Oikos

**OIK-05531**

Norevik, G., Boano, G., Hedenström, A., Lardelli, R., Liechti, F. and Åkesson, S. 2018. Highly mobile insectivorous swifts perform multiple intra-tropical migrations to exploit an asynchronous African phenology. – Oikos doi: 10.1111/oik.05531

# Appendix 1

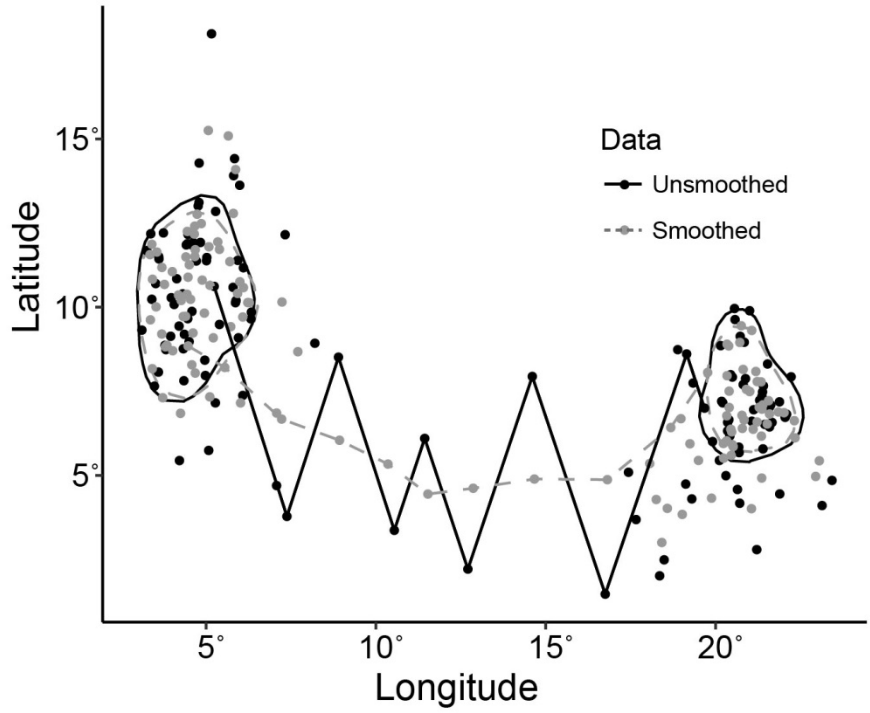


Figure A1.1. The geolocation data were smoothed twice by a running three-day mean to ease the interpretation of positions during potential movement episodes (dots interconnected with lines). The smoothed data were annotated by manually searching for episodes of directional movements that linked two clouds of dots representing periods of residency. The validity of the annotation was tested by using a Kernel Density Estimation (KDE) approach where density surfaces for each presumed residence period were generated to investigate if the 60% KDE of the two periods overlapped. At occasions they did, we merged the periods and generated a new KDE of the merged data. We used a two-dimensional KDE function which avoids the normal reference rule when estimating the smoothing factor and applies different smoothing factors for the longitudinal and latitudinal dimensions respectively, making it applicable to use on geolocation data, which often show skewed distributions of different degrees in the latitude and longitude (Botev et al. 2009). Polygons represent 60% KDE for the two residence periods, where the black line is based on unsmoothed data and grey dashed line results from smoothed data. The small differences in shape and size between the polygons indicate that the smoothing procedure has limited effect on the shape of the KDE although the latitudinal component may differ more when evaluating sites closer to the equinoxes as the uncertainty in the estimate of the latitudinal component elevates. Timing of arrival and departure to and from the site was defined as the first and last position to be within the polygons representing the 60% KDE.

