Site fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* wintering on Johnston Atoll, central Pacific Ocean

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We monitored the return of marked Pacific Golden-Plovers *Pluvialis fulva* for five seasons on Johnston Island (JI), the largest of four islands comprising Johnston Atoll in the central Pacific Ocean, one of the world's most isolated wintering grounds. The return rate for territorial birds (60%) was significantly lower than on the island of Oahu, Hawaii (83%). Reasons for fewer territorial birds returning to JI are uncertain, but possibilities include higher mortality associated with longer migratory flights, weaker site fidelity because of human disturbance and/or lack of food on JI, and failure to find the tiny island during fall migration. There was no statistically significant difference in return rates of non-territorial plovers on JI and Oahu (59% vs 70%, respectively). Monthly counts over a 12-year period showed considerable variation in the number of plovers wintering on JI. Most of this variability is likely to be related to stopovers by passing migrants and annual breeding success. The migratory schedule at JI was similar to the annual cycle of arrival and departure in Hawaii. To date, non-breeding season studies of marked Pacific Golden-Plovers have been conducted only on Oahu and JI. Further understanding of the species during this period awaits additional investigations in other regions of the winter range.

INTRODUCTION

A sizeable wintering population of Pacific Golden-Plovers *Pluvialis fulva* occurs at Johnston Atoll, one of the most isolated bits of land in the world. From its location in the central Pacific Ocean (at 16°44'N, 169°32'W), the nearest landfalls are Tern Island 850 km to the northeast in the Hawaiian Islands, and Kingman Reef in the Line Islands, 1,570 km to the southeast (Fig. 1). Johnston was claimed by the United States in 1856, and by governmental executive order was declared a federal bird refuge in 1926. Since 1934, the atoll has been under the jurisdiction of the military while at the same time retaining its status as a protected refuge. There are four islands comprising the atoll – the largest being Johnston Island at 254 hectares; the combined area of the three smaller islands is about 26 hectares. Originally, the total landmass of the atoll was much less (only about 20 hectares) with the present-day area having been created by dredging in the period 1939–1964. This expansion was for military purposes that during various periods included aviation, submarine refueling, communications, high altitude nuclear detonations, rocket testing, and storage of hazardous chemicals. Most recently (1990–2002) the military used Johnston Island as the site of a large-scale chemical weapons incineration facility. Over the past four decades, the human population (restricted to Johnston Island) has varied depending on military activities from roughly 600 to 1,200, and the attendant infrastructure has led to a surreal urbanized environment (Fig. 2) surrounded by vast stretches of ocean. The foregoing dates, land areas, and other details are from Amerson & Shelton's (1976) monographic treatment of the atoll plus unpublished records available on-site at Johnston Island. The U.S. Fish and Wildlife Service has maintained a presence on Johnston since 1986.

Relative to the extensive Hawaiian Archipelago, Johnston Atoll is a tiny remotely situated landfall. Previous to this investigation, the only studies of marked *fulva* anywhere on the species' winter range were done on the island of Oahu. Plovers there showed high rates of interyear survival and strong site fidelity (Johnson *et al.* 2001a, O.W. Johnson unpubl. data). In an effort to determine whether plovers elsewhere (in this case a very isolated wintering ground) have the same characteristics, we monitored colour-banded birds at Johnston Atoll over several seasons.

METHODS

We captured 47 plovers (21 during 14–18 February 1998, 20 during 9–20 February 1999, and 6 during 10–12 April 2000) at various sites on Johnston Island (JI). The study was limited to this island as frequent access to other parts of the atoll via small boat was not feasible. Furthermore, almost all plovers on the atoll are concentrated on JI from early morning until evening with the outlying islands used mainly for nighttime roosting (unpubl. records of D.L. O'Daniel, O.W. Johnson & R.W. Schreiber); also, large aggregations of seabirds on the smaller outer islands essentially ruled out our plover-capture techniques at those sites. During periods of limited visibility (pre-dawn, dusk, and occasionally at night), we caught plovers in mist nets; with daylight, we switched to a self-triggering 60 cm diameter clap-net (patterned after the "luchock" design, Priklonsky 1960) baited with pieces of boiled egg. We marked each individual with a U.S. Geological Survey metal ring, plus a unique combination of colour-

bands (the 1998 and 1999 birds) or colour-flags (the 2000 birds). All of the bands and flags were placed on the tibio-tarsi.

