In recent years, globalization of trade has accelerated the rate of biological invasions and led to disturbances to and destruction of native ecosystems around the world (Perring et al. 2005). Social insects, especially ants, are regarded as one of the most devastating groups of invaders because ants have important roles in various ecosystems as keystone species (Williams 1994; Chapman & Bourke 2001; Holway et al. 2002; O’Dowd et al. 2003). The Yellow Crazy Ant *Anoplolepis gracilipes* is ranked as among the top 100 of the ‘World’s Worst Invaders’ and leads to predation on birds and crustaceans, the collapse of symbiosis, and changes in community structure (Lowe et al. 2000; O’Dowd et al. 2003; Lester & Tavite 2004). For example, Yellow Crazy Ants altered the rainforest structure on Christmas Island by massacring the indigenous key species in the ecosystem, the Red Land Crab *Gecarcoidea natalis* (O’Dowd et al. 2003). Red Land Crabs, having had formic acid sprayed into their eyes and mouthparts during attacks by the ants, died within 48 hours (O’Dowd et al. 2003). Formic acid produced by ants, such as the Yellow Crazy Ant or the Wood Ant *Formica rufa*, and alkaloids produced by fire ants *Solenopsis* species can be lethal to vertebrates (MacConnell et al. 1970; Bennett et al. 1996; Holway et al. 2002). Formic acid can cause burns and irritation when it contacts the skin or the eyes of humans and inflammation of the skin of the legs and feet, peeling skin and bleeding from the plantar surface of the foot in the Common Starling *Sturnus vulgaris* (Veeresh & Gubbaih 1984; Bennett et al. 1996; Lester & Tavite 2004). Thus, it is considered that ants producing formic acid are potentially capable of killing and damaging various animals from invertebrates to vertebrates (Holway et al. 2002).

The impact of ants on birds depends on the activity of the ants and on the ecology of the birds. Generally, the activity of foraging workers in Yellow Crazy Ants is higher on the ground than on tree trunks because the ants mainly use holes in the ground for nesting (see Abbott 2005). Consequently, bird species that spend more time foraging or nesting on the ground are more likely to be seriously impacted by invasive ants. In fact, ground-nesting Sooty Tern *Sterna fuscata* failed to occupy parts of their nesting colony on
Bird Island, in the Seychelles, because Yellow Crazy Ants had occupied some areas (Feare 1999). In addition, numbers of Emerald Dove 
*Chalcophaps indica*, a species that forages exclusively on the forest floor, are significantly lower in ant-invaded forest than in ant-free forests (Davis et al. 2008). Therefore, concerning the conservation of birds, it is important to investigate interactions between invasive ants and native birds.

The Yellow Crazy Ant, which presumably originated in Africa, has now spread to most Pacific islands and throughout much of the world’s tropical rainforest areas (Lewis et al. 1976; Lester & Tavite 2004). In Japan, the distribution of the ant has been confirmed in 16 islands in the central and southern Ryukyu Islands, in the Ryukyu Archipelago, on Minami- and Kita-daito islands in the Daito Islands, and on the Iwo Islands in the Volcano Islands (Yamane et al. 1999; Takamine 2002; Terayama & Kubota 2002; Ohnishi et al. 2007). To date, whereas several researchers have conducted studies on the phylogeography of exotic ants and assessments of their impacts on native ant communities, little is known about the impact of invasive ants on other taxa in Japan (e.g. Sugiyama 2000; Miyake et al. 2002; Touyama et al. 2003; Ohnishi et al. 2007; Okaue et al. 2007. But see Touyama et al. 2008). This report describes, for the first time, harmful effects of Yellow Crazy Ants on wild birds in Japan: the ants swarmed and assailed the fledglings of two land bird species, Bull-headed Shrike 
*Lanius bucephalus* and Daito White-eye 
*Zosterops japonicus daitoensis*, and forced a cavity-nesting bird species, Daito Scops Owls 
*Otus elegans interpositus*, to abandon the continuous use of nest sites on Minami-daito Island.

**METHODS**

The study was conducted on Minami-Daito Island (25°50′N, 131°14′E), which is situated in the northwest Pacific Ocean approximately 360 km east of Okinawa Island, in the Ryukyu Archipelago (Fig. 1). Minami-daito Island is about 30.57 km² in area with a maximum altitude of 76 m. Bull-headed Shrikes have naturally established populations on the Daito islands since the 1970s (Takagi 2000; Matsui et al. 2006), and the Daito White-eye and the Daito Scops Owl are endemic subspecies of the Daito Islands (Ornithological Society of Japan 2000).

