SABINE'S GULLS *XEMA SABINI* OUTSIDE OF THEIR MAIN WINTERING AREAS ARE NOT NECESSARILY VAGRANTS

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ABSTRACT

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We reviewed published and unpublished 'vagrant' (herein referred to as 'unusual') records of Sabine's Gull *Xema sabini* worldwide and discuss these records according to age, marine productivity/fishing grounds, and migration corridors. Of the 151 unusual records, 135 (89%) were in or near areas with high productivity and/or known fishing grounds; 10 out of 14 documented records were young birds in their first or second migration, and the 'unusual' areas identified in this study could have been reached through known migration pathways used by other bird species. The fact that the majority of records are associated with productive/fishing zones (and are also in areas with low or no at-sea effort for bird surveys), and that juveniles and young adults typically migrate further, suggests that some individuals may search for productive areas for wintering outside of the main, or well-known, destinations. Our findings suggest that at least some individuals of Sabine's Gull, rather than being 'disoriented', might be in genuine areas of migration corresponding to their life stage, therefore expanding the known distribution range of this species.

Key words: distribution, migratory behavior, vagrancy, pseudo-vagrancy, seabirds

INTRODUCTION

Migratory behavior is observed in assorted animal groups, including birds. This behavior is driven primarily by seasonality in environmental conditions, such as food availability and extreme weather conditions (Newton 2008). Although migratory seabirds demonstrate high fidelity to wintering areas (Phillips *et al*. 2005, van Bemmelen *et al*. 2017), some individuals can be found outside of these grounds (Bourne 1967, Kenefick & Hayes 2006, Portflitt-Toro *et al*. 2018). These birds are called 'vagrants', defined as "any exotic visitor of a species which does not normally breed, overwinter or pass through the region concerned" (*sensu* Newton 2008). The reasons for vagrancy are not clear, but there are several possibilities, such as drift by wind forces, migration overshoots, and migration misdirection (Gilroy & Lees 2003, Newton 2008). Over time, some vagrants are actually verified as 'pseudo-vagrants'—a term that was proposed to characterize individuals that perform genuine annual migration but belong to a species for which the area and/or the migration routes of the species are not well understood (*sensu* Gilroy & Lees 2003). Records of vagrants and pseudo-vagrants can provide useful information about factors that influence the migratory and wintering behavior of birds (Gilroy & Lees 2003) and can also help to establish their spatial distribution.

Sabine's Gull *Xema sabini* has a circumpolar breeding range, extending from low to high Arctic regions (Howell & Dunn 2007, Olsen 2018). Among the smallest Arctic-breeding gulls, this species is the only to exhibit consistent trans-equatorial migration, considered the longest for any gull (Stenhouse *et al*. 2012). Its population size is *ca*. 330 000–700 000 individuals (BirdLife International 2020), and its known wintering areas are in the coastal upwelling zones off Peru, and off Namibia and South Africa (Stenhouse *et al*. 2012, Davis *et al*. 2016). Individuals that winter off the west coast of South America are most likely to breed in Siberia, Alaska, and the Western Canadian Arctic, whereas those found along the west coast of Africa are likely to breed in the Eastern Canadian Arctic, Greenland, and Svalbard (Blomqvist & Elander 1981, Stenhouse *et al*. 2012, Davis *et al*. 2016). Although these areas are considered the main non-breeding sites for Sabine's Gull, their full range is not well known (Howell & Dunn 2007).

Individuals outside of the main wintering areas have been recorded worldwide (Olsen 2018). Therefore, a compilation of records termed 'vagrants' can improve knowledge regarding the distribution pattern of Sabine's Gull. This study aims to review the 'vagrant' (hereafter called 'unusual') records of the species globally, based on published and unpublished data from three scientific databases. We discuss these records according to age, marine productivity and fisheries grounds, and already-known migration corridors.

METHODS

The review of unusual records of Sabine's Gull was based on published (peer-reviewed papers and books) and unpublished data

from scientific databases. We used three databases: the Global Biodiversity Information Facility (GBIF; https://www.gbif.org/); the Ocean Biodiversity Information System (OBIS; https://obis.org); and eBird (https://ebird.org/; Sullivan *et al*. 2009, eBird 2020). All records are shown in the Appendix 1 (available on the website; Figs. S1, S2, S3). Data gathered from these sources were filtered to build the final data set (unusual records) based on several criteria (see below).

To define unusual areas, we first created a 75% kernel contour line (Appendix 1, Fig. S4) based on all the occurrence data, using the "adehabitatHR" package (Calenge 2006). To avoid biases caused by uneven record densities, we thinned the original datasets using a minimum spacing of 200 km radius between occurrence records, through the "spThin" package (Aiello-Lammens *et al*. 2015), before kernel analysis. After the kernel analysis, we excluded records that were inside the 'usual' species range polygons provided by BirdLife International & Handbook of the Birds of the World (2019) and that were inside the 75% kernel contour generated by our analyses using the "sf" package (Pebesma 2018). We removed records North of 60°N due to proximity to breeding colonies. For records off western South America, we considered North of 20°S as 'usual' area (see Davis *et al*. 2016). Additionally, records in the Bering Sea, as well as records on the Gulf of Guinea, were considered to be within the 'usual' passage area.