We determined age (either adult or first-year) from distinctive plumage characteristics, especially retention of juvenile primaries through the first non-breeding season (Johnson & Johnson 1983, Johnson & Connors 1996). In all, we banded 33 adults and 14 first-year birds. After release, we made repeated observations to locate marked individuals and to determine their mode of wintering behaviour – whether territorial or non-territorial. In the case of territorial birds, we recorded the locations of their territories on sector maps of the island.

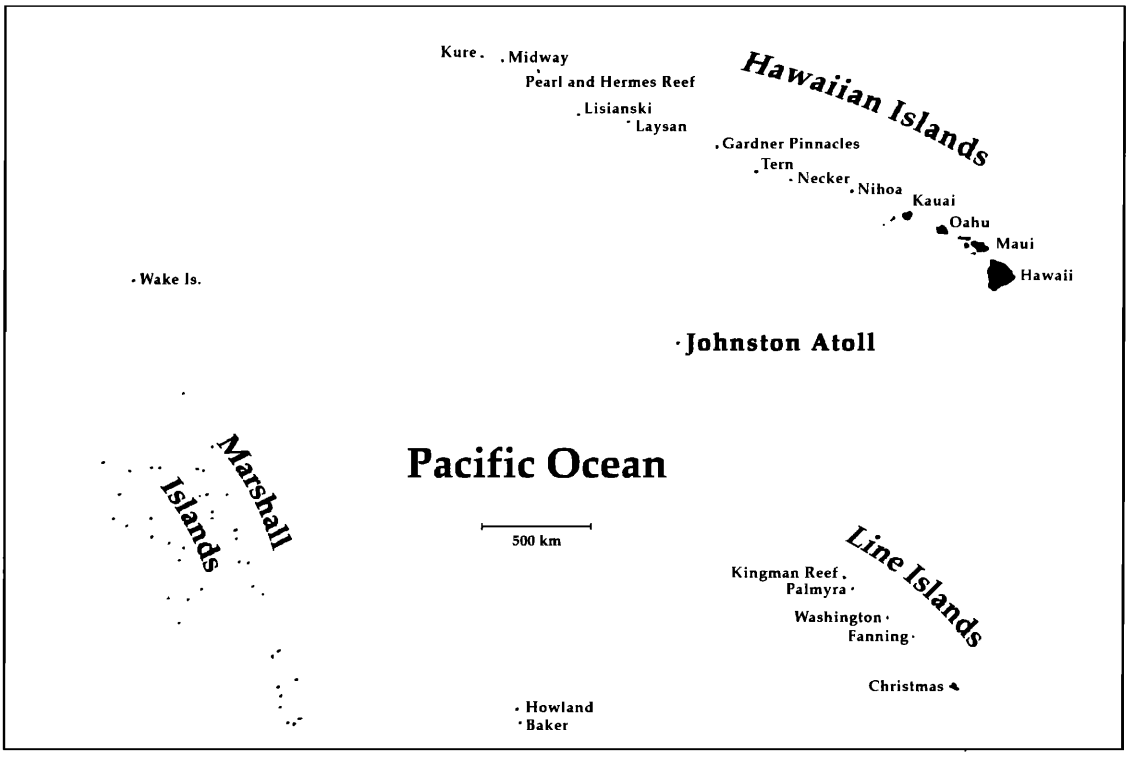

Fig. 1. Map of the central Pacific Ocean showing the remote location of Johnston Atoll.

Fig. 2. Aerial view of Johnston Island. The small land mass is covered with numerous buildings and other structures. Note the extensive airfield complex (centre and left side of the island) that dominates much of the area.