When we unexpectedly found that fledgling Bull-headed Shrikes and Daito White-eyes had been killed or injured, we identified the causes of death or fatal injury from 2004 to 2008. We considered that corneal inflammation and inflammation of the skin of the fledglings over which Yellow Crazy Ants had swarmed, were caused by formic acid released by the ants (refer Bennett 1996; Lester & Tavite 2004). A fledgling Bull-headed Shrike, over which ants had swarmed, was measured on 2 and 9 June 2004, its body mass was recorded to the nearest 0.1 g using a digital balance and its tarsus length and natural wing length were measured to the nearest 0.01 mm with calipers. The date of hatching was estimated by body mass (see Takagi 2001). To estimate whether presence of invasive ants influenced the reproductive success of Daito Scops Owls or not, we investigated the number of fledglings in a cavity with Yellow Crazy Ants and in four cavities without the ants from 2004 to 2008. The number of fledglings was defined as the number of nestlings at 25 days after hatching. We also recorded the number of years owls used the nesting cavities from 2004 to 2008. Nesting height (height of cavity entrance above the ground), length and width of entrance of the nesting cavity, and depth of the cavity were measured in 2008.

**RESULTS**

The causes of death for fledgling Bull-headed Shrikes were traffic accidents (N=3, injury by external impact on the road), predation perhaps by mam-
mals (N=2, feather remains on the ground), typhoon (N=1, depression just after a typhoon passed), and attacks by Yellow Crazy Ants (N=1, corneal inflammation) from 2004 to 2008. We found that the ants assailed a fledgling Bull-headed Shrike on a farm road near the northwest fishing port on 9 June 2004 (Fig. 2a). The fledgling had hatched about 18 days previously, and was still unskilled in flying. It suffered from serious corneal inflammation probably caused by the ants, and died after a few days. There were no remarkable lesions other than the corneal inflammation. The measurement values were 29.1 g and 27.8 g (body mass), 24.36 and 25.98 mm (Tarsus), 36.22 and 59.66 mm (natural wing) at 11 days (just before fledging) and 18 days after hatching, respectively. We observed its vigorous sibling, which weighed less than the wounded individual at 11 days after hatching, on a tree near the nest on 8 June 2004.

The causes of death for fledgling Daito White-eyes were: predation by feral cat (N=1, direct observation), and attack by Yellow Crazy Ants (N=1, corneal inflammation) during 2006 and 2007. We found that three fledgling Daito White-eyes were assailed by the ants on the courtyard of the elementary school on 12 July 2007, during strong wind (mean wind speed 11.3 m/s) as a typhoon (T0704) approached (http://www.okinawa-jma.go.jp). The white-eyes had fledged from their nest that day and were unskilled in flying. Out of three fledglings, one fledgling on the ground was swarmed over by more than 10 ants, and suffered from serious corneal inflammation, inflammation of skin around its eyes and suppuration in the nostrils (Fig. 2b). There were no remarkable lesions other than those described above. The individual died on 15 July 2007. Although fewer than 10 ants swarmed over the other young white-eyes perching on a tree nearby or on a concrete border, they were not seriously wounded by the ants. We observed that a parent white-eye provided food for the fledgling on the tree.

We compared the breeding success of Daito Scops Owls during the five years from 2004 to 2008 between one natural cavity in a Horsetail Tree *Casuarina equisetifolia* with Yellow Crazy Ants and four cavities in Horsetail Trees without ants (Table 1). Out of four cavities without ants, three cavities were successively used for five years from 2004 to 2008 and the other was used for three years from 2004 to 2006. In other words we observed total 18 breeding attempts in the four cavities over the five years. The breeding attempts resulted in success in fledgling (N=14), predation (N=2), and failure in hatching (N=2). In the cavity with ants, Daito Scops Owls attempted to breed every year, and succeeded in fledging young in 2004 and in 2006–08. However a female had disappeared during the pre-laying period in 2005 when we observed eggs and larvae of the ant in the cavity during that period. Although ants had been seen in the cavity for five years, their breeding activities were unknown except in 2005. One male owl had used the cavity from 2004 to 2008 (Table 1), however, each year the female changed, whereas in other natural cavities without ants some females have continued nesting for several years (Table 1). Breeding success and traits of the nest cavity (except depth) in the nests with ants did not differ from four nests with-
DISCUSSION

We observed a fledgling Bull-headed Shrike swarmed over by Yellow Crazy Ants. It is likely that the individual suffered fatal injury caused by the ants, because 1) there were no remarkable lesions other than corneal inflammation, 2) its wings and tarsi developed normally after fledging, 3) weight loss from fledging would not be fatal, 4) we observed another vigorous sibling on a tree the day before finding the wounded fledgling. Fledgling Bull-headed Shrikes move and forage near the ground around arboreal natal nests for a week because they are unskilled in flying. Therefore, they may be at high risk of predation and harassment by Yellow Crazy Ants, because the probability of contact between actively foraging ants and fledglings on the ground is high. Therefore, they may be at high risk of predation and harassment by Yellow Crazy Ants, because the probability of contact between actively foraging ants and fledglings on the ground is high. Similarly, the cause of death of the fledgling white-eye was likely the attack by the ants. We reveal that fledglings are at risk of attack by ants even though they are active because the ants swarmed over an active fledgling being provided with food by its parents. Birds can avoid harassment and attack by ants by hopping or pecking and by stamping their feet (Gerlach 2004; Davis et al. 2008). The fatal injuries caused to the fledgling shrike and white-eye may have resulted from their lack of these avoidance behaviors. However, based on the extent of this study it is not possible to prove whether the birds were vigorous or already dying when the ants began their attack. It is necessary to collect further data to document our hypothesis that Yellow Crazy Ants influence the survival of fledglings unskilled in flying on the ground.