The unusual records were classified as documented (with photographs) or undocumented (without photographs) records. The information obtained from each record included, when available, the date of occurrence (at least the month), geographic coordinates (or locality), and plumage maturity. Plumage maturity was defined following Howell & Dunn (2007) and Olsen (2018), and based on the same references we defined the life-cycle schedule as 'breeding period' (May–Aug), 'southbound migration' (Aug–Oct), 'non-breeding period' (Oct–Mar), and 'northbound migration' (Mar–May).

We verified the importance of the identified areas in terms of marine productivity and fishing grounds on a global scale based on available scientific literature (Stewart *et al*. 2010, Boyce *et al*. 2012, Guiet *et al*. 2019), and on a local scale through oceanographic/fisheries literature that was specific to each record/locality. By overlapping a chlorophyll-*a* image with the geographic location of unusual records of Sabine's Gulls, we were able to assess the visual relationship between the mean chlorophyll-*a* concentration (a proxy for primary productivity) and these unusual records. This image was obtained from Sea-viewing Wide Field-of-view Sensor (SeaWiFS), with the average concentration calculated based on the 2002–2018 period and mapped through the "oceanmap" package (Bauer 2020).

All analyses and visualizations were performed using R version 3.6.2 (R Development Core Team 2019). Code is available in Appendix 2 (available on the website), which also contains the full list of packages used.

RESULTS

We found 151 unusual records. Of these, 14 and 137 were documented and undocumented, respectively (Table 1). The majority of records occurred off Chile (n = 79), South Africa (n = 21), Australia (n = 16), Taiwan (n = 6), and Mozambique (n = 6) (Table 1). Eighty-nine percent of all records (n = 135) were within or nearby areas with high productivity or known fishing grounds (Table 1; Figure 1 and 2). Ten out of fourteen documented records were juveniles or young-adults (pre-breeding birds) in the

TABLE 1
Documented (photographed) and undocumented (unphotographed) records of Sabine's Gull *Xema sabini* outside their main wintering areas, obtained from published (peer-reviewed papers and books) and unpublished data (GBIF, OBIS, and eBird)

Country	Date	Life-cycle period[a]	Plumage	No. of records	No. of records in productive areas[b]	Source	Reference[c]	Local oceanographic/ fisheries importance[d]
Documented records								
Somalia	11 May 1981	NB migration/ Breeding	First-summer	1	1	Published	Ash 1983	Qasim 1977; Nair & Pillai 1983; Madhupratap *et al*. 1996; Stewart *et al*. 2010
Sumatra	22 Oct 1984	Non-breeding	Adult-winter	1	1	Published	Andrew 1985	Priyono & Sumiono 1997; Susilowati *et al*. 2005; Sunoko & Huang 2014
Antarctica	05 Feb 2006	Non-breeding	First-summer/ Second-winter	1	0	eBird	eBird (50584381)	–
Australia	26 Aug 2006	Breeding/ SB migration	Adult-summer (molting to winter)	1	0	eBird	eBird (61851091; 127554071)	–
Brazil	16 Nov 2009	Non-breeding	Juvenile/ First-winter	1	1	Published	Parrini & Carvalho 2009	Ciotti *et al*. 1995; Haimovici *et al*. 1998
India	03 May 2013	NB migration/ Breeding	Second-summer/ Adult-winter	1	1	Published	Sreenivasan *et al.* 2013	Qasim 1977; Nair & Pillai 1983; Madhupratap *et al*. 1996; Robin *et al*. 2010
Brazil	24 Aug 2013	Breeding/ SB migration	First-summer	1	1	Published	Lees *et al*. 2014	Artigas *et al*. 2003; IBAMA 2009; Daudt *et al*. 2019

