

Migratory linkages of Pacific Golden-Plovers *Pluvialis fulva* breeding in Chukotka, Russian Far East

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For the first time, we have tracked the annual migrations of Pacific Golden-Plovers nesting in northern Russia. We used geolocators to determine the timing and migration routes of four male plovers trapped at one site in SE Chukotka. Before leaving the north in autumn, each bird moved from nesting grounds and made one or two pre-migratory stopovers of 13–22 days (presumably on coastal tundra) in either Russia (Kamchatka and Khabarovsk Krai) or the USA (St. Matthew Island and the Pribilof Islands). After departing these sites, three birds traveled southward via eastern Asia and Japan to non-breeding grounds in the Philippine Islands, and one bird followed an oceanic route to Majuro Atoll in the Marshall Islands. All of these linkages were previously unknown. Two birds made non-stop flights of 4–6 days directly to non-breeding grounds, whereas two made additional stopovers *en route* (16 d in Japan and 18 d in China, respectively). In spring, return migrations from the Philippines variously included stopovers in South Korea, Taiwan, and China; the bird migrating from Majuro stopped-over only in Japan. Mean minimum flight speed on all legs in both autumn (after pre-migratory stopovers) and spring was 53 kph. On average, plovers spent 24 days at stopovers during the autumn journey, and 36 days at stopovers during the spring passage. Stopover sites and also non-breeding grounds probably included agricultural lands, most likely rice fields. While the migrations of these four birds shed light on migratory connectivity of Pacific Golden-Plovers nesting in Chukotka, additional studies are needed to: (1) further explore the non-breeding range of plovers breeding there and elsewhere in northern Russia, (2) better define important stopover sites including pre-migratory sites in the north, and (3) more fully understand the relationships between plovers and trophic resources associated with agriculture.

Keywords

Pacific Golden-Plover

Pluvialis fulva

Chukotka

geocator

migration

flight speed

connectivity

stopovers

rice fields

INTRODUCTION

Pacific Golden-Plovers *Pluvialis fulva* nest on tundra from western Alaska across northern Russia to the Yamal Peninsula, and winter on inland and coastal habitats of the insular Pacific, Australia, New Zealand, SE Asia, India and NE Africa (Hayman *et al.* 1986, Johnson & Connors 2010, Lappo *et al.* 2012). In these vast regions, knowledge of the species' migratory movements, migration strategies and winter range connectivity is limited mostly to studies conducted in Alaska, Hawaii, and a few locations in

Oceania. As for the Russian Far East, nothing was known concerning the routes, stopovers, and non-breeding grounds of plovers (see Tomkovich 2003) until recently when: (1) birds wintering at Saipan in the Mariana Islands (East Asian-Australasian Flyway) were tracked to breeding grounds in Chukotka and Kamchatka (Johnson *et al.* 2012), (2) plovers from Kwajalein Atoll in the Marshall Islands (mid-Pacific Flyway) were tracked to Chukotka (Johnson *et al.* 2015), and (3) a plover flagged at its nest in SE Chukotka was observed for two consecutive seasons at Darwin, Northern Territory, Australia (PST unpubl.

