Geolocators track Ruddy Turnstone to Newcastle, NSW en route to King Island (Tasmania)

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The tracking of birds using light-level geolocators has become a relatively frequent technique in the study of migratory shorebirds. The geolocator program, commenced in Australia by the Victorian Wader Studies Group in 2009, has provided insights into many of the strategies and outcomes of the species studied. The most numerous of these studies have been on the Ruddy Turnstone *Arenaria interpres*. While an increasing number of these are multiple tracks for the same bird, there are relatively few with field sightings to enable supporting calibration and confirmation of computed locations, hence the value of the sightings in Newcastle of Ruddy Turnstone with leg flag WMA described in this paper. The migrations of this bird, described over three consecutive years, show southward tracks over the Pacific Ocean and stopovers in Newcastle on its return journeys to King Island (Tasmania). Information regarding breeding locations and incubation characteristics are also described.

INTRODUCTION

While light-level geolocators have long been deployed to provide an understanding of a range of animal movements, it is over the last 10 years that they have been used on a number of shorebird species to track migratory movements and identify breeding, stopover, and wintering areas (Bridge *et al*. 2011, Tomkovich 2016, Lisovski *et al*. 2016a). These devices measure and store ambient light levels which can be used to determine latitude and longitude when the data are downloaded. They have become a frequently used tool in migration research. Australia was one of the first countries to utilise these loggers for tracking the movements of migratory shorebirds. Since 2009 the Victorian Wader Study Group (VWSG) and the Australasian Wader Studies Group have deployed geolocators on a range of species at non-breeding locations around the country, including coastal Victoria, King Island (Tasmania), SE South Australia, NW Western Australia, and SE Queensland. This extensive program has gathered a wealth of information on the movements of eight of Australia's long-distance migratory species, mostly with high retrieval rates, and, after some initial technical issues, high success of the units deployed. The migratory tracks obtained, including several multi-year tracks, allow us to detail routes and strategies used along the East Asian-Australasian Flyway. Critically, this information has allowed the assessment of the relative importance of stopover sites along the Flyway - fundamental to developing conservation strategies. More recent geolocator units have also enabled assessment of breeding locations and incubation strategies, many of which were unknown given the remote, low density breeding sites used by these species. These insights have informed conservation measures Flyway-wide (including the development of initiatives for the Yellow Sea) and on a local scale.

The Ruddy Turnstone *Arenaria interpres* was chosen for the initial studies using geolocators due to its relative abundance at selected sites and for its site faithfulness, having in mind the need to recapture the bird to retrieve the instrument. Over the period 2009 to early 2017, a total of 485 geolocators were deployed on this species, of which 206 have been retrieved (52%). The VWSG has undertaken studies on other species in southern Australia including Eastern Curlew *Numenius madagascariensis*, Sanderling *Calidris alba* and Red-necked Stint *Calidris ruficollis*; geolocators were deployed on Curlew Sandpiper *Calidris ferruginea* for the first time this year. These programs have only been possible through the dedicated volunteers of the VWSG and the close collaboration of Professor Marcel Klaassen and his team at Deakin University.

The following provides a snapshot of the nature and extent of the program and highlights the Ruddy Turnstone with leg flag WMA which appears to have regularly utilised the Newcastle region as part of its migration strategy on its southward journey back to King Island where it spends at least part of its non-breeding period.

METHODOLOGY

In common with all species on which geolocators have been deployed, Ruddy Turnstones were captured in cannon nets at high-tide roosts. Over the last 4 years, geolocators identified as Intigeo-W65 supplied by Migrate Technology Ltd, Cambridge, UK, have been adopted (see http://www.migratetech.co.uk/IntigeoSummary.pdf). The units were mounted on plastic leg-flags (made from a Darvic PVC sheet) using Kevlar thread reinforced with Araldite resin cement. The geolocator unit weighed 0.65g and when mounted vertically on a flag, the combined weight was 1.2g (1.2% of fat-free body weight). The geolocator was placed on the left tibia of each bird (**Figure 1**). All units were deployed on adult birds considered to be in their second year of life (or older). During the subsequent non-breeding periods following deployment, Ruddy Turnstones carrying geolocators were specifically targeted in cannon net catches.

