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Migration by Radio-tagged Pacific Golden-Plovers from Hawaii to Alaska, and their Subsequent Survival

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Many Pacific Golden-Plovers (*Pluvialis fulva*) and other shorebirds winter in the Hawaiian Islands. This is the first landfall for mid-Pacific migrants after overwater flights of 4,000 km or more from Alaska (Johnson et al. 1989, Johnson and Connors 1996). Previous findings (sightings of marked birds and wing-length measurements) showed Alaska affinities for golden-plovers wintering in Hawaii (Johnson and Connors 1996), but there had been no attempt to demonstrate movements between the two regions using radiotelemetry. We made such an effort in spring 1996 by radio-tagging plovers on wintering grounds in Hawaii just before their migration. Some of these birds were later found at three sites in Alaska, including a breeding ground.

Methods.—Plovers were trapped (by the Johnsons and Kienholz) from 18 to 23 April 1996 in Honolulu, Oahu, Hawaii. Capture was in the predawn using mist nets placed on winter territories. We determined sex from the dimorphic breeding plumage and identified first-year (i.e. yearling) birds from their retained juvenal primaries (Johnson and Johnson 1983, Johnson and Connors 1996). Each bird was weighed (± 1 g) and marked with a U.S. Fish and Wildlife Service band plus a unique combination of colored plastic bands, all placed on the tibiotarsi. Twenty plovers had 1.65-g, 60-day radio transmitters (Holohil Systems Limited, Carp, Ontario, Canada) glued to clipped feathers on their lower backs (Warnock and Warnock 1993). Based on chronology of body molt (Johnson and Connors 1996), transmitters probably were retained until at least late June or early July. Although body masses at departure were unknown, the transmitters must have averaged less than 1% of total mass (the last 10 birds captured, from 20 to 23 April and nearing departure, weighed 162 to 200 g, $\bar{x}$ = 183 g). We captured 16 birds on lawns at the National Memorial Cemetery of the Pacific (NMCP), and four on lawns at the Honolulu Zoo. The NMCP provides excellent wintering habitat that supports about 100 plovers; a much smaller group winters at the zoo. The radio-tagged birds were conspicuous residents on winter territories (all plovers at the NMCP and the zoo are territorial) and were easily monitored by direct observation or with a hand-held antenna. Abandonment of territories is a clear indicator of migration (either actual departure or premigratory aggregation elsewhere), and we checked territories several times a day for presence or absence of radio-tagged birds. Pacific Golden-Plovers on Oahu are very faithful to specific winter territories from season to season (Johnson and Connors 1996). Thus, it was relatively simple to determine survival after return migration in the fall.

In Alaska, plover radio frequencies were monitored almost entirely by air (Iverson et al. 1996) at major shorebird stopovers along the coast and at two inland breeding locations (Fig. 1). Search dates varied from site to site, the overall range was 23 April to 28 June 1996. Bishop and Warnock coordinated and integrated the search for radio-tagged plovers with concurrent studies of radio-tagged Western Sandpipers (*Calidris mauri*).

Results.—Three of the 20 radio-tagged plovers were detected in Alaska (Table 1, Fig. 1). Bird No. 9 was recorded during the first monitoring flight at the Copper River Delta on 27 April. Signals were heard at the east end of the delta (Controller Bay) on the mornings of 27 and 28 April; by the morning of 29 April the bird had moved about 100 km to the western part of the delta (vicinity of the Egg Islands), where it remained until last detected on the morning of 5 May. No. 9 was found again on 29 and 31 May during two aerial surveys by Bennett across breeding grounds in the Mulchatna and Nushagak River regions northwest of Lake Iliamna. Signals from plover No. 10 were recorded by Bennett on the same breeding grounds on the same dates. The two individuals were located about 16 km apart at 59°37′N,

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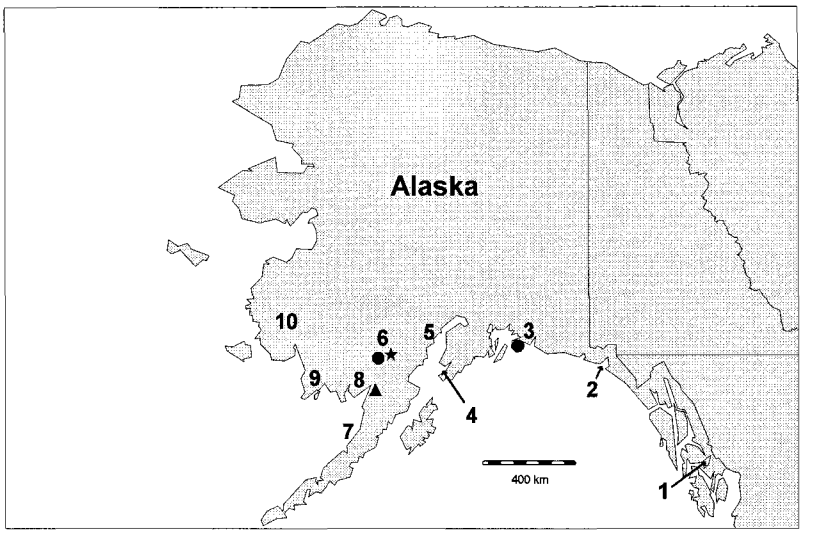