During five post-banding wintering seasons (August–April, 1998–2003), we recorded the presence or absence of marked birds. This involved monthly surveys (with the aid of binoculars and/or spotting scope) from a golf cart used as a mobile hide/blind or on foot. Return rates represent the cumulative total of birds re-sighted as a proportion of birds potentially available for re-sighting. The latter value for each season was the number of marked plovers found (plus others banded, if any) in the previous season. Over the course of the study, 4 birds (2 territorial and 2 non-territorial) went missing for one season, but were then found again. As it was unlikely that the two territorial birds could have escaped detection if present, these individuals were counted among returnees only in the seasons they were observed (i.e., they were regarded as temporary emigrants in the seasons when missing). We treated the two missing non-territorial birds differently. Because non-territorial plovers are inherently difficult to locate and may go unrecorded despite multiple surveys, we made the assumption that each of these birds was in fact present during the season in question. To assess overall numbers of plovers at JI, we used data from island-wide census counts that were conducted monthly by refuge personnel over the period 1991–2002.

Sixteen unmarked plovers were found dead at JI during 1998 and 1999. All were frozen by refuge workers and kept for our examination. For each specimen, we recorded age (from plumage characteristics, and presence or absence of the cloacal bursa; see Johnson & Johnson 1983, Johnson & Connors 1996), weight, and cause of death if known.

RESULTS

Of the 47 golden-plovers banded, 31 were territorial (i.e., they were found repeatedly and predictably in the same places where they exhibited aggressive behaviours toward neighbouring plovers), and 16 were non-territorial (i.e., seen inconsistently at various locations). The 31:16 ratio between the two groups was not representative of the actual composition of the wintering population as the latter consisted predominantly (by about 3:1) of non-territorial birds. Instead, the larger number of territorial plovers in the sample reflects our frequent use of the clap-trap to catch specific territorial individuals. Most of the territorial birds in our sample were adults when captured (25 of 31), while non-territorial individuals were evenly divided between adults and first-year birds (eight of each). We are unable to break down the sample by sex as almost all plovers were captured in February before dimorphism is evident.

The post-banding return rates of marked birds are shown in Table 1. The rates for the territorial and non-territorial groups were essentially the same at 60.0%, and 59.4%, respectively. Both of these rates were lower than comparable measurements on Oahu (Table 1). The difference in returns between JI and Oahu territorial plovers was highly significant ($\chi^2 = 22.16$, d.f. = 1, $p < 0.0001$), but there was no significant difference between non-territorial birds ($\chi^2 = 0.762$, d.f. = 1, $p = 0.38$). Territorial birds that returned to JI reoccupied their previous winter territories. Long-term records of plover numbers at JI are summarized in Figure 3. The graph shows monthly averages based on counts made over a 12-year period.

For plovers banded in February, the mean body mass of territorial birds was 129.3 g (SD = 19.6 g, range = 90–172 g, n = 19 adults and 6 first-year) and of non-territorial birds, 112.7 g (SD = 12.1 g, range = 92–133 g, n = 8 adults and 8 first-year), a statistically significant difference (t = 3.04, P = 0.004, df = 39). For the April sample (n = 6 territorial adults), average mass was 171.0 g (SD = 16.4 g, range = 150–195 g). Body mass data from JI were in reasonable agreement with similar data from Oahu where a combined sample of 52 territorial and non-territorial plovers (mostly the former) banded over the period 17 February–14 March during various years (1980–1987) averaged 117.1 g, range 94–146 g (Johnson *et al.* 1989); and 27 territorial adults captured 9–14 April (1997–2003) averaged 175.3 g, range 150–204 g (O.W. Johnson, unpubl. data).

