DIFFERING SEX-RELATED ARRIVAL OF RED PHALAROPES *PHALAROPUS FULICARIUS* AT WINTERING GROUNDS IN CHILE

YERKO A. VILINA[1], VALERIA SABAJ[2], PAOLA SÁEZ[3], DANIELA LEIVA-CALDERÓN[1]*, & FRANCO CRUZ-JOFRÉ[4]

*[1]Biolog Chile, Group for Studies and Consulting on Wildlife Conservation, Santiago, Chile *(daniela.lc@biologch.com)*
[2]Instituto de Ciencias Biomédicas, Universidad de Chile, Santiago, Chile
[3]Centro de Ecología Aplicada, Santiago, Chile
[4]Facultad de Recursos Naturales y Medicina Veterinaria, Universidad Santo Tomás, Viña del Mar, Chile

Received 27 March 2025, accepted 18 April 2025

ABSTRACT

Vilina, Y. A., Sabaj, V., Saéz, P., Leiva-Calderón, D., & Cruz-Jofré, F. (2025). Differing sex-related arrival of Red Phalaropes *Phalaropus fulicarius* at wintering grounds in Chile. *Marine Ornithology*, *53*(2), 281–284. http://doi.org/

Information is often sparse about whether sex affects arrival of long-distance migratory species at wintering grounds. In this paper we analyze the Red Phalarope *Phalaropus fulicarius*, a species exhibiting sex-role reversal in its nesting patterns. Between September and December 2005, 166 individuals were found dead along the northern Chile coast, which borders the Humboldt Current. Each individual was tagged, and the date of finding was recorded. Nuclear DNA samples were obtained from 46 individuals and analyzed using a molecular sexing method. Results indicate that females arrived between September and early October, with males appearing in late October. On average, females arrived 26.8 d before males. Results confirm the differential migration according to sex for this species, with females being the first to arrive at the wintering grounds in Chile.

Key words: Chile, differential migration, Humboldt Current, *Phalaropus fulicarius*, Red Phalarope, wintering grounds

INTRODUCTION

Birds are well known for their diversity of migratory strategies (Berthold, 2001; Newton, 2024). One strategy is differential migration within the same population, depending on sex and age (Newton, 2024), which has been extensively studied in several species (Cristol et al., 1999; Ketterson & Nolan, 1983; Payevsky, 2020). However, less is known about how environmental and/or endogenous variables may affect the pattern. Intra-population differences can occur in the routes and distances traveled, in the wintering areas, or in the temporality of migratory patterns (Cohen et al., 2019; Cristol et al., 1999; Newton, 2024).

Regarding seasonality, differences related to sex can occur in individuals' arrival at the breeding grounds (Newton, 2024; Payevsky, 2020) and also in the start of migration from the breeding grounds to the wintering grounds. The sex that dedicates more time to parental care is the one that leaves the breeding grounds later (Conklin, 2019), and the difference is greater when the mode of care is single-parental (Newton, 2024). In most bird species, care is provided by both parents, with varying degrees of participation from males and females, but in a few species, care is completely uniparental, sometimes exhibiting sex-role reversal (Cockburn, 2006; Liker et al., 2013).

In sex-role reversal species, the females compete for access to the males, can mate with more than one individual (polyandry), and leave incubation and parental care mostly or completely to the males (Connors et al., 1979; Eens & Pinxten, 2000; Emlen & Oring, 1977; Liker et al., 2013). In general, sex-role reversal is rare in birds, but it occurs in some migratory species of Charadriiformes such as the Eurasian Dotterel *Eudromias morinellus*, the Spotted Sandpiper *Actitis macularius*, and the three species of the genus *Phalaropus*: Wilson's Phalarope *P. tricolor*, Red-necked Phalarope *P. lobatus*, and Red Phalarope *P. fulicarius* (Colwell & Haig, 2019; Emlen & Oring, 1977; Oring & Lank, 1982; Tracy et al., 2002; Wiersma & Kirwan, 2023).

