua Valley	2	2	2010	
7	Mākaha Valley	5	13	2009	Number of pairs declined despite rat control from 2006 to 2009
8	Waiʻanae Kai FR	0	4	2009	
9	Schofield Pulee	1	3	2010	Includes guava, coffee, and lama
10	Schofield North Haleʻauʻau	12	1	2010	
11	Schofield Central Haleʻauʻau	15	11	2010	
12	Schofield South Haleʻauʻau	1	1	2010	Also called Baby Water Gulch
13	Schofield North Mohiākea	8	2	2010	Also called Banana Gulch
14	Schofield South Mohiākea	5	2	2010	Also called Big Lucky Gulch
15	Schofield South Range	0	0	2004	Single male last observed in 2002
16	Lualualei Naval Magazine	0	0	2009	2 single males last observed in 2006
17	Waiʻeli Gulch	0	0	2006	
18	Kaluaʻa Gulch	1	5	2006	
19	Maunalina Gulch	0	0	2006	
20	Manuwaielelu Gulch	0	1	2006	
21	Huliwai Gulch	0	5	2006	
22	ʻĒkahanui North	1	3	2009	
23	ʻĒkahanui Central+South	37	8	2009	2010 data not compiled yet
24	Puʻumaialau Gulch	0	0	2006	
25	Pōhākea Gulch	0	0	2006	
26	Pualiʻi Gulch	0	1	2006	
27	Nepepeiauolelo Gulch	0	0	2006	
28	Pālāwai Gulch	0	6	2006	
29	Kaʻaikukui Gulch (Palikea)	1	2	2009	
30	Manuwaikaale Gulch	1	1	2010	
31	Namoʻopuna Gulch	1	2	2010	
32	Kaloi Gulch (Pālehua)	15	4	2010	
	Total	108	84		Total population = 300

Note: Numbered location codes correspond to those in Figure 1. Abbreviations: FR, forest reserve; GMA, game management area; NAR, natural area reserve.

accurate but may be slight over- or underestimates. During initial surveys of Pālehua in 2006, we detected 11 pairs and 10 single males, but more thorough monitoring in 2007, including mist netting and color banding to allow identification of individual birds, showed that there were 10 pairs and 10 single males, indicating that the number of birds had either declined or been overestimated by 6%. During similar surveys of the Koʻolau Mountains in the 1990s, initial surveys detected eight ʻElepaio pairs in Kuliʻouʻou Valley and 28 pairs in Pia Valley, and more intensive monitoring subsequently revealed the presence of nine and 30 pairs in those areas, respectively, resulting in underestimates of 6%–11% (VanderWerf et al. 1997). We covered virtually all areas of suitable forest habitat in the Waiʻanae Mountains, but it is possible we missed a few birds. Male ʻElepaio usually respond rapidly to playbacks of recorded songs (VanderWerf 2007*a*), but a few males do not respond on any given day. Female ʻElepaio usually accompany the male during