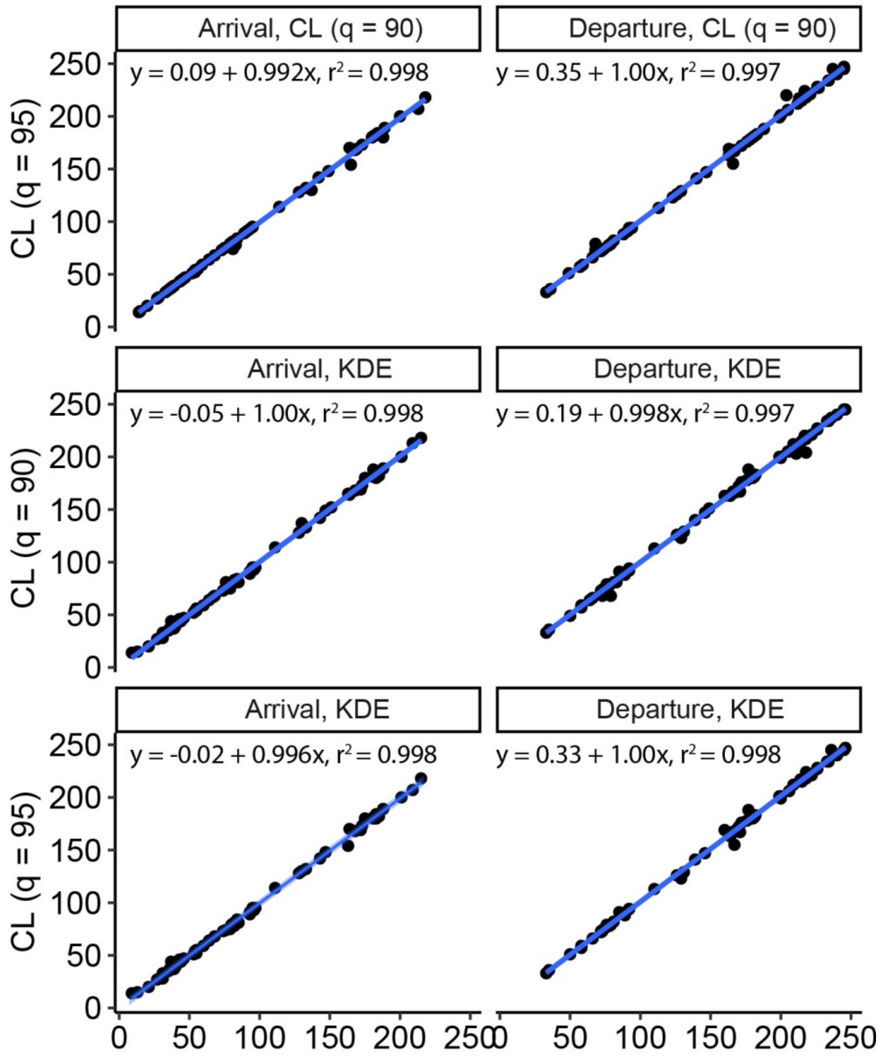


Figure A1.2. Comparisons of the arrival (left column) and departure (right column) timing estimated by different methods and settings, where CL (90/95) are the results from the *changeLight* function in the R package *GeoLight* (Lisovski and Hahn 2012) with a minimum of 5 days stop, and 0.90 and 0.95 quantiles are the probability thresholds for the stationary site selection (Lisovski et al. 2015). KDE represents the method used here. Numbers on axis are days from 1 September. Overall, the estimated timing of both arrival and departure corresponds very well between methods. However, the KDE approach is based on a potentially subjective selection of residence periods which is objectively evaluated with a KDE isocline as a yard stick varying dynamically depending on the spread of the underlying point distribution. The approach involving the *changeLight* function is to first perform an objective a priori annotation of residency periods based on light data. However, as the *changeLight* function appears to generate a number of false positives, generally observed as largely overlapping point clouds, which is usually merged (Finch et al. 2015, Koleček et al. 2016). This appear to occur commonly enough for the inclusion of a *post hoc mergeSites* function in the *GeoLight* package (Lisovski et al. 2015), although little information is provided how to perform the selection of sites to merge which in combination with the settings of minimum days of stops and threshold level risk to include a currently unknown degree of subjectivity in the process.