In phalaropes, and in Charadriiformes in general, most studies related to differential migration have been done at breeding grounds (Hayman et al., 1986; Reynolds et al., 1986; Tracy et al., 2020), with limited information about arrival at wintering grounds and departure from wintering grounds to breeding grounds. In Wilson's and Red-necked Phalaropes, females arrive at the breeding grounds before males and are also the first to leave, doing so in the middle of the incubation period (Colwell & Jehl, 2020; Reynolds et al., 1986; Rubega et al., 2020). Similarly, in the Red Phalarope, females arrive first and leave earlier than males, suggesting differential migration (Connors et al., 1979; Saalfeld et al., 2024; Tracy et al., 2020).

The Red Phalarope breeds in the coastal tundra of Siberia, Iceland, Greenland, and North America from Alaska (60°N) to the Canadian High Arctic (80°N) (Mayfield, 1979; Tracy et al., 2020). In the Americas, after leaving the breeding grounds and making their first stopovers, these phalaropes become pelagic, heading south along the coastal waters of the Pacific and Atlantic Oceans. The Pacific route is within the California and Humboldt Currents, with wintering grounds being in the Gulf of California, southern Peru, and Chile (Hayman et al., 1986; Murphy, 1936; Saalfeld et al., 2024; Tracy et al., 2020). In Chile, records stretch the entire length of the country (Araya & Millie, 1998; Barros, 1932; Goodall et al., 1951; Murphy et al., 1936; Venegas & Sielfeld, 1998). Little information exists on this species's biology in Chilean waters.

Between September and December 2005 (austral spring–summer), a mass mortality event of Red Phalaropes was recorded in Mejillones, northern Chile, where 166 dead individuals were found over several months. Light pollution due to lights associated with port activities was involved in this mortality. These lights attract and disorient the birds, causing exhaustion and/or death by collision, a phenomenon known as fallout (Rodríguez et al., 2017).

The Red Phalarope is sexually dimorphic in its breeding plumage (Delhey et al., 2024) but not in its non-breeding plumage (Hayman et al., 1986; Murphy et al., 1936). In such groups of birds, including the Red Phalarope, individuals have been captured, allowing the application of morphometric and/or molecular differentiation of sex (Delhey et al., 2024; Giroux et al., 2016; Vucicevic et al., 2013). Because the species frequents pelagic waters during migration and wintering, working with dead animals is of great value (Jessup, 2003), and the incidental mortality event described above allowed us to obtain samples in a serial and systematic way. Despite the limited knowledge about the wintering grounds of the species in Chile, we hypothesized based on its behavior at breeding grounds that female Red Phalaropes arrive before the males. Therefore, our objective was to determine the patterns of differential arrival of the sexes of Red Phalaropes to the wintering grounds in northern Chile.

STUDY AREA AND METHODS

Study area and sampling

Mejillones Bay (23°06′S, 070°28′W) is in northern Chile (Fig. 1). Between 09 September and 04 December 2005, a total of 166 dead Red Phalarope specimens were collected by the environmental authorities from the facilities of Angamos Port in Mejillones Bay (Fig. 1) and provided to us. Date of death (date of discovery) was recorded for each individual, and all were stored frozen. Forty-six individuals were selected at random, and 0.5 cm³ of pectoral muscle was sampled from each individual and preserved in 20% dimethyl sulfoxide solution.

Sexing

Total genomic DNA was extracted using the DNeasy Tissue Kit (QIAGEN). The samples were analyzed between September 2005 and January 2006 at the molecular ecology laboratory of the Universidad Santo Tomás, Santiago, Chile. First, the sex of each individual was determined by dissection and macroscopic identification of the gonads. Subsequently, the sex of each individual was determined by the molecular methods of Griffiths et al. (1998), Fridolfsson and Ellegren (1999), and Clinton et al. (2001).

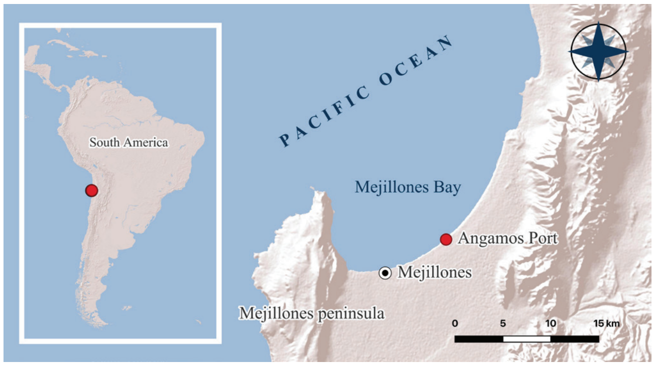

Fig. 1. Study area in northern Chile.