Table 1 continued on next page

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Country	Date	Life-cycle period[a]	Plumage	No. of records	No. of records in productive areas[b]	Source	Reference[c]	Local oceanographic/ fisheries importance[d]
Oman	19 Nov 2013	Non-breeding	Adult-summer (molting to winter)	1	1	eBird	eBird (63891041)	Qasim 1977; Nair & Pillai 1983; Madhupratap *et al*. 1996
Taiwan	02 Jan 2014	Non-breeding	Juvenile/ First-winter	1	1	eBird	eBird (61267201 61267211; 61267231; 61267241)	Lin *et al.* 2005; Liu 2013
Mozambique	10 May 2015	NB migration/ Breeding	First-summer/ Second-winter	1	1	Published	Allport 2018	Qasim 1977; Nair & Pillai 1983; Lutjeharms 2006; Tew Kai & Marsac 2010
Brazil	16 Mar 2017	Non-breeding	Second-summer/ Adult-winter	1	1	This work	This work (Fig. S5, Appendix 1)	Ciotti *et al*. 1995; Haimovici *et al*. 1998
Brazil	08 Jun 2017	Breeding	Second-summer/ Adult-summer (molting to winter)	1	1	This work	This work (Fig. S6, Appendix 1)	Ciotti *et al*. 1995; Haimovici *et al*. 1998
Australia	19 Jan 2019	Non-breeding	Adult-Winter	1	0	eBird	eBird (143813771)	–
Australia	17 Jan 2019	Non-breeding	Adult-winter/ Second-winter	1	0	eBird	eBird (135544601)	–
Undocumented records								
Antarctica	Feb	Non-breeding		2	0	GBIF/ OBIS	–	–
Arab Emirates	May, Jun, Jul	NB migration/ Breeding	–	4	4	GBIF	–	Qasim 1977; Nair & Pillai 1983; Madhupratap *et al*. 1996
Australia	Jan, Mar, Apr, Jun, Aug, Oct, Dec	Year-round	–	13	9	eBird/ GBIF/ OBIS	–	McClatchie *et al*. 2006; Ward *et al.* 2006; Hassler *et al*. 2014; Brieva *et al*. 2015
Chile	Jan, Feb, Mar, Apr, May, Aug, Sep, Oct, Nov, Dec	Year-round	–	79	79	eBird/ GBIF	–	Fonseca 1989; Thiel *et al*. 2007
India	May	Year-round	–	1	1	eBird	–	Qasim 1977; Nair & Pillai 1983; Madhupratap *et al*. 1996; Robin *et al*. 2010
French Guiana	Jan	–	–	1	1	GBIF	–	Ffield 2005; Silva *et al*. 2009; Willems *et al.* 2017; Daudt *et al*. 2019
Mozambique	–	–	–	5 other than those documented	5	Allport (2018)	–	Qasim 1977; Nair & Pillai 1983; Lutjeharms 2006; Tew Kai & Marsac 2010
Russia	Jun	Breeding	–	4	2	eBird/ GBIF	–	This work (Figure 2)
South Africa	Jan, Feb, Mar, Apr	Non-breeding/ NB migration	–	21	18	eBird/ GBIF	–	Qasim 1977; Nair & Pillai 1983; Lutjeharms 2006; Tew Kai & Marsac 2010
Taiwan	Jan, Feb, Mar	Non-breeding/ NB migration	–	6	6	eBird/ GBIF	–	Lin *et al*. 2005; Liu 2013
North Pacific Ocean	–	–	–	1	0	GBIF	–	–

[a] NB = Northbound; SB = Southbound.

[b] The number of records within or nearby areas with high productivity and/or known fishing grounds.

[c] For eBird records, the reference refers to the Macaulay Library number (ML); GBIF = Global Biodiversity Information Facility (https://www.gbif.org/); OBIS = Ocean Biodiversity Information System (https://obis.org).

[d] Local oceanographic/fisheries importance, based on scientific literature.