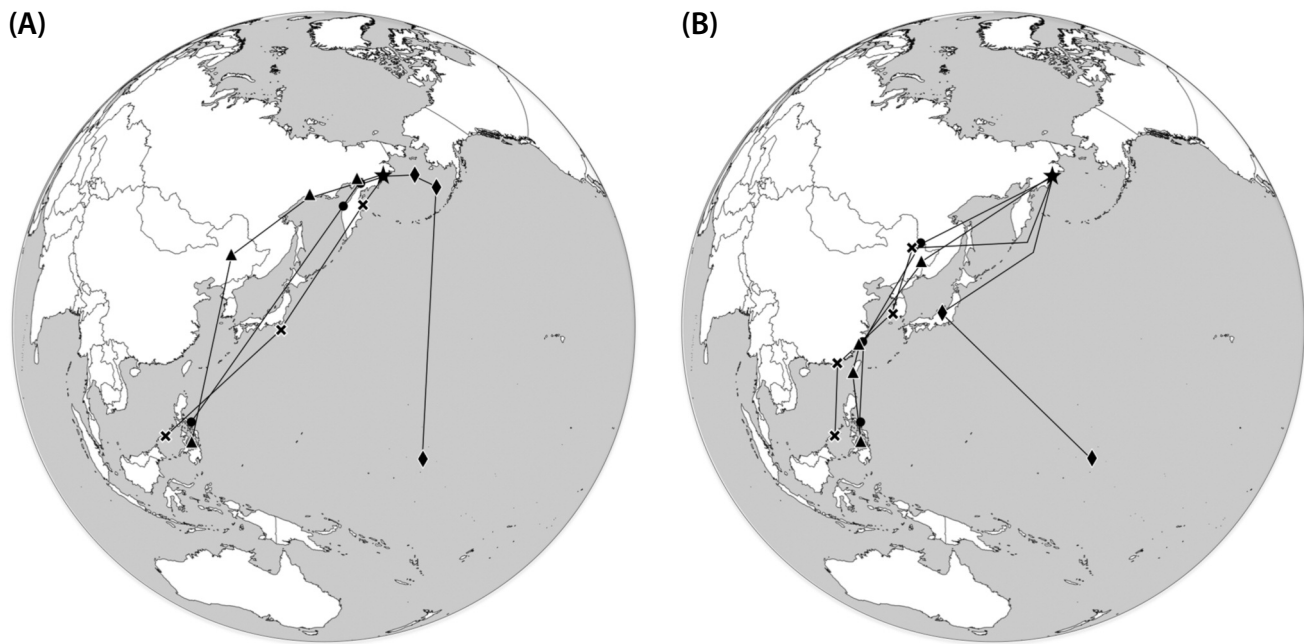


Fig. 1. The migratory tracks (A = southward/autumn migration; B = northward/spring migration) of four geolocator-equipped Pacific Golden-Plovers captured on nesting grounds near Meinypilgyno Village (★) in SE Chukotka, Russia. Symbols (✕ = Plover No. 1; ● = No. 2; ▲ = No. 3; ◆ = No. 4) indicate locations of stops.

data). Here we augment those findings with the first geolocator tracking of plovers captured on nesting grounds in Chukotka. These data substantially expand our knowledge of the winter range distribution of Pacific Golden-Plovers migrating from Chukotka and the annual routes they follow between breeding and non-breeding grounds.

METHODS

We trapped 14 Pacific Golden-Plovers on their nests at a study site in SE Chukotka, Russia near Meinypilgyno Village (62.54°N, 177.05°E; Fig. 1), and fitted them with light-level geolocators (archival data loggers). We deployed the loggers in June and July, and recovered them a year later when the plovers were again nesting (Table 1). We captured plovers using a self-triggering clap-net (Priklonsky 1960). Two of four males were recaptured using the same technique, and two were collected by shooting (under permit issued to PST by authorities in Chukotka). The latter birds were escorting partly grown chicks when found, and therefore were impossible to recapture by conventional means. Subsequent observations indicated

that the two females absent their mates continued to guard and brood their young, but whether the chicks successfully fledged is unknown.

We mounted geolocators on leg flags, using model Mk-10b loggers (British Antarctic Survey, UK) in 2011, and Intigeo model W65 A9 (Migrate Technology, UK) in 2013. The flag plus the logger weighed 1.8 g (BAS units) or 1.1 g (Intigeos), both <1% of probable average mass of plovers at migrations (Johnson & Connors 2010). Our methodology for preparation and attachment of locators followed Johnson *et al.* (2011, 2012), with the exception that geolocators were mounted horizontally (instead of vertically) on the flags used in 2013. The data archived by the geolocators were analyzed using BasTrak software (British Antarctic Survey, UK) with procedures described by Porter & Smith (2013).

Given the positional error inherent to geolocator technology, we emphasize that the only precise geographic locations in this paper are the GPS coordinates of the area where loggers were deployed and retrieved. To assess accuracy,

Table 1. Geolocators deployed on Pacific Golden-Plovers near Meinypilgyno Village, SE Chukotka, Russian Far East.