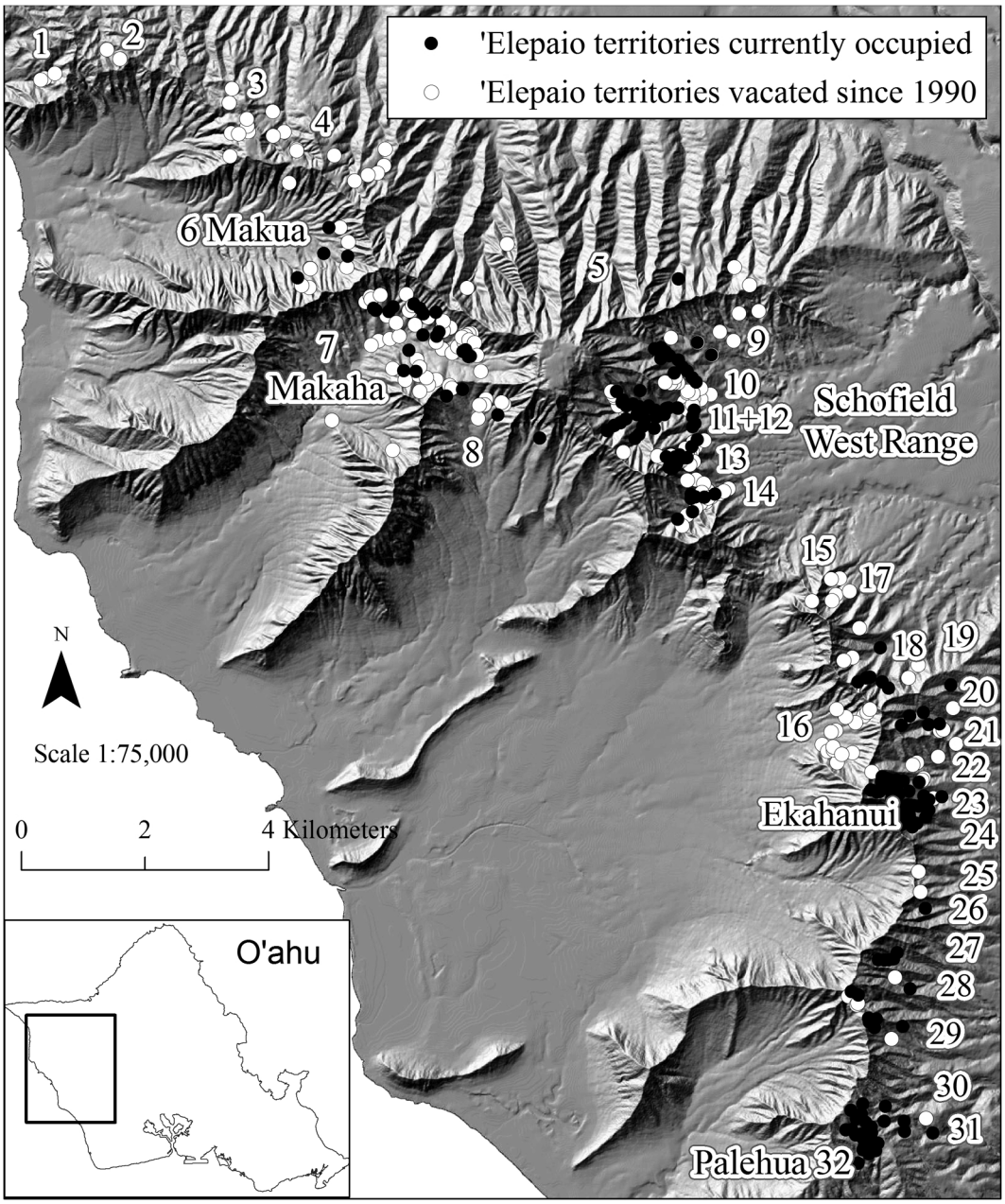

Figure 1. Map of the Wai‘anae Mountains on O‘ahu showing locations where ‘Elepaio were detected during surveys from 2006 to 2010 and where they have disappeared since 1990. Numbers correspond to location codes in Table 1.

territorial disputes and during responses to playbacks, but females are less aggressive and less vocal (VanderWerf and Freed 2003, VanderWerf 2007*a*), so it is possible that some males counted as single actually had a mate.

Although it is clear that ʻElepaio have declined in number and range since the 1990s, some of the apparent decline may be an artifact of previous population estimates that were too high in some areas. Previous estimates in some areas were not based on a complete census but instead used extrapolation of ʻElepaio territory density in a portion of the area surveyed to the total extent of suitable habitat within that area (VanderWerf et al. 2001). Some suitable habitat may not have been occupied in certain areas, resulting in overestimates of the actual population. For example, four pairs and five single males were found in a portion of Lualualei during a single day in March 2000, and it was assumed that ʻElepaio occurred at a similar density throughout the valley, leading to an estimate of over 50 birds. ʻElepaio have completely disappeared from Lualualei in the past 10 yr, and in retrospect it seems likely that their distribution was more restricted in 2000 and fewer birds were actually present. Similarly, ʻElepaio occurred at high density in portions of Schofield Barracks West Range when they were first surveyed in 1996, but the density may not have been as high throughout the area, leading to an overestimate of the population size.

Several causes have contributed to the decline of Oʻahu ʻElepaio during the past century, including the period from 1990 to 2010. At least two epizootics of avian poxvirus have occurred recently in Oʻahu ʻElepaio, in 1995–1996 and 2003–2004 (VanderWerf et al. 2006), and ʻElepaio numbers declined in parts of the Waiʻanae Mountains immediately following those two incidents. For example, surveys in Schofield Barracks West Range in 1996 found a large number of ʻElepaio in north and central Haleʻauʻau drainages, but many fewer ʻElepaio were observed in those areas after 1996. Similarly, several ʻElepaio pairs were found along the main stream in Mākaha Valley in 1996, but they have since retreated to the headwaters and steep side drainages, leaving the majority of the valley unoccupied. VanderWerf (2009) found that the mortality rate of Oʻahu ʻElepaio with active pox infections was about 5% higher than in healthy ʻElepaio, but those results were based on ʻElepaio captured in mesic forests of the Koʻolau Mountains where ʻElepaio probably have been exposed to poxvirus more often. Prevalence of poxvirus was higher in dry areas of the Waiʻanae Mountains, and more birds in those areas may have had no previous exposure to the disease and experienced higher mortality (VanderWerf et al. 2006). In Mākua Valley, prevalence of poxvirus in ʻElepaio was 100% in 1996, and many of the infected birds disappeared over the next 2 yr. The remaining survivors may have greater immunity, but their numbers are very low.