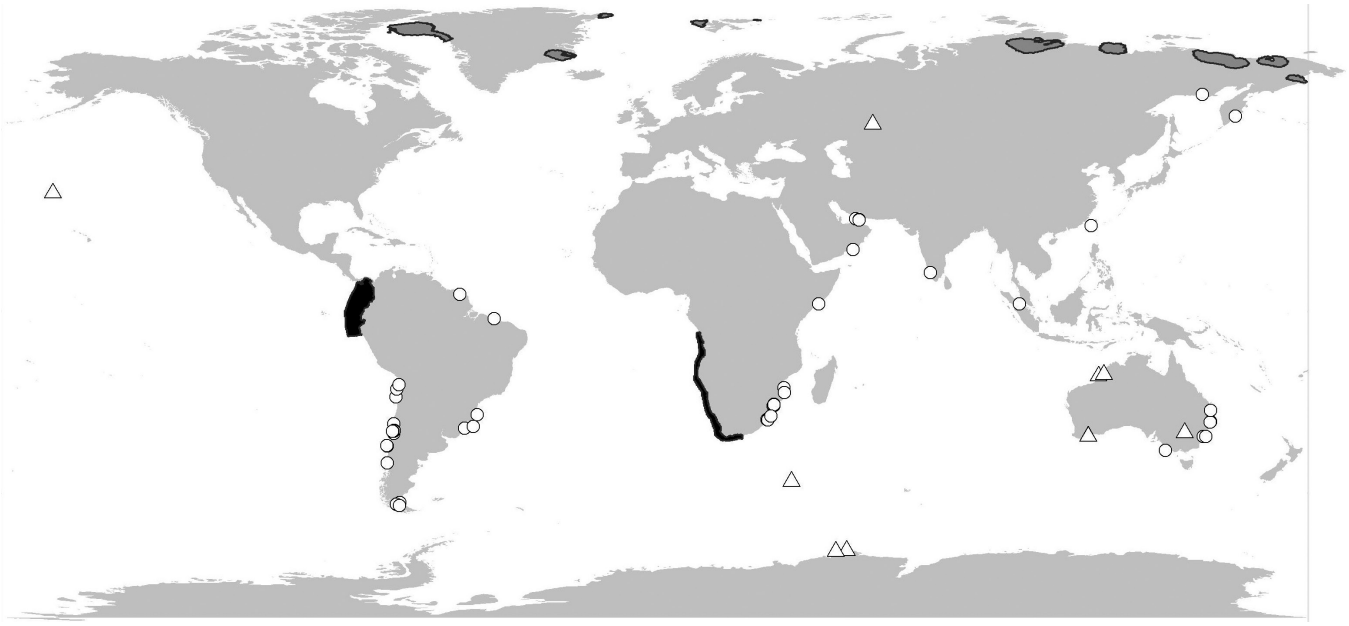

Fig. 1. Records of Sabine's Gull *Xema sabini* out of their usual wintering areas. Buffers represent main wintering areas (black) and breeding grounds (dark gray) according to BirdLife International & Handbook of the Birds of the World (2019); white filled circles represent individuals recorded within or nearby productive/fishing grounds, and white filled triangles represent individuals recorded outside of these areas.

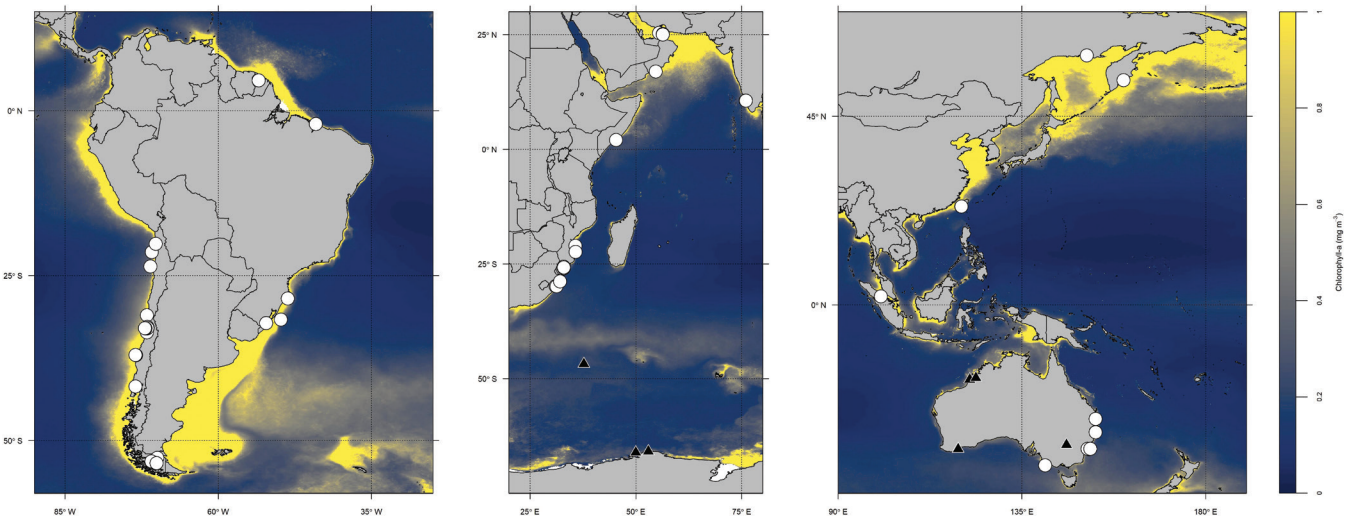

Fig. 2. Plate showing average chlorophyll-*a* concentration between 2002–2018, with zoom-in on the Sabine's Gull *Xema sabini* unusual records shown in Figure 1. White circles represent records within or nearby areas of high primary productivity and/or known fishing grounds, and black triangles represent records outside of these areas.

first or second plumage-cycle (first-summer/winter or second-summer/winter).

DISCUSSION

Sabine's Gulls outside of their main wintering grounds are not necessarily vagrant birds. We argue that these birds could have reached these 'unusual' areas through genuine migration routes used by other species, and that these areas are often associated with high primary productivity and/or fishing grounds; therefore, Sabine's Gulls in these unusual areas may not, in fact, be 'disoriented' birds. Because Sabine's Gull has a large population size, and satellite tracking studies of this species have been limited to two colonies and adult birds, there is considerable room for future studies that address the migration patterns and routes of Sabine's Gull, as well as the relative importance of different areas across age classes.

Almost three-quarters (71%) of the documented records verified here were from young adults. Differential dispersion between ages is well known in birds, as juveniles and young adults tend to migrate further and even with delayed schedules (Newton 2008, Wolfson *et al*. 2020). The use of tracking devices has demonstrated age-dependent migrations in seabirds, including trans-equatorial migrants (Marques *et al*. 2010, Péron & Grémillet 2013, de Grissac

et al. 2017, Orben *et al*. 2018). Moreover, juveniles, immature, and inexperienced adults can move far from their expected migration route or staging areas due to competition with experienced adults, even in wintering areas (Thiebot *et al*. 2012, Missagia *et al*. 2015, Campioni *et al*. 2020). Records presented here could indicate that younger Sabine's Gulls may range further than experienced adults, targeting high productivity areas, perhaps using predominant winds instead of going directly to the 'usual' foraging areas, a pattern also found in other seabirds (Campioni *et al*. 2020, Frankish *et al*. 2020).