Statistical analysis

The time of arrival of each individual was compared by sex. We kept in mind that, with the beginning of the austral winter (21 June, the day with the fewest hours of light), the migratory cycles would be partially regulated by the light-dark cycles. The average arrival of males and females was compared in a means comparison test (*t*-test) using the PAST software (Hammer & Harper, 2001). The days of arrival have been graphed in a violin plot (shown with a kernel density plot) and boxplot (Fig. 2), and the number of individuals by time period is also presented (Fig. 3).

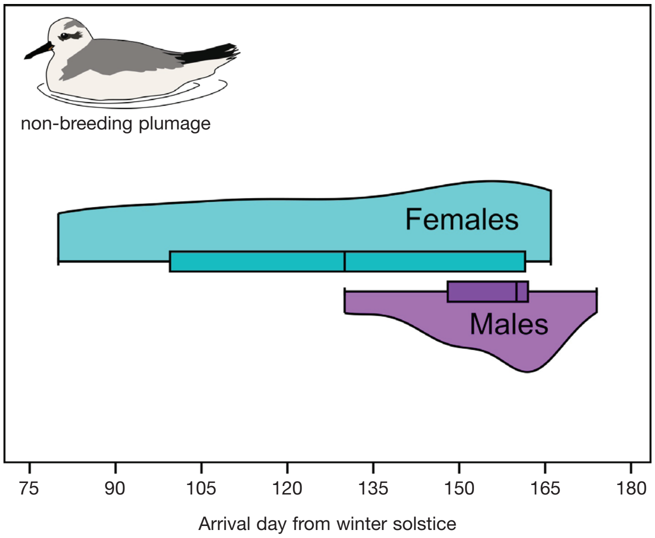

Fig. 2. Violin plot (half of a continuous histogram) and boxplot of the days of arrival of Red Phalaropes *Phalaropus fulicarius* in non-breeding plumage at Mejillones Bay for each sex. The days are counted from the beginning of the austral winter (21 June). The box plots show the median (central vertical line) and the interquartile range of the arrival day for each sex. The flat ends in each violin plot indicate the first and last arrival dates of the successfully sexed individuals.

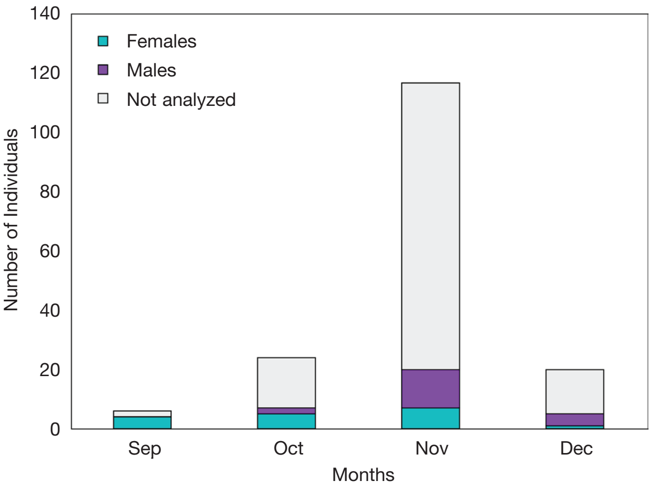

Fig 3. Number of Red Phalarope *Phalaropus fulicarius* individuals collected in Angamos Port during 2005. Number of females/males analyzed per month: September, 4/0; October, 5/2; November, 7/13; December, 1/4.

RESULTS

Of the 46 analyzed samples, macroscopic sexing was difficult, since individuals were in a non-reproductive state, with underdeveloped gonads, and also because most of the samples already showed signs of decomposition. Therefore, it was possible to determine the macroscopic sex in only seven individuals (19.4% of the samples). The molecular sexing method was successful for 36 of the 46 analyzed samples (78.3%) (Table 1). Of the three methods used, the most successful was that of Fridolfsson and Ellegren (1999), with all 36 individuals successfully sexed: 17 females and 19 males (Appendix 1, available on the website).