FIG. 1. Map of Alaska showing monitoring sites and locations where radio-tagged Pacific Golden-Plovers were found in spring 1996. Birds recorded were: No. 9 (dots), No. 10 (star), and No. 20 (triangle). Site 9 was monitored from the ground; all other searches were by air. Sites and monitoring periods were: (1) Stikine River Delta, 27 April to 9 May; (2) Yakutat to Dry Bay, 27 April to 15 May; (3) Copper River Delta, 27 April to 12 May; (4) Cook Inlet, Kachemak Bay, 28 April to 17 May; (5) Cook Inlet, Redoubt Bay to Chinitna Bay, 3 to 14 May; (6) Lake Iliamna, Mulchatna/Nushagak River breeding grounds, 29 and 31 May; (7) Bristol Bay, Alaska Peninsula, from eastern Unimak Island to Bear River near Port Moller, 23 April and 7 May to 1 June; (8) Bristol Bay, Kvichak Bay to Nushagak Bay, 28 April to 5 June and Togiak area, 30 April and 17 to 20 May; (9) Bristol Bay, Cape Peirce and Hagemeister Strait, 3 to 28 May; (10) Yukon-Kuskokwim Delta, transect on breeding grounds, from northwest of Bethel to the Kashunuk River, 21 and 28 June. Plover radio frequencies also were monitored during U. S. Fish and Wildlife Service breeding waterfowl surveys from the Yukon-Kuskokwim Delta to Kotzebue, 30 May to 10 June. These flights were at low altitude, which limited the effective area over which radio signals could be detected, and no plover signals were heard.

156°47'W (No. 9) and 59°42'N, 156°33'W (No. 10). Bird No. 20 was detected on 1 May near the town of King Salmon. Nineteen of the 20 birds (95%) returned to Oahu in fall 1996 and reoccupied their previous winter territories. The missing individual was No. 20.

Discussion.—Pacific Golden-Plovers were discovered nesting northwest of Lake Iliamna in 1994 (Bennett 1996), which may indicate breeding over a relatively large area in southwestern Alaska. Although the status of Nos. 9 and 10 was not confirmed on the ground, finding both individuals at specific locations on Bennett's study site during two flights in late May leaves little doubt that they were nesting. Notably, Nos. 9 and 10 occupied neighboring winter territo-

TABLE 1. Records of three Pacific Golden-Plovers radio-tagged in Hawaii and relocated in Alaska after transpacific migration, spring 1996.

Details of capture and departure from Hawaii[a]	Details of relocation in Alaska
No. 9 (first-year male)	
Caught 19 April, NMCP; last seen on territory morning of 23 April	Copper River Delta, 27 April to 5 May; breeding ground NW of Lake Iliamna, 29 and 31 May
No. 10 (adult male)	
Caught 19 April, NMCP; last seen on territory morning of 23 April	Breeding ground NW of Lake Iliamna, 29 and 31 May
No. 20 (adult female)	
Caught 23 April, NMCP; last seen on territory afternoon of 24 April	Near King Salmon, 1 May

[a] NMCP = National Memorial Cemetery of the Pacific, Honolulu, Oahu.

ries in the NMCP. We conclude that some fraction of plovers wintering on Oahu, and probably elsewhere in Hawaii, breeds in southwestern Alaska. Bird No. 20 was recorded about 130 km southwest of the coordinates given above and may have been en route to the same general region in which Nos. 9 and 10 were found.

This is the first time that radiotelemetry has shown a link between specific wintering and breeding grounds for an insular Pacific shorebird. Previous studies demonstrated strong site fidelity to breeding and wintering grounds in Pacific Golden-Plovers (Johnson and Connors 1996) but gave no insight as to whether a particular assemblage remained intact throughout the annual cycle. Although the sample is small, our results suggest cohesiveness of populations, with the same birds sharing discrete breeding and wintering grounds. Similar findings (from observations of color-banded birds) exist for Bristle-thighed Curlews (*Numenius tahitiensis*) wintering in the Northwestern Hawaiian Islands and breeding in the Nulato Hills on the Yukon-Kuskokwim Delta (J. S. Marks and B. J. McCaffery pers. comm.). Knowledge of specific linkages provides intriguing possibilities for exacting studies of energetics, flight speeds, and other details of migration between Hawaii and Alaska. These possibilities are enhanced by the remarkable survival rate of our experimental birds. Clearly, this plover is very capable of carrying radio transmitters over great distances on nonstop transoceanic flights.