The 16 plovers that had been found dead consisted of 13 juveniles and 3 adults. Almost all mortality occurred in late fall with 4 juveniles and 2 adults found in October, 8 juveniles in November, 1 juvenile in December, and 1 adult in May. The cause of death was uncertain for 6 birds. The others died from accidents (four struck by vehicles, one by a golf ball) and starvation (five individuals). Starved birds were emaciated (body masses <70 g) and all were juveniles. The preponderance of juveniles in this sample was consistent with ages of birds found dead at various locations in the Hawaiian Islands (see Johnson & Connors 1996), and attests to the vulnerability of naïve young plovers during their first wintering season.

DISCUSSION

The wintering biology of Pacific Golden-Plovers has been studied primarily on the island of Oahu, Hawaii, where the birds have adapted well to urban conditions (Johnson *et al.*

Table 1. Summary of returns of marked Pacific Golden-Plovers at Johnston Island.

Behavioural group & age composition[a]	Seasons after banding[b]					Return rate[c]
	1	2	3	4	5	
Territorial plovers: n = 25 adults + 6 first-year	18	10	11	5	1	45/75 = 60.0% 508/613 = 82.9%[d]
Non-territorial plovers: n = 8 adults + 8 first-year	7	6	5	3	1	22/37 = 59.4% 90/134 = 70.1%[d]

[a] Ages of birds when captured.

[b] Post-banding seasons from the fall of one year to the spring of the next.

[c] The cumulative number of birds re-sighted relative to the number of birds potentially available for re-sighting each season (see Methods).

[d] Second set of figures in each group represents return rates of territorial and non-territorial plovers through five post-banding seasons on Oahu (Johnson *et al.* 2001a, plus O.W. Johnson unpubl. data).

2001a). On Oahu and elsewhere in the main Hawaiian Islands, territorial and non-territorial plovers use a wide array of habitats with lawns and other low-growing vegetation especially favoured (Johnson & Connors 1996). Similar compatibility with humans has been reported from observations of unmarked birds at various insular Pacific locations (e.g., Child 1960, Fosberg 1966, Woodward 1972, Ely & Clapp 1973, Clapp 1990, Beichle 2001). An earlier effort to assess site fidelity at Johnston Atoll was made by Pacific Ocean Biological Survey Program (POBSP) personnel who banded 119 plovers there in the 1960s. Unfortunately, almost nothing was learned from these birds as most of them died before migrating probably from insecticide poisoning (Amerson & Shelton 1976). Thus, aside from our Hawaii findings (Johnson *et al.* 2001a) and the present investigation, there exist only sighting records, counts, and other general observations of plovers on insular Pacific wintering grounds.

Plovers defending territories on Johnston were recorded years ago by the POBSP (Amerson & Shelton 1976). We observed the same behaviours, and found most territorial birds on grassy areas such as small lawns amidst buildings and other structures, a 9-hole golf course (built atop imported soil), and borders along the runway and taxiways. A few territorial individuals occurred on sparsely vegetated coralline flats. Territories were occupied during the day, but disturbance from motor vehicles, bicycle riders, pedestrians, etc. often caused birds to retreat for variable periods of time to nearby rooftops or to join on-ground aggregations (of mostly non-territorial birds) elsewhere. In a few instances, we found plovers on their territories at night. Non-territorial birds formed flocks ranging in size from a few individuals to 100 or more. Larger flocks appeared to result from human activities forcing birds to seek less disturbed places. Notably, "flocks of more than half a dozen were rare" in the 1960s "even during the height of migration" (POBSP records from Amerson & Shelton 1976). Although flocked birds foraged communally, there were frequent aggressive responses to maintain individual space within the group. Such intolerance is typical in almost any flocking situation involving this species (Johnson & Nakamura 1981, Johnson & Connors 1996).