Comparing the days of arrival showed differences between sexes: on average females arrived 127.4 d after the start of the austral winter (range: 81–166 d), while males arrived on average 154.2 d after that date (range: 130–174 d). This difference was statistically significant ($t = 3.365$, $p = 0.0019$; 9,999 permutations). Females arrived on average 26.8 d earlier than males (Fig. 2).

DISCUSSION

Results presented new information on differential migration in the Red Phalarope. Most of the available information on the distribution and ecology of this species is associated with the breeding grounds or along the northern part of their migratory routes (Tracy et al., 2020). Information on what happens in the wintering grounds in the Southern Hemisphere has been scarce.

Although we were unable to determine the sex of all the dead individuals collected, our analysis showed significant differences between the sexes in the day of arrival in the study area. Saalfeld et al. (2024) found that females leave on average 17 d earlier than males from breeding grounds in Alaska and Canada. Our results show an even greater time difference in the arrival at this wintering ground, with females arriving 26.8 d earlier than males, on average. All the birds analyzed between 09 September and 12 October 2005 were females ($n = 8$); males began to be recorded from 29 October onwards.

In this study the ages of the individuals were not determined; however, due to the system of parental care in this species, these results could indicate that males might stay with the juveniles along the migratory route. Doing so would lead to slower migration, with more stops. This is consistent with studies carried out in breeding grounds, where it has been observed that adult females, non-breeding females, and males that did not nest begin migration earlier (end of June); breeding males and juveniles (males and females) then leave between July and August (Connors et al., 1979; Tracy et al., 2020). Furthermore, in a study using satellite tagging, it was observed that after the start of migration, males stop more often and for longer than females at stopovers near the breeding grounds (Saalfeld et al., 2024).

TABLE 1
Number of Red Phalarope *Phalaropus fulicarius* individuals successfully sexed using macroscopic and molecular techniques

	Molecularly sexed individuals	Macroscopically sexed individuals (%)
Males	19	1 (5.26%)
Females	17	6 (35.29%)
Total	36	7 (19.44%)

Based on the sex ratio obtained (17 females, 19 males), we assume that there is no sampling bias with respect to sex in our study. It is likely that in this species of phalarope both sexes are affected equally by light pollution, although there are no studies on this in the genus *Phalaropus*. In a study based on museum collections (Myers, 1981), no latitudinal segregation between sexes was recorded in the wintering range in North America, which is consistent with our results.

Considering the period in which the mortality event described here occurred (spring–summer), it is most likely that southward migratory individuals were involved. Since a second period of mortality was not reported in the subsequent fall–winter period, it is possible that the return migratory route north was different.

The mortality event we recorded was very worrying and was successfully stopped with the support of the company Angamos Port and the Chilean authorities, using management measures that were implemented with our support (Y. A. Vilina, personal observation, December 2024). At present, however, dead individuals continue to be recorded sporadically on this coast, although generally fewer than 10 individuals per year (Y. A. Vilina, personal observation, December 2024).

ACKNOWLEDGEMENTS

This study was partially supported by Angamos Port Company. We would like to thank Leslie Ramírez for collaborating on the molecular sexing process in the laboratory. Our thanks, also, to Jaime Zavala and Cesar Barrera for allowing access to the dead birds collected. Franco Cruz-Jofré is thankful for support from CONICYT-PCHA/Doctorado Nacional/2015-21150821. We thank the editor and reviewers for their comments.

REFERENCES

Araya, B., & Millie, G. (1998). *Guía de campo de las aves de Chile*. Editorial Universitaria.

Barros, R. (1932). Apuntes acerca de varios pájaros de Llico. *Revista Chilena de Historia Natural*, *36*, 162–166.