<i>n</i> deployed	Deployment period	<i>n</i> recaptured*	Recapture period
6 males, 2 females	23 June–13 July 2011	1 male	14 July 2012
6 males	21 June–6 July 2013	3 males	13 June–13 July 2014

*These were the only individuals seen in subsequent seasons.

we calculated distances over two seasons between geolocator fixes and known coordinates of the four plovers at their nesting sites and found longitude error ranging from 2 km ($n = 71$ fixes) to 72 km ($n = 39$ fixes), and latitude error when calibrated to the cluster edge (Porter & Smith 2013) ranging from 14 km ($n = 71$ fixes) to 158 km ($n = 31$ fixes). Notably, the foregoing longitude deviations were similar to those reported for Red Knots *Calidris canutus rogersi* on nesting grounds (sympatric with the sample plovers) and during migrations (see Tomkovich *et al.* 2013). Overall, the measurements above suggest that ± 100 km accuracy is a reasonable assumption for the stopover and non-breeding locations described in this paper. All distance estimates are based on great circle calculations and thus the measurements are minimal. Estimates of minimum flight speeds represent the distance between departure and arrival points for each leg of the annual journey divided by the maximum flight time for each leg. The minimum annual distance traveled by each bird is the sum of all flights from its nest site to its non-breeding grounds in autumn and return in spring.

RESULTS

Of the 14 birds equipped with geolocators (Table 1), four males and no females were found at our study site in subsequent years and their geolocators recovered. Because the loggers were not programmed for salt water detection, we were unable to determine whether the birds had used tidal flats during stopovers or at non-breeding grounds. The migratory tracks of the four males are shown in Fig. 1, and using the symbols in the figure, the travels of each bird are chronicled in Box 1.

Before leaving the northern Pacific region in autumn, the plovers made relatively short flights (413–966 km) in order to reach pre-migratory stopover sites in Kamchatka, Khabarovsk Krai, St. Matthew Island, and the Pribilof Islands. These movements took a day or less, and where flights traversed land they may have included brief stops *en route*. All other flights, both autumn and spring (with the exception of Taiwan to the China coast by Plover 3) were substantially longer. After departure from the north, the migrations of Plovers 1, 2, and 3 traversed both continental and oceanic pathways, while the route followed by Plover 4 was entirely oceanic. Southward flights ranged from 2,091 km (Plover 3) to >5,000 km, the two longest being non-stop oceanic passages by Plover 2 from Kamchatka to the Philippines (5,644 km over about 4–5 days) and Plover 4 from the Pribilofs to Majuro (5,786 km over about 5–6 days). Northward flights leading to spring stopovers varied from 499 km (Plover 3) to 4,724 km (Plover 4), and final tracks to Chukotka from last stopovers in China and Japan ranged from 3,298 km (Plover 2) to 3,844 km (Plover 4). Overwater flights were non-stop, and overland legs appeared to be non-stop as well. Estimated mean minimum flight speed for all legs (those in autumn between nest sites and pre-migratory stopovers are not included) flown by the four birds was 53 kph (SD ± 11).

In autumn, pre-migration stopovers in the north ranged from 13 days (Plovers 1 and 3) to 22 days (Plover 4). During the subsequent migratory flight, Plovers 1 and 3 each made one additional stopover (16 and 18 days, respectively) before reaching non-breeding grounds; Plovers 2 and 4 flew non-stop. Aggregate stopover time prior to arrival on non-breeding grounds averaged 24 days (range = 16 [Plover 2] to 31 days [Plover 3]). In spring, Plovers 1, 2, and 3 made two to three stopovers during their northward journeys, whereas Plover 4 stopped only in Japan. Notably, Plovers 2 and 3 stopped-over in the same coastal region in eastern China. While *en route* north, aggregate stopover time per individual averaged 36 days (range = 24 [Plover 4] to 45 days [Plover 2]). The aggregate times spent stopping-over during autumn and spring migrations were not significantly different ($P = 0.082$).