It seems a reasonable assumption that larger islands with well developed soils and insect faunas would offer the most abundant trophic resources for non-breeding plovers. Coralline atolls, on the other hand, might be among the least favourable wintering habitats. Amerson & Shelton (1976) point out, that most of the substrate at JI consists of "hard packed coral material" (the product of dredging); consequently the soil is "poor", and insects though relatively diverse ("at least 87 species") are "scarce". Thus, compared to our study sites on Oahu (mostly lawns), which appear to be food-rich, plovers wintering at JI possibly face a more difficult situation. If this is true (our general observations agreed with Amerson & Shelton, but we have no conclusive measurements of prey abundance), supplemental feeding practiced by several JI residents may be an important factor in the survival of plovers through the wintering season. A striking behavioural feature of plovers wintering on the atoll was that large numbers learned to gather at specific places and times for "handouts" (Fig. 4). Also, we found that plovers almost anywhere on the island would respond throughout the day when food was presented to them. Birds sometimes ran to within 1–2 m of us and ate boiled egg that we tossed from the golf cart. We often saw marked territorial plovers among the supplemental feeding aggregations at JI. This behaviour, coupled with the significant weight difference between territorial and non-territorial birds in February (129.3 g vs 112.7 g), suggests that territorial birds on JI were enjoying the best that the atoll had to offer (i.e., their own territorial resources plus "handouts"), whereas non-territorial plovers were at an energetic disadvantage.

Long-term studies of marked plovers on Oahu have shown that territorial birds are extremely site-faithful to specific winter territories from one season to the next. In fact, the bond is so strong that we have regarded absence from a territory (i.e., when a bird fails to reappear in the fall or disappears during the non-breeding season) as an indicator of mortality (Johnson *et al.* 2001a, O.W. Johnson unpubl. records). Territorial plovers returned to JI at a lower rate than comparable birds on Oahu (Table 1), and this raises difficult to resolve questions concerning mortality, emigration, and

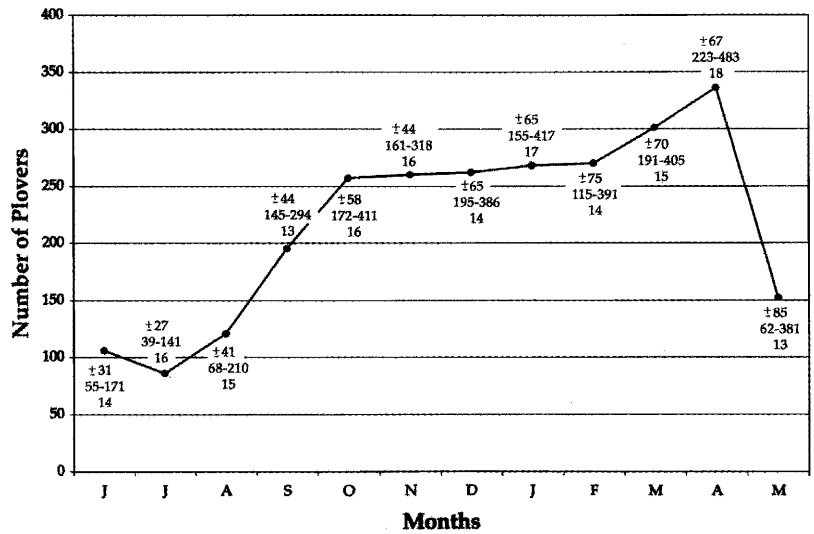

Fig. 3. Monthly counts of plovers on Johnston Island over a 12-year period from 1991–2002. Dots indicate means, associated values are ±SD, range, and number of counts. The cumulative counts/month exceeded 12 because workers occasionally made two census counts in a given month.

Fig. 4. A late afternoon gathering of Pacific Golden-Plovers being fed by Johnston Island resident Henry Tahara in April 2000. The food was primarily scraps of bread from the JI dining hall. Learned behaviour like this raises the possibility that artificial feeding might be useful in the future as a management tool in situations where natural food is limited or to offset loss of wintering habitat. Note that Bristle-thighed Curlews *Numenius tahitiensis* were accepting "handouts" as well. Though not clearly evident in the photograph, Ruddy Turnstones *Arenaria interpres* and Wandering Tattlers *Heteroscelus incanus* also were in the feeding aggregation.