The majority of unusual Sabine's Gull records (89%) were within or nearby high productive and/or known fishing grounds. High primary-production and fisheries regions are known to attract top predators, with higher seabird densities associated with oceanographic features, such as fronts, eddies, and river discharges (Scales *et al*. 2014, Daudt *et al*. 2019). The Atlantic continental shelf off Argentina, Uruguay, and southeastern Brazil (23–55°S) is a rich and productive habitat that sustains big fisheries fleets and a wide and diverse community of top predators (Croxall & Wood 2002, Jiménez *et al*. 2011, Gil *et al*. 2019). The high productivity of the region supports an abundant and diverse seabird community, including trans-equatorial migrants such as Arctic Tern *Sterna paradisaea* and South Polar Skua *Stercorarius maccormicki* (Dias *et al*. 2012, Daudt *et al*. 2018). In the northeast of South America, the freshwater discharge of the Amazon and Pará Rivers make this region both highly productive and an important fishing area (Artigas *et al*. 2003, IBAMA 2009). Seabird distribution studies conducted in Suriname and north Brazilian waters demonstrate a high diversity of migratory species, including many trans-equatorial migrants (Willems *et al*. 2017, Daudt *et al*. 2019).

The presence of Sabine's Gull in the Indian and Pacific Oceans are also associated with high productivity and fishing grounds. Somalia's coast is considered one of the most productive fishing stocks globally and encompasses abundant and diverse marine resources, including seabirds and other marine megafauna (Griffiths 2005, Sumaila *et al*. 2006, Stewart *et al*. 2010). In the Mozambique channel, the upwelling triggered by eddies has noticeable importance for productivity and higher-trophic animals (Lutjeharms 2006, Tew Kai & Marsac 2010). On the southwest coast of India, the wind-driven coastal upwelling makes this region the major fishing ground of the country (Robin *et al*. 2010). The waters surrounding Indonesia are very productive (Susilowati *et al*. 2005), which supports one of the most important fisheries of the world (Priyono & Sumiono 1997, Stewart *et al*. 2010, Sunoko & Huang 2014). In the Pacific Ocean, the east China Sea and the Yellow Sea are very productive zones, resulting in an important fishing area off China (Liu 2013). The Tasman Sea and the sub-Antarctic zone are both important regions for Australia's biodiversity (Hassler *et al*. 2014), and the east coast of Australia across Victoria and New South Wales is considered one of the country's most productive marine zones, supporting their most significant sardine fisheries (McClatchie *et al*. 2006, Ward *et al*. 2006). In the Southeastern Pacific Ocean, the upwelling system extending from 05°S off Peru to 40°S off southern Chile is considered one of the major primary-productive areas of the global ocean (Thiel *et al*. 2007, Stewart *et al*. 2010, Guiet *et al*. 2019). Notably, we observed many unusual records of Sabine's Gull on the coast of Chile. This indicates that wintering areas of Sabine's Gull in the Southeastern Pacific Ocean could be extended further south to Chilean seas.

The presence of Sabine's Gull in the western Atlantic Ocean may be related to the prevailing wind system. In general, trans-equatorial species of the North Atlantic follow a figure-eight flight pattern to exploit the prevailing wind system of the North and South Atlantic gyres to facilitate speed and energy-efficient migrations (Felicíssimo *et al*. 2008, González-Solís *et al*. 2009). Although Sabine's Gull does not follow the entire figure-eight pattern, the high-speed and offshore route during its northbound migration suggested that it can exploit the prevailing winds around the South Atlantic gyre (Stenhouse *et al*. 2012). Therefore, some individuals could be using the prevailing wind systems to explore new feeding areas in the western Atlantic Ocean, similar to many other seabird species (e.g., Guilford *et al*. 2009, Kopp *et al*. 2011, Hedd *et al*. 2012).

The large number of Sabine's Gull records in Europe (Appendix 1, Figs. S1, S3) suggest that Europe could serve as a migration route to and from the Indian Ocean. In fact, some bird species use the East-Europe flyway as a migratory route, similar to the Siberian Crane *Leucogeranus leucogeranus*, which migrates from Siberia through eastern Europe to reach its Iranian wintering ground (Kanai *et al*. 2002). Lesser Black-backed Gulls *Larus fuscus* cross the Baltic Sea and eastern Europe to reach eastern Africa, and stopover areas around Israel (Bustnes *et al*. 2013) overlap with areas where Sabine's Gulls were recorded as 'vagrants' (Appendix 1, Figs. S1, S3). Based on storm-independent records in the Baltic region in autumn and spring, Olsen & Larsson (2004) and Kormann & Stumberger (2013) hypothesize that Sabine's Gull from Svalbard (Norway) and Siberia (Russia) could migrate through the Baltic Sea and the European mainland, which seems to be a feasible pathway. Therefore, Sabine's Gull could use this migration flyway to reach high productive areas in the Indian Ocean.