Although ʻElepaio have declined over most of the Waiʻanae Mountains, there is evidence that rat control programs have benefitted some populations and helped stop declines. The only areas where the sex ratio was not highly skewed, which would indicate predation on nesting females, were ʻĒkahanui, Pālehua, and portions of Schofield West Range (Table 1), and it is no coincidence that those areas have been the most intensively managed with rat control. The number of ʻElepaio in those areas has increased over the last 4–5 yr (VanderWerf et al. 2011), but to allow these increases to continue, management efforts must expand to keep pace with ʻElepaio population growth. Rodent control also was conducted in Mākaha but was less effective due to lower density of bait stations and snap traps (VanderWerf et al. 2011). Rodent control at Schofield has been hindered in some years by restrictions on access imposed by military training.

Rat control is an effective means of increasing nest success and survival of female Oʻahu ʻElepaio and is the best management tool available to aid in conservation of the species (VanderWerf and Smith 2002, VanderWerf 2009), but only a small fraction of ʻElepaio on Oʻahu have benefitted from this management. Given the serious demographic effects of nest predation by black rats, the observed declines in ʻElepaio numbers are not surprising, and further declines can be

expected unless a larger proportion of the ‘Elepaio population is actively managed. The most important recovery action for O‘ahu ‘Elepaio is to control black rats on a larger scale. Alternative methods of rat control should be explored, such as large trapping grids, construction of predator-proof fences, and broadcast application of rodenticude to create predator-free “mainland islands” (Clout 2001, Saunders and Norton 2001). There currently is no environmentally responsible method of controlling mosquitoes over large areas of forested habitat to reduce disease transmission, but it may be possible to accelerate evolution of resistance to disease through rodent control (VanderWerf and Smith 2002, Kilpatrick 2006). If there is natural, heritable variation in immunity to disease, actions such as rat control that increase reproduction will allow the proportion of birds with greater immunity to increase more rapidly.

Restoration of native trees that are less attractive to rats would benefit ‘Elepaio by providing safer nest sites and may be a means of reducing the need for rat control. On O‘ahu, ‘Elepaio nest primarily in alien trees that bear fruit or nuts, including strawberry guava (*Psidium cattleianum*), kukui (*Aleurites moluccana*), and mango (*Mangifera indica*), which provide abundant food for rats and may attract rats into the forest canopy, where they encounter and prey on bird nests (VanderWerf 2009). Predominant use of alien trees for nesting by O‘ahu ‘Elepaio does not necessarily imply a preference for those species but simply reflects the dominance of alien plants in the riparian habitats where most remaining O‘ahu ‘Elepaio occur (VanderWerf et al. 2001). On Hawai‘i, ‘Elepaio occur primarily in native forest and nest in native trees, particularly ‘ōhi‘a (*Metrosideros polymorpha*), which has tiny, wind-dispersed seeds that do not provide food for rats, and their nest success is higher (VanderWerf 2004). Gradual replacement of native trees on O‘ahu by invasive alien fruit trees likely has contributed to the decline of O‘ahu ‘Elepaio through increased nest predation and allowed the decline to expand as more areas become alien-dominated. Restoration of native vegetation on Cousin Island in the Seychelles resulted in improved habitat quality for native birds (Diamond 1985). Safford and Jones (1998) recognized restoration of native vegetation as a useful conservation strategy for birds in Mauritius but also cautioned that such restoration may be effective only at small scales, and that management of threats in alien vegetation can be more cost-effective in some cases. Forest restoration had mixed effects on nest success of Western Bluebirds (*Sialia mexicana*) in Arizona; number of young fledged per nest was higher in restored areas, but fledglings in restored areas also had higher rates of infestation by parasitic flies (Germaine and Germaine 2002). Nordby et al. (2009) found that Song Sparrow (*Melospiza melodia*) nests in California were more likely to fail due to flooding when built in alien Atlantic cordgrass (*Spartina alterniflora*) than in native vegetation, and that conversion to nonnative habitat potentially could act as an ecological trap. Alien fruit-bearing trees may represent a similar ecological trap for O‘ahu ‘Elepaio, slowly replacing native forest and reducing availability of safe nest sites. If alien trees are removed from O‘ahu ‘Elepaio habitat, simultaneous reforestation with native species and careful planning of the size and distribution of restoration efforts would minimize any disruption of nest site availability and foraging habitat.

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