Berthold, P. (2001). *Bird migration: A general survey* (2nd ed.). Oxford University Press. https://doi.org/10.1093/oso/9780198507864.001.0001

Clinton, M., Haines, L., Belloir, B., & McBride, D. (2001). Sexing chick embryos: A rapid and simple protocol. *British Poultry Science*, *42*(1), 134–138. https://doi.org/10.1080/713655025

Cockburn, A. (2006). Prevalence of different modes of parental care in birds. *Proceedings of the Royal Society B: Biological Sciences*, *273*(1592), 1375–1383. https://doi.org/10.1098/rspb.2005.3458

Cohen, E. B., Rushing, C. R., Moore, F. R., Hallworth, M. T., Hostetler, J. A., Ramirez, M. G., & Marra, P. P. (2019). The strength of migratory connectivity for birds en route to breeding through the Gulf of Mexico. *Ecography*, *42*(4), 658–669. https://doi.org/10.1111/ecog.03974

Colwell, M. A., & Haig, S. M. (Eds.). (2019). *The population ecology and conservation of* Charadrius *plovers*. CRC Press. https://doi.org/10.1093/condor/duaa010

Colwell, M. A., & Jehl, J. R., Jr. (2020). Wilson's Phalarope (*Phalaropus tricolor*), version 1.0. In A. F. Poole & F. B. Gill (Eds.), *Birds of the world*. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.wilpha.01

Conklin, J. R. (2019). Evolutionary and ecological flexibility in migration of *Charadrius* Plovers. In M. A. Colwell & S. M. Haig (Eds.), *The population ecology and conservation of* Charadrius *plovers* (pp. 149–182). CRC Press. https://doi.org/10.1201/9781315152882-7

Connors, P. G., Myers, J. P., & Pitelka, F. A. (1979). Seasonal habitat use by Arctic Alaskan shorebirds. *Studies in Avian Biology*, *2*, 101–111.

Cristol, D. A., Baker, M. B., & Carbone, C. (1999). Differential migration revisited: Latitudinal segregation by age and sex class. In V. Nolan, E. D. Ketterson, & C. F. Thomson (Eds.), *Current ornithology* (Vol. 15, pp. 33–88). Springer. https://doi.org/10.1007/978-1-4757-4901-4_2

Delhey, K., Krietsch, J., Parisi, A., Valcu, M., & Kempenaers, B. (2024). Variation in nuptial color in relation to sex, individual quality and mating success in the sex-role reversed *Phalaropus fulicarius* (Red Phalarope). *Ornithology*, *141*(3), Article ukae016. https://doi.org/10.1093/ornithology/ukae016

Eens, M., & Pinxten, R. (2000). Sex-role reversal in vertebrates: Behavioural and endocrinological accounts. *Behavioural Processes*, *51*(1–3), 135–147. https://doi.org/10.1016/S0376-6357(00)00124-8

Emlen, S. T., & Oring, L. W. (1977). Ecology, sexual selection, and the evolution of mating systems. *Science*, *197*(4300), 215–223. https://doi.org/10.1126/science.327542

Fridolfsson, A.-K., & Ellegren, H. (1999). A simple and universal method for molecular sexing of non-ratite birds. *Journal of Avian Biology*, *30*(1), 116–121. https://doi.org/10.2307/3677252

Giroux, M.-A., Ditlecadet, D., Martin, L. J., Lanctot, R. B., & Lecomte, N. (2016). Sexing a sex-role-reversed species based on plumage: Potential challenges in the red phalarope. *Peer J*, *4*, Article e1989. https://doi.org/10.7717/peerj.1989

Goodall, J. D., Johnson, A. W., & Philippi Bañados, R. A. (1951). *Las aves de Chile: Su conocimiento y sus costumbres*. Platt Establecimientos Gráficos.

Griffiths, R., Double, M. C., Orr, K., & Dawson, R. J. G. (1998). A DNA test to sex most birds. *Molecular Ecology*, *7*(8), 1071–1075. https://doi.org/10.1046/j.1365-294x.1998.00389.x

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). Past: Paleontological statistics software package for education and data analysis. *Paleontologia Electrónica*, *4*(1), Article 4. https://palaeo-electronica.org/2001_1/past/past.pdf

Hayman, P., Marchant, J., & Prater, T. (1986). *Shorebirds: An identification guide to the waders of the world*. Houghton Mifflin.

Jessup, D. A. (2003). Opportunistic research and sampling combined with fish and wildlife management actions or crisis response. *ILAR Journal*, *44*(4), 277–285. https://doi.org/10.1093/ilar.44.4.277

Ketterson, E. D., & Nolan, V., Jr. (1983). The evolution of differential bird migration. In R. F. Johnston (Ed.), *Current ornithology* (Vol. 1, pp. 357–402). Springer.