There are also migration routes across the Pacific Ocean used by other species that could be suitable for Sabine's Gulls. For instance, shorebirds like Far Eastern Curlews *Numenius madagascariensis*, Ruddy Turnstones *Arenaria interpres*, and Greater Sand Plovers *Charadrius leschenaultii* use the East-Asia flyway to reach the Southern Hemisphere, including the Australian coast (Ueta *et al*. 2002, Minton *et al*. 2011), whereas the Curlew Sandpiper *Calidris ferruginea* and the Red-necked Stint *Calidris ruficollis* migrate from non-breeding areas in Australia to breeding sites in the Russian Arctic (Lisovski *et al*. 2021) via this route. Greater White-fronted *Anser albifrons* and Tundra Bean *Anser serrirostris* geese also depart from eastern Siberian regions (where there are Sabine's Gull colonies) to reach south China crossing eastern Asia (Si *et al*. 2018, Li *et al*. 2020). For some species of shorebirds, identified stopovers were in Southeast Asia and/or the Indonesian Islands and in the Yellow Sea, China—sites where unusual Sabine's Gulls were recorded.

Here, we present the first summary of Sabine's Gulls outside of their usual wintering areas, shedding light on possible new areas explored by (at least) younger individuals. The fact that several records outside their main wintering areas have been associated with high productivity suggests that some individuals, rather than being 'disoriented', may have been in search of productive areas during their winter migration. Although the concept of pseudo-vagrants is not widely applied to seabirds (but see Dias *et al*. 2010), the results presented here suggest that these individuals might be in genuine areas of migration corresponding to their life stage. It is important to emphasize that all unusual records identified in this study are in areas of little- or no-effort of monitoring programs (Mott & Clarke 2018, La Sorte & Somveille 2020, Lees *et al*. 2020), and the assumption that these birds are disoriented might be a consequence of information gaps about

seabird assemblages in these areas. Quiñones *et al*. (2021a, 2021b) recently showed that certain seabird species commonly occur seasonally off the coast of Peru, an area that has been subject to few at-sea survey efforts.

Although we did not test if Sabine's Gulls occupy the unusual areas identified in this study or if it is a series of casual coincidences, we strongly argue that the ornithological community should avoid using the term 'vagrant' for birds in understudied regions. We suggest the use of 'pseudo-vagrant' for records of occurrence along what is likely a genuine migration route or feeding area. Moreover, expert range maps do not agree with empirical data of species occurrence in most of the cases (Hughes *et al*. 2021); therefore, accessing the extent of 'vagrant' and 'pseudo-vagrant' records of any taxa can potentially indicate 'new' suitable areas for wide-ranging species, as well as yet unknown destinations.

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REFERENCES

AIELLO-LAMMENS, M.E., BORIA, R.A., RADOSAVLJEVIC, A., VILELA, B. & ANDERSON, R.P. 2015. spThin: an R package for spatial thinning of species occurrence records for use in ecological niche models. *Ecography* 38: 541–545. doi:10.1111/ecog.01132

ALLPORT, G. 2018. Notable recent records of terns, gulls and skuas in southern Mozambique including the first country records of Black Tern *Chlidonias niger*. *Bulletin of the British Ornithologists' Club* 138: 101–116. doi:10.25226/bboc.v138i2.2018.a5

ANDREW, P. 1985. Sabine's Gull *Larus sabini* off the coast of Sumatra. *Kukila* 2: 9.

ARTIGAS, L.F., VENDEVILLE, P, LEOPOLD, M., GUIRAL, D. & TERNON, J.-F. 2003. Marine biodiversity in French Guiana: estuarine, coastal, and shelf ecosystems under the influence of Amazonian waters. *Gayana* 67: 302–326.

ASH, J.S. 1983. Over fifty additions of birds to the Somalia list including two hybrids, together with notes from Ethiopia and Kenya. *Scopus* 7: 54–79.

BAUER, R.K. 2020. *Oceanmap: a plotting toolbox for 2D oceanographic data*. Package 'oceanmap'. Version 0.1.1. [Accessed online at https://CRAN.R-project.org/package=oceanmap on 15 June 2021.]

BIRDLIFE INTERNATIONAL. 2020. *Species factsheet:* Xema sabini. Cambridge, UK: Birdlife International. [Accessed online at http://datazone.birdlife.org/species/factsheet/sabines-gull-xema-sabini on 20 December 2020.]

BIRDLIFE INTERNATIONAL & HANDBOOK OF THE BIRDS OF THE WORLD. 2019. *Bird species distribution maps of the world*. Version 2019.1. [Data accessed at http://datazone.birdlife.org/species/requestdis on 15 Oct 2020.]

BLOMQVIST, S. & ELANDER, M. 1981. Sabine's Gull (*Xema sabini*), Ross's Gull (*Rhodostethia rosea*) and Ivory Gull (*Pagophila eburnea*) Gulls in the Arctic: a review. *Arctic* 34: 122–132.