trophic resources. Possibly, stresses associated with longer flights well beyond the Hawaiian Islands and/or marginal food resources at JI resulted in higher mortality. Alternatively, the lower return rates among JI territorial birds might have been unrelated to mortality. Perhaps frequent disturbance by humans and/or lack of food weakened interseason territorial ties, or possibly some returning plovers simply failed to locate the tiny atoll during southward migration (Fig. 1). If either of these explanations is true, missing territorial birds may have been alive and wintering elsewhere as was apparently the case with the two temporary emigrants (see Methods). Statistically similar return rates among non-territorial plovers at JI and Oahu (Table 1) suggest that birds lacking territorial fidelity share a common tendency for emigration (see Johnson *et al.* 2001a). However, any interpretation concerning returns of non-territorial plovers must be regarded as speculative because these birds are often very difficult to find and though present may go undetected.

Monthly census counts over a 12-year period showed considerable variation in plover numbers at JI (Fig. 3). While some counts may have been biased by movements of birds during surveys or unfavourable weather, the primary variables were most likely migrants stopping on the atoll for periods of time before moving on, and seasonal reproductive success (i.e., annual recruitment of juveniles higher in some years than others). Counts from late May to early August were primarily of over-summering birds, some of which may have come from the south then arrested their migration at the atoll. Although we have no information on age composition within these summer flocks, most of the birds were probably immature first-year plovers (see Johnson & Connors 1996). Among our marked birds, four individuals (one territorial adult, two territorial first-year, and one non-territorial first-year) did not migrate in the spring following their capture and remained on Johnston through the summer. The upward trend from late August to October represents first the arrival of adults followed several weeks later by juveniles. The highest numbers occurred in late March and April coinciding with the northward passage of migrants from other parts of the winter range. Marked resident plovers typically departed the atoll on spring migration in late April. Overall, the counts at JI indicate a schedule similar to the migratory cycle of plovers in the Hawaiian Islands (Johnson & Connors 1996, Johnson *et al.* 2001a,b).

To what degree plovers, especially non-territorial birds, might wander among atolls in the period between migrations (November to February) and thus influence counts at JI is unknown. However, given the remoteness of Johnston coupled with the energetic requirements of lengthy flights, it seems unlikely that this could be a significant source of variation. On this assumption, we estimate from Fig. 3 that the average resident wintering population on JI from 1991–

2002 was around 270 plovers. POBSP workers documented plover occurrence at Johnston from 1963–1969. The annual patterns they found (in both abundance and monthly variation, Amerson & Shelton 1976) were similar to Fig. 3, except their counts were only about one-half of what we report here. Presumably, the higher populations in recent years are the product of at least two factors: the expansion in the size of JI achieved by dredging and completed in 1964, which was subsequently discovered by plovers traversing this region of the Pacific, and the food made available through artificial feeding.

A great deal remains to be learned about Pacific Golden-Plovers during their non-breeding sojourn on tropical atolls. Multi-year monitoring of marked birds is needed to resolve questions concerning site-fidelity, interseason survival, etc. on these far-flung wintering grounds. Aside from atoll environments, valuable insight would emerge from similar investigations on larger landmasses in the southern Pacific. American Samoa, where one finds Hawaii-like wintering grounds at the terminus of a long migratory route (see Beichle 2001), seems well-suited for such a project.

Over the next several years, the environment at Johnston Atoll will change profoundly. Military occupancy is ending and, along with it, human presence on Johnston will be dramatically scaled back or possibly eliminated altogether. This is probably an undesirable turn of events for plovers. If supplemental feeding is discontinued, mortality rates of plovers are likely to increase, especially among the annual contingent of juveniles. Many of the latter probably arrive at Johnston with fat reserves exhausted and unable to travel farther. Moreover, without periodic mowing, what is now suitable plover habitat will become overgrown and unusable. Overall, it appears inevitable that the number of plovers wintering on the atoll will decrease substantially. Following the withdrawal of people from Johnston, it will be of considerable interest to track the plover population there and document whatever changes occur.

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