Liker, A., Freckleton, R. P., & Székely, T. (2013). The evolution of sex roles in birds is related to adult sex ratio. *Nature Communications*, *4*, Article 1587. https://doi.org/10.1038/ncomms2600

Mayfield, H. F. (1979). Red Phalaropes breeding on Bathurst Island. *Living Bird*, *17*, 7–39.

Murphy, R. C. (1936). *Oceanic birds of South America: A study of species of the related coasts and seas, including the American quadrant of Antarctica based upon the Brewster-Sanford collection in the American Museum of Natural History* (Vol. 2). The Macmillan Company.

Myers, J. P. (1981). A test of three hypotheses for latitudinal segregation of the sexes in wintering birds. *Canadian Journal of Zoology*, *59*(8),1527–1534. https://doi.org/10.1139/z81-207

Newton, I. (2024). *The migration ecology of birds* (2nd ed). Academic Press. https://doi.org/10.1016/C2020-0-00573-6

Oring, L. W., & Lank, D. B. (1982). Sexual selection, arrival times, philopatry and site fidelity in the polyandrous spotted sandpiper. *Behavioral Ecology and Sociobiology*, *10*, 185–191. https://doi.org/10.1007/BF00299684

Payevsky, V. A. (2020). Differential migration of birds: Diversity and inconsistency. *Biology Bulletin*, *47*, 724–734. https://doi.org/10.1134/S1062359020070134

Reynolds, J. D., Colwell, M. A., & Cooke, F. (1986). Sexual selection and spring arrival times of red-necked and Wilson's phalaropes. *Behavioral Ecology and Sociobiology*, *18*(4), 303–310. https://www.jstor.org/stable/4599894

Rodríguez, A., Holmes, N. D., Ryan, P. G., Wilson, K. J., Faulquier, L., Murillo, Y., Raine, A. F., Penniman, J. F., Neves, V., Rodríguez, B., Negro, J. J., Chiaradia, A., Dann, P., Anderson, T., Metzger, B., Shirai, M., Deppe, L., Wheeler, J., Hodum, P., . . . Corre, M. L. (2017). Seabird mortality induced by land-based artificial lights. *Conservation Biology*, *31*(5), 986–1001. https://doi.org/10.1111/cobi.12900

Rubega, M. A., Schamel, D., & Tracy, D. M. (2020). Red-necked Phalarope (*Phalaropus lobatus*), version 1.0. In S. M. Billerman (Ed.), *Birds of the world*. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.renpha.01

Saalfeld, S. T., Valcu, M., Brown, S., English, W., Giroux, M.-A., Harrison, A.-L., Krietsch, J., Kuletz, K., Lamarre, J.-F., Latty, C., Lecomte, N., McGuire, R., Robards, M., Scarpignato, A., Schulte, S., Smith, P. A., Kempenaers, B., & Lanctot, R. B. (2024). From land to sea: The fall migration of the red phalarope through the Western Hemisphere. *Marine Ecology Progress Series*, *729*, 1–29. https://doi.org/10.3354/meps14531

Tracy, D. M., Schamel, D., & Dale, J. (2002). Red Phalarope (*Phalaropus fulicarius*). In A. Poole & F. Gill (Eds.), *The birds of North America* (No. 698). The Birds of North America Inc. https://doi.org/10.2173/tbna.698.p

Tracy, D. M., Schamel, D., & Dale, J. (2020). Red Phalarope (*Phalaropus fulicarius*), version 1.0. In S. M. Billerman (Ed.), *Birds of the world*. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.redpha1.01

Venegas, C., & Sielfeld, W. (1998). *Catálogo de los vertebrados de la región de Magallanes y Antártica chilena*. Ediciones de la Universidad de Magallanes.

Vucicevic, M., Stevanov-Pavlovic, M., Stevanovic, J., Bosnjak, J., Gajic, B., Aleksic, N., & Stanimirovic, Z. (2013). Sex determination in 58 bird species and evaluation of CHD gene as a universal molecular marker in bird sexing. *Zoo Biology*, *32*(3), 269–276. https://doi.org/10.1002/zoo.21010

Wiersma, P., & Kirwan, G. M. (2023). Eurasian Dotterel (*Eudromias morinellus*), version 1.1. In J. Del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, & E. de Juana (Eds.) *Birds of the world*. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.eurdot.01.1