BOURNE, W.R.P. 1967. Long-distance vagrancy in the petrels. *Ibis* 109: 141–167. doi:10.1111/j.1474-919X.1967.tb00415.x

BOYCE, D.G., LEWIS, M. & WORM, B. 2012. Integrating global chlorophyll data from 1890 to 2010. *Limnology and Oceanography: Methods* 10: 840–852. doi:10.4319/lom.2012.10.840

BRIEVA, D., RIBBE, J. & LEMCKERT, C. 2015. Is the East Australian Current causing a marine ecological hot-spot and an important fisheries near Fraser Island, Australia? *Estuarine, Coastal and Shelf Science* 153: 121–134. doi:10.1016/j.ecss.2014.12.012

BUSTNES, J.O., MOE, B., HELBERG, M. & PHILLIPS, R.A. 2013. Rapid long-distance migration in Norwegian Lesser Black-backed Gulls *Larus fuscus fuscus* along their eastern flyway. *Ibis* 155: 402–406. doi:10.1111/ibi.12022

CALENGE, C. 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. *Ecological Modelling* 197: 516–519. doi:10.1016/j.ecolmodel.2006.03.017

CAMPIONI, L., DIAS, M.P., GRANADEIRO, J.P. & CATRY, P. 2020. An ontogenetic perspective on migratory strategy of a long-lived pelagic seabird: timings and destinations change progressively during maturation. *Journal of Animal Ecology* 89: 29–43. doi:10.1111/1365-2656.13044

CIOTTI, Á.M., ODEBRECHT, C., FILLMANN, G. & MÖLLER, O.O., JR. 1995. Freshwater outflow and Subtropical Convergence influence on phytoplankton biomass on the southern Brazilian continental shelf. *Continental Shelf Research* 15: 1737–1756. doi:10.1016/0278-4343(94)00091-Z

CROXALL, J.P. & WOOD, A.G. 2002. The importance of the Patagonian Shelf for top predator species breeding at South Georgia. *Aquatic Conservation: Marine and Freshwater Ecosystems* 12: 101–118. doi:10.1002/aqc.480

DAUDT, N.W., MARTINS, S.P., KIRINUS, E.P. & BUGONI, L. 2019. Seabird assemblage at the mouth of the Amazon River and its relationship with environmental characteristics. *Journal of Sea Research* 155: 101826. doi:10.1016/j.seares.2019.101826

DAUDT, N.W., PEREIRA, A., TAVARES, M. & CARLOS, C.J. 2018. South Polar Skua *Catharacta maccormicki* in Rio Grande do Sul, southern Brazil. *Cotinga* 40: 44–49.

DAVIS, S.E., MAFTEI, M. & MALLORY, M.L. 2016. Migratory connectivity at high latitudes: Sabine's Gulls (*Xema sabini*) from a colony in the Canadian High Arctic migrate to different oceans. *PLoS One* 11: e0166043. doi:10.1371/journal.pone.0166043

DE GRISSAC, S., BARTUMEUS, F., COX, S.L. & WEIMERSKIRCH, H. 2017. Early-life foraging: behavioral responses of newly fledged albatrosses to environmental conditions. *Ecology and Evolution* 7: 6766–6778. doi:10.1002/ece3.3210

DIAS, R.A., AGNE, C.E., BARCELOS-SILVEIRA, A. & BUGONI, L. 2012. New records and a review of the distribution of the Arctic Tern *Sterna paradisaea* Pontoppidan, 1763 (Aves: Sternidae) in Brazil. *Check List* 8: 563–567. doi:10.15560/8.3.563

DIAS, R.A., AGNE, C.E., GIANUCA, D., GIANUCA, A., BARCELLOS-SILVEIRA, A. & BUGONI, L. 2010. New records, distribution and status of six seabird species in Brazil. *Iheringia, Serie Zoologia* 100: 379–390. doi:10.1590/S0073-47212010000400013

EBIRD. 2020. *eBird Basic Dataset*. Version: EBD_relJun-2020. Ithaca, USA: Cornell Lab of Ornithology.

FELICÍSSIMO, A.M., MUÑOZ, J. & GONZÁLEZ-SOLIS, J. 2008. Ocean surface winds drive dynamics of transoceanic aerial movements. *PLoS One* 3: e2928. doi:10.1371/journal.pone.0002928

FFIELD, A. 2005. North Brazil current rings viewed by TRMM Microwave Imager SST and the influence of the Amazon Plume. *Deep-Sea Research I* 52: 137–160. doi:10.1016/j.dsr.2004.05.013

FONESECA, T.R. 1989. An overview of the poleward undercurrent and upwelling along the Chilean coast. In: NESHYBA, S.J., MOOERS, C.N.K., SMITH, R.L. & BARBER, R.T. (Eds.) *Poleward flows along eastern ocean boundaries. Coastal and Estuarine Studies (formerly Lecture Notes on Coastal and Estuarine Studies), Vol 34*. New York, USA: Springer. doi:10.1007/978-1-4613-8963-7_15

FRANKISH, C.K., PHILLIPS, R.A., CLAY, T.A., SOMVEILLE, M. & MANICA, A. 2020. Environmental drivers of movement in a threatened seabird: insights from a mechanistic model and implications for conservation. *Diversity and Distributions* 26: 1315–1329. doi:10.1111/ddi.13130

GIL, M.N., GIARRATANO, E., BARROS, V. ET AL. 2019. Southern Argentina: the Patagonian Continental Shelf. In: Sheppard, C. (Ed.) *World Seas: An Environmental Evaluation (Second Edition), Vol 1*. London, UK: Academic Press.