Each of the four plovers was visually monitored following attachment of its geolocator. All of the birds continued incubation and hatched chicks. Hatching dates were 6 July for the single bird in 2011, and 2–4 July for the three birds in 2013. Autumn departures from the nesting grounds occurred during 4–7 August (see Box 1); thus the interval between hatching and the start of autumn migration of the male parents was 29–36 days.

DISCUSSION

The findings reported here are the first of their kind for Pacific Golden-Plovers captured on breeding grounds in northern Russia. To previously known linkages (Saipan–Chukotka, Saipan–Kamchatka, Kwajalein–Chukotka, Chukotka–Australia; Johnson *et al.* 2012, 2015, PST unpubl. data), we can now add Chukotka–Philippine Islands (Plovers 1, 2, and 3) and Chukotka–Majuro Atoll (Plover 4). Clearly, the non-breeding grounds of Pacific Golden-Plovers nesting in the Russian Far East span a vast area of the world from at least 171°E to 118°E (Majuro to Palawan) and 9°N to 12°S (Kwajalein to Darwin).

Given the lack of data concerning contact with saltwater, we are unable to assess the possible use of tidal habitats during migrations and wintering. However, we suspect that the birds' primary foraging habitats were inland, and base this on the species' strong preference for uplands as evidenced by: (1) the scarcity of plovers in shorebird aggregations on mudflats in the north and along the Asian coast including China (Gerasimov 2003, Gerasimov *et al.* 2016, sources in Johnson & Connors 2010, Lappo *et al.* 2012), (2) the concentration of plovers at inland sites during stopovers in Mongolia and Japan (Wijmenga *et al.* 2011, Johnson *et al.* 2015), (3) the nature of non-breeding grounds as described in other studies (Johnson *et al.* 2006, 2008, Johnson & Connors 2010), (4) the satellite transmitter-equipped Pacific Golden-Plover that wintered at Sulawesi (see below) in an area with many rice fields, (5) the use of croplands by plovers in China (Zhao 2001, Wang *et al.* 2006), and (6) the inland foraging behavior of the world's other two species of golden-plovers (Eurasian *P. apricaria* and American *P. dominica*;

Byrkjedal & Thompson 1998, Johnson & Connors 2010, Stodola *et al.* 2014). Furthermore, where geolocator fixes of our sample birds indicated shorelines as possible stopover or wintering habitat there were also potential inland habitats (as visualized with Google Earth) situated nearby well within the margin of error. These consisted of coastal tundra in the north and agricultural lands (typically rice fields) elsewhere. The latter were often interspersed with villages and other human development producing a somewhat urbanized landscape comparable to non-breeding habitats in Hawaii and elsewhere in the Pacific (Johnson & Connors 2010). Of the four stopover sites in NE China (see Box 1) three were far enough inland (>600 km) to exclude the possibility of coastal feeding; one site (at about 250 km) was less certain.

The autumn stopovers of Plovers 2 and 3 in the Penzhina Gulf region (northern Sea of Okhotsk) were in an area where large pre-migratory aggregations of shorebirds occur on extensive tidal flats. As mentioned above, Pacific Golden-Plovers are relatively scarce in these gatherings, which suggests that plovers tend to favor coastal tundra uplands instead of shorelines as they prepare for southbound migration. Comparable findings during autumn migration in Alaska are mixed: on the Alaska Peninsula, Gill *et al.* (1981) reported that plovers (adults and juveniles) “preferred intertidal areas and were recorded away from there on only two occasions”, whereas on the Yukon-Kuskokwim Delta, Gill & Handel (1990) found only juvenile plovers using intertidal habitats. Current knowledge of pre-migratory stopover times in the north indicates

Box 1. Migration chronologies of four geolocator-tracked Pacific Golden-Plovers from Chukotka. Symbols refer to tracks shown in Fig. 1.