Figure 1. Geolocator deployed on a Ruddy Turnstone

The bird, WMA, a male (sexed by plumage), was initially captured and banded in a cohort of 39 Ruddy Turnstones at Burgess Bay on King Island on 13 February 2015. The initial geolocator was deployed on WMA at this time. It was recaptured at Manuka South on King Island on 30 March 2017 and the geolocator removed and a new one fitted. This was subsequently retrieved at Burgess Bay on 9 December 2017.

Migration Pathway

Data were downloaded from the retrieved geolocators and the initial analysis undertaken using the threshold method embodied in the manufacturer's software (Lisovski & Hahn 2012). This enabled locations to be computed from the record of sunrise and sunset events. This method fails to produce position estimates under 24-hour daylight conditions as the sun does not fall below the horizon and sunrise/sunset times cannot be detected (Lisovski *et al.* 2012). To further improve the location estimation accuracy and estimates of uncertainty, an analysis using the R package FlightR (Rakhimberdiev *et al.* 2017) was subsequently undertaken. The location accuracy is estimated to be between 70 and 200 km depending on weather and latitude. The record of conductivity was used to supplement these analyses as this indicates when the bird was in flight and when it was feeding in saline water. These results enabled maps to be drawn to show the best estimate of the routes taken by each bird together with major stopover locations. Dates were also extracted for all important elements of each bird's movement.

Breeding Sites

We used the template-fit method described in Lisovski *et al.* (2016a) to estimate the positions of the breeding sites. The level of accuracy of the estimated breeding sites is 100-300 km Lisovski *et al.* (2016a).

Incubation Pattern

Both the light intensity recordings and the recorded temperature patterns over time can be used to make inferences of the incubation and chick-rearing behaviour on the breeding grounds. Gosbell *et al.* (2012) describes how the occurrence of alternating "light" and "dark" signals in the geolocator output recorded in the breeding area was interpreted as an indication for shading associated with nesting activities including, especially, incubation and brooding (see also Lisovski *et al.* (2016b)).

RESULTS

The data collected from the two geolocators fitted to WMA recorded 3 consecutive years of migrations viz 2015, 2016 (partial) and 2017. The migration tracks are shown in **Figure 2**.

2015 Track

Following deployment of the geolocator in February 2015, the bird remained on King Island until departure on 18 April. It flew nonstop to