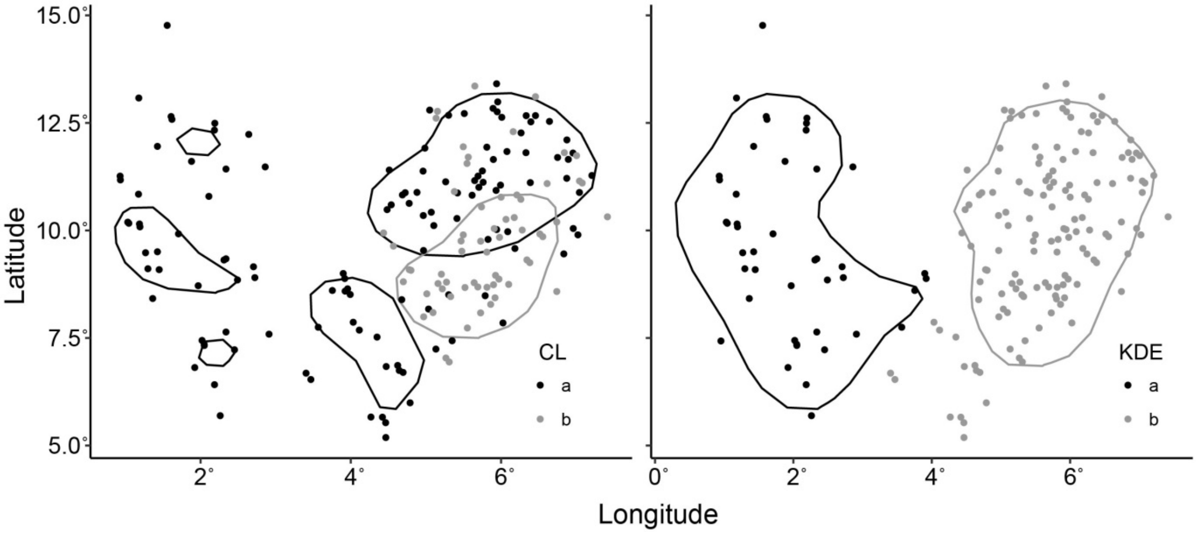


Figure A1.3. A representative presentation of a subset of site estimated based on the *changeLight* function (left) with a minimum stop duration of 5 days and 95% probability thresholds for the stationary site selection (Lisovski et al. 2015) and the approach used here (right), where approaches have yielded different outcomes. Black and grey dots and polygons represent site ‘a’ and site ‘b’, respectively, polygons represents 60% KDE. The overlap of the grey and black polygons to the left suggests that points represent the same stationary sites. In addition, the multimodality of site ‘a’ revealed by the multiple polygons indicates that the selected subset of positions may represent more than on stopover site. Presumably, the sites in the left graph would be merged in the approach involving *changeLight*, although there is an apparent longitudinal shift from site ‘a’ to site ‘b’ as demonstrated in the right graph.

# References

Botev, Z. I. et al. 2010. Kernel density estimation via diffusion. – Ann. Stat. 38: 2916–2957.

Finch, T. et al. 2015. A pan-European, multipopulation assessment of migratory connectivity in a near-threatened migrant bird. – Divers. Distrib. 21: 1051–1062.

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Lisovski, S. and Hahn, S. 2012. GeoLight – processing and analysing light-based geolocator data in R. – Methods Ecol. Evol. 3: 1055–1059.

Lisovski, S. et al. 2015. Package Geolight: analysis of light based geolocator data. – <https://cran.r-project.org/web/packages/GeoLight/GeoLight.pdf>.

## Appendix 2

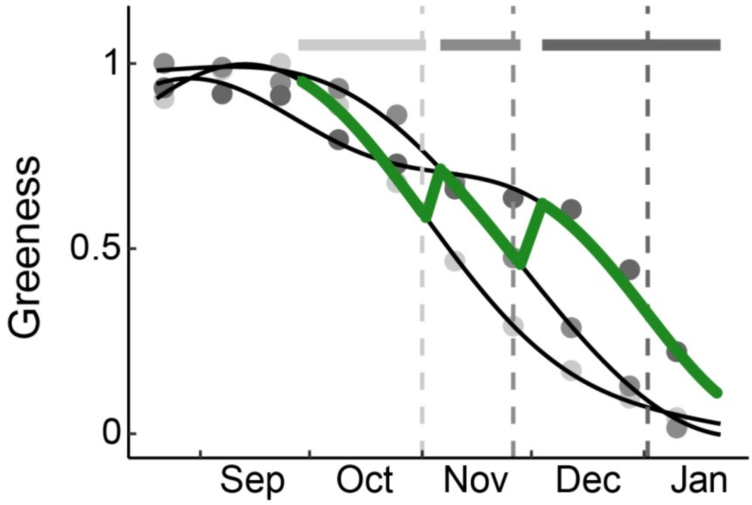


Figure A2.1. The temporal distribution of movements and stops in an individual pallid swift illustrating the timing of residency in three consecutive residence areas (horizontal grey bars), the time series of standardised greenness at the three sites (dots) with fitted models (continuous black lines), and the timing of the local maximum deterioration rate (vertical dashed lines). The green line illustrates the phenology as experienced by the bird.