Plover No. 1 (✕)

4 August 2011, departed nesting grounds, stopped-over in E Kamchatka 58.1°N, 161.9°E (966 km) for 13 days until **18 August**. **20 August**, arrived at Kojima Island, Japan, 33.1°N, 139.8°E (3,236 km), stopped-over for 16 days until **5 September**. **8 September**, arrived Palawan Island, Philippines 9.4°N, 118.1°E (3,447 km) and wintered, departed on northward migration **13 April 2012**. **14 April**, arrived in SE China 25.9°N, 116.1°E (1,851 km), stopped-over for 22 days until **6 May**. **7 May**, arrived South Korea 34.4°N, 126.1°E (1,351 km), stopped-over for 4 days until **11 May**. **12 May**, arrived NE China 47.5°N, 127.0°E (1,459 km), stopped-over for 8 days until **20 May**. Made direct flight back to Chukotka nest site (3,483 km), final tracking was overwater east of the Kamchatka Peninsula, arrived **23 May**. Minimum round-trip distance traveled = 15,793 km.

Plover No. 2 (●)

7 August 2013, departed nesting grounds, stopped-over at Kamchatka isthmus (eastern side of Penzhina Gulf) 61.9°N, 164.5°E (653 km) for 4 days until **12 August**. Shifted to western Kamchatka 57.8°N, 157.1°E (618 km), stopped-over for 12 days until **25 August**. **29 August**, arrived Luzon Island, Philippines 14.2°N, 122.4°E (5,644 km) and wintered, departed on northward migration **2 April 2014**. **3 April**, arrived east coast of China 27.6°N, 120.6°E (1,496 km), stopped-over for 33 days until **6 May**. **8 May**, arrived NE China 49.1°N, 128.0°E (2,484 km), stopped-over for 12 days until **20 May**. Made direct flight back to Chukotka nest site (3,298 km), arrived **24 May**. Minimum roundtrip distance traveled = 14,193 km.

Plover No. 3 (▲)

7 August 2013, departed nesting grounds and stopped-over at Kamchatka isthmus (eastern side of Penzhina Gulf) 60.7°N, 162.9°E (774 km) for 8 days until **16 August**. Shifted to NE Khabarovsk Krai close to border with Magadan Oblast 59.5°N, 146.6°E (913 km), stopped-over for 5 days until **22 August**. **24 August**, arrived NE China 46.2°N, 124.2°E (2,091 km), stopped-over for 18 days until **10 September**. **13 September**, arrived Philippines (probably Bohol Island) 10.0°N, 124.1°E (4,027 km) and wintered, departed on northward migration **2 April 2014**. **3 April**, arrived Taiwan 23.1°N, 120.0°E (1,523 km), stopped-over for 19 days until **22 April**. **23 April**, arrived east coast of China 27.6°N, 120.6°E (499 km), stopped-over for 11 days until **4 May**. **6 May**, arrived NE China 45.4°N, 131.5°E (2,207 km), stopped-over for 13 days until **19 May**. Made direct flight back to Chukotka nest site (3,430 km), arrived **22 May**. Minimum roundtrip distance traveled = 15,464 km.

Plover No. 4 (◆)

7 August 2013, departed nesting grounds, stopped-over at St. Matthew Island 60.4°N, 172.7°W (593 km) for 8 days until **16 August**, shifted to Pribilof Islands 57.0°N 169.8°W (413 km), stopped-over for 14 days until **30 August**. **4 September**, arrived Majuro Atoll, Marshall Islands 7.1°N, 171.4°E (5,786 km) and wintered (probably at the international airport), departed on northward migration **20 April 2014**. **24 April**, arrived Honshu Island, Japan 37.2°N, 138.4°E (4,724 km), stopped-over for 24 days until **18 May**. Made direct flight back to Chukotka nest site (3,844 km), arrived **21 May**. Minimum roundtrip distance traveled = 15,360 km.

wide variation: 13–22 days in this study, and 1–40 days in Alaska (Johnson *et al.* 2011, 2012).