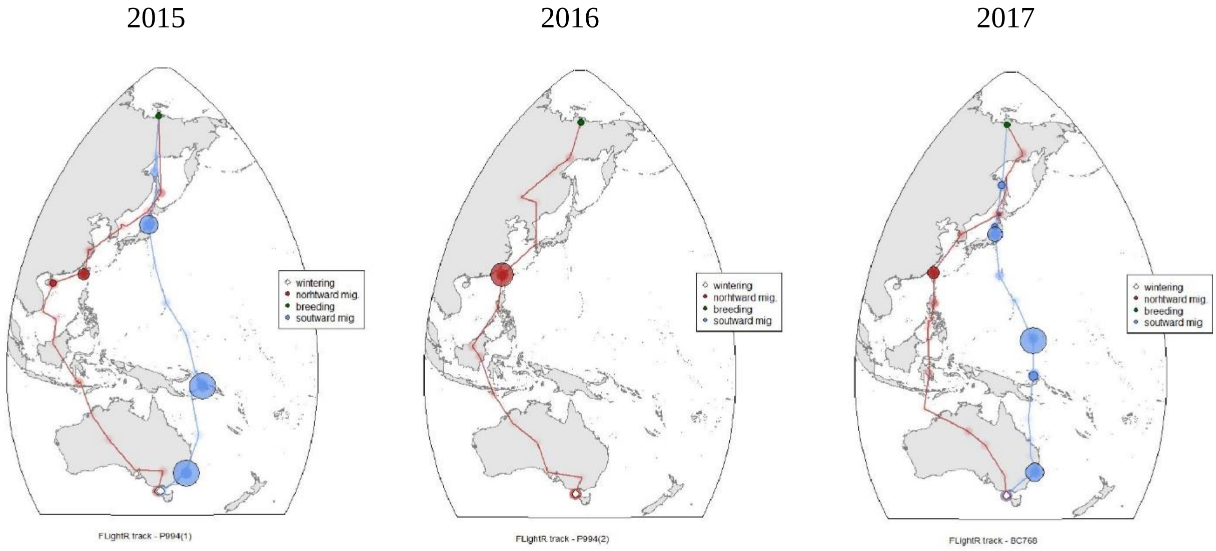

Figure 2. Migration tracks for Ruddy Turnstone WMA for years 2015, 2016, 2017.

Hainan where it remained until 6 May when it went to Taiwan and stayed 6 to 23 May before flying to Sakhalin Island and on to the breeding grounds (estimated latitude 72°N longitude 142°E), arriving 2 June. It stayed on the breeding grounds until 23 July when it travelled south to the west side of the Sea of Okhotsk and on to Japan where it stopped over from 1 to 29 August. It then made a long non-stop flight of 5,500 km across the Pacific to Bougainville Island arriving 8 September and staying until 20 October. On this date it flew south to the Newcastle region of NSW. It was observed at Stony Point and Newcastle Beach on 23 October, 28 December and was last photographed there on 16 January 2016 (pers. comm. J. Thomas). The bird returned to King Island on 13 February 2016.

2016 Track

The bird was not recaptured before it departed again on 12 April 2016 and flew non-stop to Taiwan (7,500 km) in 6 days at an estimated average ground speed of 55 kph. It stopped over in Taiwan until 24 May when it headed for the breeding grounds with only a short stop on the western side of the Sea of Okhotsk. It reached the breeding grounds, estimated to be latitude 70°N longitude 146°E, on 31 May. It departed the breeding grounds on 23 July; however, after this time the geolocator failed to record any further data. The track south is therefore not available, but the bird was observed again at Newcastle Beach on 4 November 2016. The bird subsequently returned to King Island where it was recaptured on 30 March 2017 and a new geolocator attached.

2017 Track

WMA again departed on its northward migration on 23 April 2017 and flew to Taiwan arriving 6 May after a short stop in the Philippines. On 24 May it flew to Sakhalin Island, and then on to the breeding grounds arriving 6 June (latitude 70°N longitude 142°E). It departed the breeding grounds 9 August, flew to the west coast of the Sea of Okhotsk and on to Japan where it arrived 16 August. On 7 September it flew south across the Pacific, 3,500 km to the Chuuk Islands, a series of atolls in Micronesia. It stayed from 15 September to 12 October when it flew south to East New Britain. On 24 October it flew to Newcastle arriving 28 October. It was observed there on 28 October (pers. comm. J. Thomas). On 24 November it undertook its final leg back to King Island where it was captured 9 December and the geolocator removed (see **Figure 3**).

Refer to **Table 1** for key dates by year.

Incubation

A review of the minimum temperatures and light intensity recorded on the geolocator indicated that in 2015 there was no sign of incubation, in 2016 there were signs of a start of incubation, but it ceased on 6 July. In 2017 there were clear signs of incubation from 24 June to 11 July; as this was only 17 days it was probably not successful. (See **Figure 4**).

Table 1. Key dates for Ruddy Turnstone WMA by year

Year	Depart King Is.	Arrive breeding grounds	Depart breeding grounds	Arrive Newcastle	Depart Newcastle	Arrive King Is.
2015	18 Apr	2 Jun	23 Jul	23 Oct	?	13 Feb 16
2016	12 Apr	31 May	23 Jul	Seen 4 Nov[1]	?	Geo retrieved 30 Mar 17
2017	23 Apr	6 Jun	9 Aug	28 Oct	24 Nov	Geo retrieved 9 Dec 17

[1] Geolocator failed July 2016.