We found no evidence of direct injury of parents or nestling Daito Scops Owls caused by Yellow Crazy Ants in a cavity with ants. Unexpectedly, Daito Scops Owls fledged their young in a cavity with ants (Table 1). The aggressive activity of the ants is lower on trees than on the ground and also lower in small colonies than in supercolonies (Abbott 2005). On Minami-daito Island, the distribution of the ants was restricted to some ports and to a small area of secondarily forest in 2005; namely, supercolonies of the ants had not been observed (Olnishi et al. 2007; Kikuchi et al. in preparation). The direct impact of the ants on birds nesting on trees, therefore, may be comparatively low so far on Minami-daito Island. The main effect of the ants on the reproductive behavior of Daito Scops Owls seemed to be that females that bred in a cavity with ants, more frequently changed their nest site than those nesting in cavities without ants. Although nesting failure or nest predation tended to decrease nest-site fidelity of females in two owl species (Linkhart & Reynolds 2007; Catlin & Rosenberg 2008), we did not find the influence of nest failure on frequent interchange of female Daito Scops

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Table 1. Comparisons of frequency of use, breeding success, interchange of breeding individuals, and traits of nesting cavity dimensions of the Daito Scops Owl between a cavity with Yellow Crazy Ants and cavities without ants from 2004 to 2008. Number within parentheses indicates number of nesting cavities unless noted otherwise.

<table>
<thead>
<tr>
<th></th>
<th>With ants</th>
<th>Without ants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed value</td>
<td>Mean</td>
<td>95% CI</td>
</tr>
<tr>
<td>The number of years owls used cavities over five years</td>
<td>5 (1)</td>
<td>4.5 (4)</td>
</tr>
<tr>
<td>The number of years owls fledged their young over five years</td>
<td>4 (1)</td>
<td>3.5 (4)</td>
</tr>
<tr>
<td>Mean no. of fledglings in successful years</td>
<td>2.5 (1, 4)</td>
<td>2.5 (4, 14)</td>
</tr>
<tr>
<td>(numbers of nesting cavities, successful breeding)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The number of breeding individuals for five years in cavities that had been successively used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of breeding female</td>
<td>5* (1)</td>
<td>2.0 (3)</td>
</tr>
<tr>
<td>No. of breeding male</td>
<td>1* (1)</td>
<td>2.3 (3)</td>
</tr>
<tr>
<td>Traits of the nesting cavity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nesting height (cm)</td>
<td>341 (1)</td>
<td>354 (4)</td>
</tr>
<tr>
<td>Entrance height (cm)</td>
<td>51 (1)</td>
<td>30 (4)</td>
</tr>
<tr>
<td>Entrance width (cm)</td>
<td>7 (1)</td>
<td>11 (4)</td>
</tr>
<tr>
<td>Depth of cavity (cm)</td>
<td>65* (1)</td>
<td>50 (4)</td>
</tr>
</tbody>
</table>

* indicates that an observed value in a nest with ants deviated in the range of 95% confidence interval in nests without ants.
Owls in a nest with ants (Table 1). As well as the known harassment by such ants of other birds (Gerlach 2004; Davis et al. 2008), ant swarming on a tree trunk may cause females incubating or brooding in a cavity to be irritated and may prompt the females to abandon their continuous use of the nest site. At present, the density of Yellow Crazy Ants is not high on Minami-daito Island (Ohnishi et al. 2007). Therefore, the impact on the native bird community is comparatively lower than in regions where several invasive ants form supercolonies. However, there remains the possibility that the Yellow Crazy Ant will form supercolonies on Minami-daito Island and the impacts on native bird species will then become more serious, because invasive ants rapidly increase in population and extend their distribution (Holway et al. 2002). We need to monitor the distribution of invasive ants on the island, to investigate direct and indirect impacts of the ants against the island’s biota in order to conserve the vulnerable insular ecosystem.

ACKNOWLEDGMENTS

We would like to thank Dennis J. O’Dowd of Monash University, Hitoshi Ohnishi and Mayuko Suwabe of University of the Ryukyus for useful information on exotic ants. We are grateful to Takashi Nagamine of Nagamine veterinary clinic and Kazumitsu Kinjyo of Okinawa International University for diagnosis of an injured fledgling of Bull-headed Shrike. We are deeply indebted to Taiki Komine, Akari Isa, and Kazuaki Higashi for informing us of the fledgling Daito White-eyes attacked by ants. I also thank two anonymous reviewers for their helpful comments.

REFERENCES


Ornithological Society of Japan (2000) Check-list of