Golden-plovers are relatively uncommon spring migrants at coastal stopover sites in Alaska. Except for one report of a large aggregation on Montague Island, Prince William Sound (Isleib 1979), most northbound plovers appear to overfly the coast (Johnson and Connors 1996). The presence of bird No. 9 at Copper River Delta demonstrates that some golden-plovers occurring in this region are from the central Pacific, as postulated by Isleib (1979). Pacific Golden-Plovers from mainland wintering grounds (mostly California; see Johnson and Connors 1996) also are likely to be found at stopovers in south-coastal Alaska. Probably because of prevailing winds, birds like No. 9 drift eastward during oceanic passage to landfalls from which they must turn back westward to reach their breeding grounds. Some Bristle-thighed Curlews, a species sympatric with plovers on insular Pacific wintering grounds, follow a similar dogleg course as indicated by spring records in the northern Gulf of Alaska (Isleib 1979; R. E. Gill, Jr. pers. comm.).

The importance of littoral resources for Pacific Golden-Plovers upon their arrival in Alaska is unknown. That no golden-plovers were seen on Copper River Delta mudflats during extensive surveys in two spring seasons (M. A. Bishop unpubl. data) suggests that bird No. 9 was using nearby uplands as it lingered in the delta area. In any case, our records of No. 9 at the Copper River Delta indicate that plovers may forage at coastal stopovers for several days (Table 1). Possibly, littoral and/or adjacent upland feeding opportunities are of greater significance to inexperienced first-year individuals like No. 9 on their initial return to the breeding grounds.

We had hoped to obtain accurate measurements of flight times from Hawaii to Alaska. However, we were unable to find radio-tagged birds on Oahu after they had deserted their territories. Most of them probably joined premigratory aggregations on the island (which occur regularly at this season) and lingered for varying periods of time before departure. Migration between Hawaii and Alaska is via the "mid-Pacific" flyway (Johnson and Connors 1996), but we have no knowledge of actual routes within this corridor. From Oahu, near the southeastern end of the Hawaiian archipelago, the most reasonable course would seem to be a direct transoceanic flight. Another possibility would be to follow the island chain northwestward for some distance prior to the transoceanic segment (Johnson et al. 1989: figure 3).

Plover No. 9 was present at the Copper River Delta when monitoring began about 90 h after the bird deserted its winter territory on Oahu (Table 1). Assuming a direct northward flight, the distance from Oahu to the Copper River Delta is approximately 4,500 km. Therefore, No. 9 traversed this hypothetical route at a minimum flight speed of 50 km/h. The actual flight almost certainly was faster than this. Golden-plovers are notable as high-speed flyers (Johnson and Connors 1996). Furthermore, the route followed by No. 9 may have been longer than our estimate (i.e. if the bird did not maintain a direct course), and delays associated with premigratory flocking were likely.

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The Effects of Fluctuating Food Availability on Breeding Arctic Terns (*Sterna paradisaea*)

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Reproduction is a costly process that involves an investment of effort that can decrease parental condition and survival (Partridge 1989, Stearns 1992). In long-lived iteroparous species such as seabirds, reproductive costs produce a tradeoff in energy allocation between current and future breeding attempts (Clutton-Brock 1984), and the breeding effort should be adjusted to maximize lifetime reproductive success. Food availability can have substantial effects on the relative costs of reproduction and thus may be an important factor in determining reproductive strategies in seabirds (Boekelheide and Ainley 1989, Sydeman et al. 1991, Pons and Migot 1995).

Cairns (1987) hypothesized that during periods of reduced food supply, seabirds should increase foraging effort in order to buffer the effects of food scarcity on breeding performance. Further reductions in food may result in parents being unable to increase foraging effort without incurring excessive costs, resulting in a decline in reproductive success (Monaghan et al. 1989, 1992). Finally, during periods of extreme food shortage, condition and survival of adults may be adversely affected (Hamer et al. 1991). Food supply is expected to affect breeding parameters within a specific range of prey availability, outside of which it will have little effect (Cairns 1987, Phillips et al. 1996).

The abundance of sandeels (*Ammodytes marinus*) was severely reduced in Shetland waters between 1985 and 1990 due to successive years of poor recruitment of the group-0 cohort (i.e. fish spawned in the current year) and a subsequent decline in spawning-stock biomass (Wright and Bailey 1993). Seabirds responded by increasing their foraging effort (Uttley 1992, Hamer et al. 1993, Monaghan et al. 1994) and exploiting alternative prey species (Martin 1989, Hamer et al. 1991). Despite these changes in behavior, the breeding success of surface-feeding species was adversely affected (Monaghan et al. 1989; Hamer et al. 1991, 1993; Phillips et al. 1996).

Arctic Terns (*Sterna paradisaea*) suffered six consecutive years of almost complete breeding failure on Shetland (Walsh et al. 1990) due to adults abandoning clutches and chicks starving shortly after hatching (Monaghan et al. 1989, 1992). The number

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