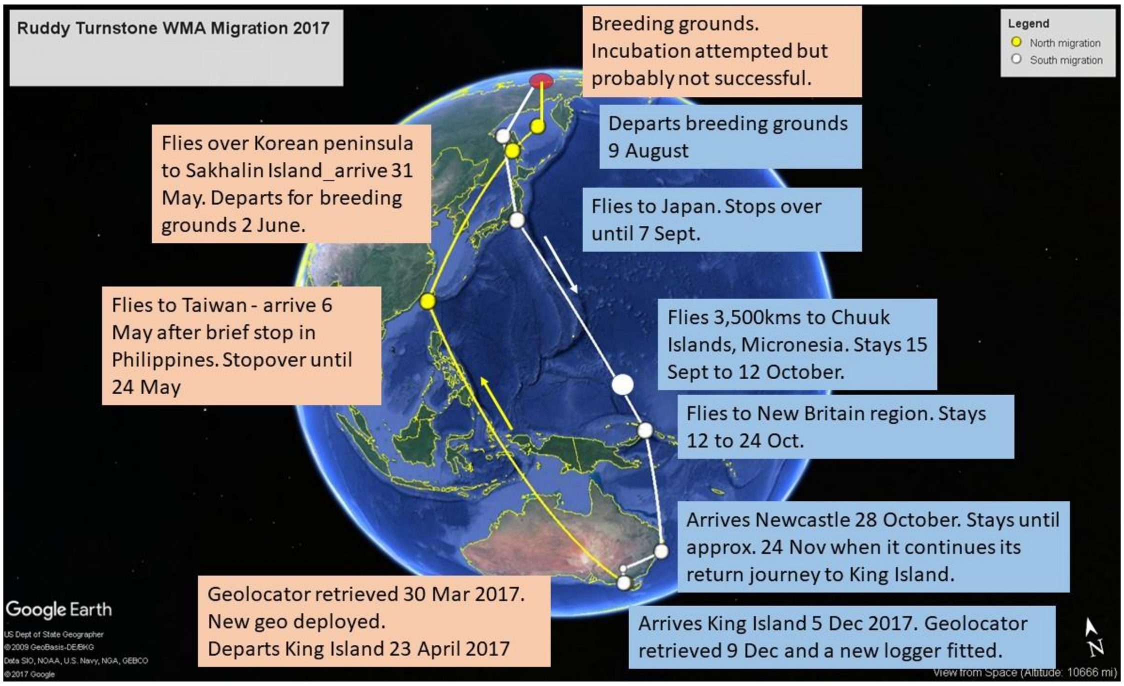

Figure 3. Track of Ruddy Turnstone WMA in 2017.

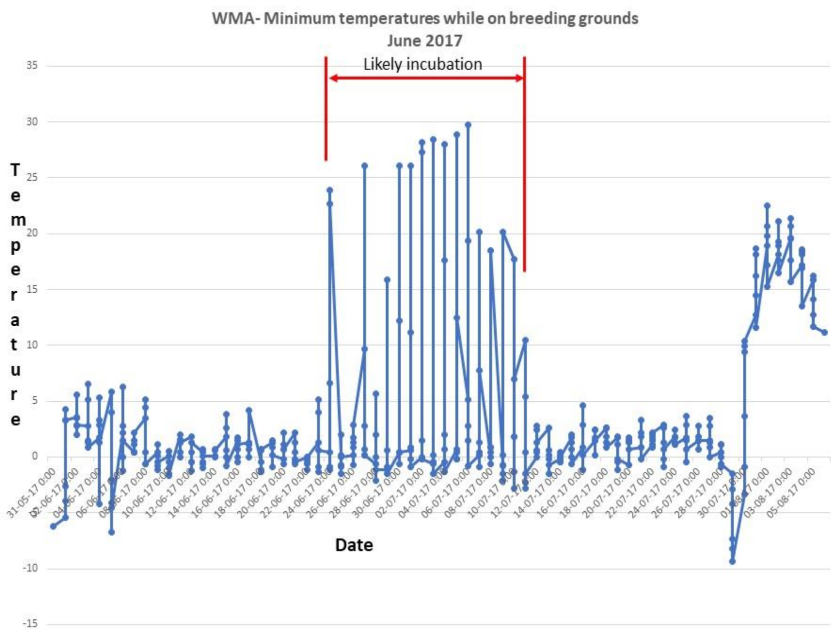

Figure 4. Chart showing minimum temperatures recorded by geolocator for the period the bird was on the breeding grounds in June 2017. The chart indicates the likely incubation period.