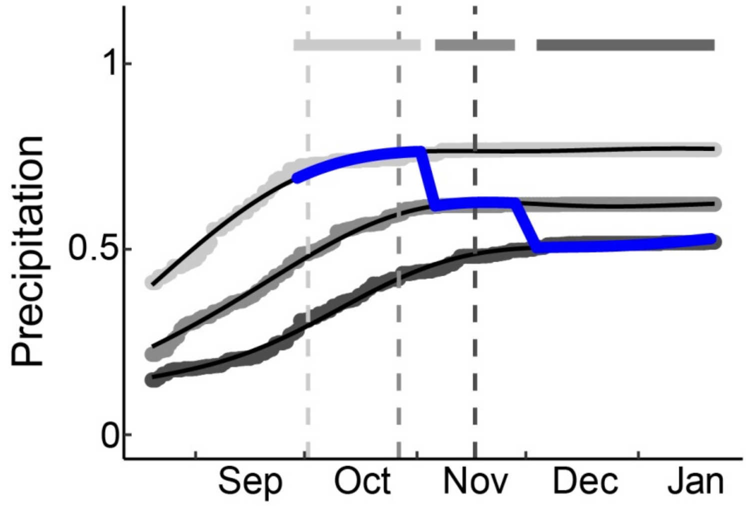


Figure A2.2. The temporal distribution of movements and stops in an individual pallid swift illustrating the timing of residency in three consecutive residence areas (horizontal grey bars), the time series of standardised cumulative precipitation at the three sites (dots) with fitted models (continuous black lines), and the timing of the local end of the rain season (vertical dashed lines, see main text). The blue line illustrates the phenology as experienced by the bird. Note that the standardised precipitation levels-off differently in the graph, due to different relative timing of the seasonal rain within the annual cycle between the sites.

# Appendix 3

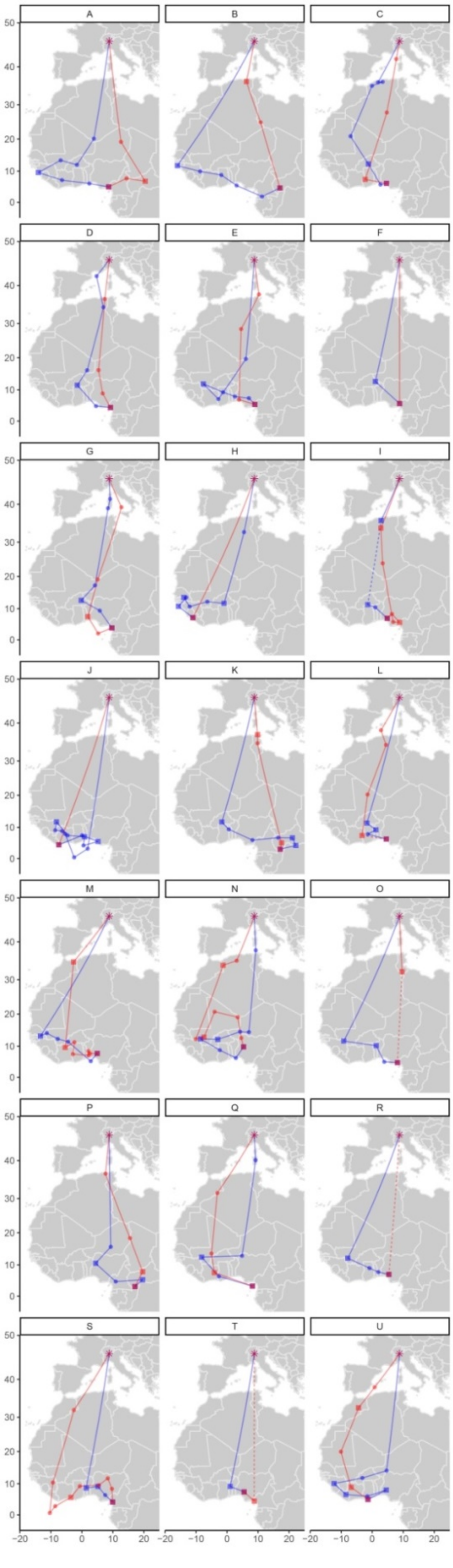


Figure A3.1. Individual maps of the 21 tracked birds (A–U). Blue and red colours represent tracks before and after 1 February, respectively. Residence areas are highlighted with squares, while dots show locations of three-day means of the estimated positions during movement phases. Maps are in a Mercator projection.