The association of Pacific Golden-Plovers with inland stopover sites, which is well documented in Mongolia (Wijmenga *et al.* 2011) and NE China (this study; L. Tibbitts & OWJ unpubl. data), is in sharp contrast to numerous species of shorebirds that depend on tidal wetlands for refueling during long-distance migrations (e.g., Red Knots, Tomkovich *et al.* 2013; Sanderlings *C. alba*, Lisovski *et al.* 2016). Foraging in agricultural fields is not without potential hazards including chemical contamination (Parsons *et al.* 2010) and new farming practices that are less bird-friendly. Nonetheless, these lands may constitute a more reliable long-term resource as compared to vulnerable coastal habitats that are rapidly being destroyed (MacKinnon *et al.* 2012, Murray *et al.* 2014, 2015). Many plovers refuel in Japan, especially Honshu Island (Bamford *et al.* 2008, Johnson *et al.* 2012, 2015), and the 24-day spring stopover of Plover 4 there matched both the location and duration reported for birds previously tracked from the Central Pacific (average 23 days, range = 15–28 days; Johnson *et al.* 2015).

As for other geolocator applications involving waders in northern Russia, only the migrations of three Red Knots nesting in the same area as the foregoing plovers (near Meinypilgyno Village, Chukotka) have been tracked (Tomkovich *et al.* 2013). The geolocator-equipped knots migrated to more distant non-breeding grounds (Australia and New Zealand) than the sampled plovers, and thus their roundtrips were longer, from 23,000 to 31,000 km, with non-stop flight legs up to 10,100 km and 8 days duration at flight speeds averaging 52.5 kph. That plovers share similar capabilities for long-distance flight is indicated by various findings: (1) previous geolocator tracking by Johnson *et al.* (2012, 2015), (2) the marked plover mentioned above that was observed at Darwin, (3) three plovers banded at Nome, Alaska and sighted in Queensland, Australia (OWJ unpubl. data), and (4) a satellite transmitter-equipped plover nesting near Nome that made a non-stop flight of at least 11,100 km from Alaska to Okinawa over 8.5 days. This last bird flew nearly to Hawaii, then turned west (minimum flight speed = 54 kph), went on to winter in southeast Sulawesi, then returned to its nesting territory via the Philippines, China, and Russia for a round trip migration of 27,360 km (L. Tibbitts & OWJ unpubl. data). Estimated mean minimum flight speed of the four plovers in the present study (53 kph, SD \pm 11) closely matched the estimate for Red Knots mentioned above, fell within previous speed estimates for the species (Johnson *et al.* 2011, 2012, 2015), and was similar to estimates of speeds during non-stop flights of other shorebirds (Driscoll & Ueta 2002, Gill *et al.* 2009, Minton *et al.* 2010, 2011, 2013, Klaassen *et al.* 2011, Battley *et al.* 2012, Niles *et al.* 2012).

The Pacific Golden-Plovers' breeding range in Russia spans about 4,300 km from eastern Chukotka westward to the Yamal Peninsula (roughly 170°W to 70°E; Lappo *et al.* 2012), and except for the connectivity described in

this paper there are no other records linking plovers nesting in this region with non-breeding grounds. While insight gained by tracking the migrations of four plovers nesting in Chukotka is valuable from a conservation perspective, these birds represent only a small part of the breeding grounds and much remains to be learned.

The species' non-breeding range is enormous (see *Introduction*), and it is likely that plovers migrating from Chukotka are among wintering flocks on islands and atolls aside from those mentioned above. Clearly, additional tracking with geolocators or other technology is needed to better define the entire non-breeding range that supports the Chukotka population. Ideally, similar studies should be conducted in other parts of northern Russia where linkages are currently unknown. Resources gleaned from agricultural fields may be vital for migrating and wintering plovers, and we encourage observations in areas revealed by this study (also see locations listed by Bamford *et al.* 2008) to clarify the use of such habitats at stopover sites and wintering grounds. Based on the criteria proposed by Warnock (2010), some of the stopovers that we list above, particularly last stops before the final passage to non-breeding or breeding grounds, might be staging areas of high conservation importance. Finally, there is the question of habitat use (intertidal vs. upland tundra) at pre-migratory autumn stopovers. Fieldwork is needed to more fully understand this phase of the plovers' annual cycle, and to assess possible age-related habitat preferences.

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