DISCUSSION

The tracking of birds using light-level geolocators has become a relatively frequent technique in the study of migratory shorebirds. The geolocator program, commenced in Australia by the VWSG in 2009, has provided insights into many of the strategies and outcomes of the species studied. There are currently 197 tracks now available as a result of studies on Ruddy Turnstone at three locations in southern Australia, namely Flinders (Victoria), SE South Australia and King Island (Tasmania). An increasing number of these are multiple tracks for the same bird. However, there are relatively few with field sightings to enable supporting calibration and confirmation of computed locations, hence the value of the field sightings in Newcastle.

There are several features of the tracks described for WMA that are of particular interest. Firstly, while this bird undertook its northern migration through Taiwan and the coasts of China and the Sea of Okhotsk to the breeding grounds in northern Siberia, its track south was via Japan and the Pacific. While the majority of pathways south to the non-breeding areas undertaken by Ruddy Turnstone are generally similar, but not identical, to the pathways followed on northern migration, there have been only a limited number of examples where the bird has travelled southeast from the breeding grounds and crossed the Pacific on its return to Australia. The earliest example was bird 9Y which returned to Flinders (Victoria) with a stopover in the Marshall Islands (Minton *et al.* 2010). The subject bird, WMA, flew from Japan to Bougainville Island in 2015 and an atoll in Micronesia in 2017 (the logger failed in 2016 so no track available). At this stage there are no cogent explanations why this is done, but it would seem that having established this strategy, the bird repeats the same or a similar route in subsequent years.

Secondly, it made a major stopover in the Newcastle region before returning to King Island. Once again, this is relatively unusual based on the tracks available at this stage. Furthermore, it appears to have made this a major stopover and even refuelling site, judging by the fact that it returned to King Island in 2016 only 7 weeks before it departed on its northern migration. Again, it adopted the same stopover location for 3 consecutive years. The value of the sightings in Newcastle are obvious not only for confirming the computed tracks but establishing the importance of this area as a refuelling location.
The breeding locations derived from the geolocator data for WMA are in the high Arctic on the northern slopes of Yakutia. Analyses of other Ruddy Turnstone data have indicated the breeding areas of this species from southern Australia to cover a range from Yakutia to the New Siberian Islands (unpublished). The 3 breeding locations identified from the analyses are within a 90 km radius, well within the accuracy for this methodology. Although incubation was attempted for the 3 years covered by these data, WMA did not achieve the full term of incubation, reported to be in the range 20.5 - 24 days for this species (Cramp & Simmons 1983). The variability of incubation success has been shown in Gosbell *et al*. (2012), and subsequent unpublished results.

The departure dates from King Island were 18, 12, and 23 April in 2015, 2016 and 2017 respectively. In common with the majority of other Ruddy Turnstones, the first leg is either a non-stop flight to Taiwan or an initial stop in Hainan and then on to Taiwan. Taiwan has been shown to be a critical stopover and refuelling location for northward migrating Ruddy Turnstones (Minton *et al*. 2013 and unpublished data).

CONCLUSION

The study of this one bird over three years has provided a lot of useful information relating to migration strategies, timings and major stopover locations including the value of appropriate Australian sites. In addition, breeding locations were derived to be in the high Arctic regions of Siberia in common with other birds of this species. An insight into incubation behaviour on the breeding grounds was also outlined.

This study has also reinforced the value of sighting and reporting birds equipped with a geolocator anywhere in the Flyway. With another replacement geolocator deployed on WMA in December 2017 it will be interesting to retrieve it and follow another year of migration.

ACKNOWLEDGEMENTS

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