GILROY, J.J. & LEES, A.C. 2003. Vagrancy theories: are autumn vagrants really reverse migrants? *British Birds* 96: 427–438.

GONZÁLEZ-SOLÍS, J., FELICÍSIMO, A., FOX, J.W., AFANASYEV, V., KOLBEINSSON, Y. & MUÑOZ, J. 2009. Influence of sea surface winds on shearwater migration detours. *Marine Ecology Progress Series* 391: 221–230. doi:10.3354/meps08128

GRIFFITHS, C.L. 2005. Coastal marine biodiversity in East Africa. *Indian Journal of Marine Science* 34: 35–41.

GUIET, J., GALBRAITH, E., KROODSMA, D. & WORM, B. 2019. Seasonal variability in global industrial fishing effort. *PLoS One* 14: e0216819. doi:10.1371/journal.pone.0216819

GUILFORD, T., MEADE, J., WILLIS, J. ET AL. 2009. Migration and stopover in a small pelagic seabird, the Manx Shearwater *Puffinus puffinus*: Insights from machine learning. *Proceedings of the Royal Society B* 276: 1215–1223. doi:10.1098/rspb.2008.1577

HAIMOVICI, M., CASTELLO, J.P. & VOOREN, C.M. 1998. Pescarias. In: SEELIGER, U., ODEBRECHT, C. & CASTELLO, J.P. (Eds.) *Os ecossistemas costeiro e marinho do extremo sul do Brasil.* Rio Grande, Brazil: Ecoscientia.

HASSLER, C.S., RIDGEWAY, K.R., BOWIE, A.R. ET AL. 2014. Primary productivity induced by iron and nitrogen in the Tasman Sea: an overview of the PINTS expedition. *Marine and Freshwater Research* 65: 517–537. doi:10.1071/MF13137

HEDD, A., MONTEVECCHI, W.A., OTLEY, H., PHILLIPS, R.A. & FIFIELD, D.A. 2012. Trans-equatorial migration and habitat use by sooty shearwaters *Puffinus griseus* from the South Atlantic during the nonbreeding season. *Marine Ecology Progress Series* 449: 277–290. doi:10.3354/meps09538

HELBERG, M., SYSTAD, G.H., BIRKELAND, I., LORENTZEN, N.H. & BUSTNES, J.O. 2009. Migration patterns of adult and juvenile Lesser Black-backed Gulls *Larus fuscus* from northern Norway. *Ardea* 97: 281–286. doi:10.5253/078.097.0303

HOWELL, S.N.G. & DUNN, J. 2007. *Gulls of the Americas*. New Jersey, USA: Princeton University Press.

HUGHES, A.C., ORR, M.C., YANG, Q. & QIAO, H. 2021. Effectively and accurately mapping global biodiversity patterns for different regions and taxa. *Global Ecology and Biogeography* 30: 1375–1388. doi:10.1111/geb.13304

IBAMA (INSTITUTO BRASILEIRO DO MEIO AMBIENTE) 2009. *Estatística da pesca 2007: grandes regiões e unidades da federação brasileira*. Brasilia, Brazil: Centro Nacional de Informação Ambiental (CNIA).

JIMÉNEZ, S., DOMINGO, A., ABREU, M. & BRAZEIRO, A. 2011. Structure of the seabird assemblage associated with pelagic longline vessels in the Southwestern Atlantic: implications for bycatch. *Endangered Species Research* 15: 241–254. doi:10.3354/esr00378

KANAI, Y., NAGENDRAN, M., UETA, M. ET AL. 2002. Discovery of breeding grounds of a Siberian Crane *Grus leucogeranus* flock that winters in Iran, via satellite telemetry. *Bird Conservation International* 12: 327–333. doi:10.1017/S0959270902002204

KENEFICK, M. & HAYES, F.E. 2006. Trans-Atlantic vagrancy of Palearctic birds in Trinidad and Tobago. *Journal of Caribbean Ornithology* 19: 61–72.

KOPP, M., HAND-ULRICH, P., MUSTAFA, O., LISOVSKI, S., RITZ, M.S., PHILLIPS, R.A. & HAHN, S. 2011. South polar skuas from a single breeding population overwinter in different oceans though show similar migration patterns. *Marine Ecology Progress Series* 435: 263–267. doi:10.3354/meps09229

KORMANN, U. & STUMBERGER, B. 2013. A Sabine's Gull *Xema sabini* in Montenegro—first record in the NE Mediterranean and a short review of the species' status in SE Europe. *Acrocephalus* 34: 79–82.

LA SORTE, F.A. & SOMEVEILLE, M. 2020. Survey completeness of a global citizen-science database of bird occurrence. *Ecography* 43: 34–43. doi:10.1111/ecog.04632

LAMBERT, K. 2005. The spatial and seasonal occurrence of seabirds (Aves) off southern Mozambique. *Durban Museum Novitates* 30: 45–60.

LEES, A.C., ROSENBERG, K.V., RUIZ-GUTIERREZ, V., MARSDEN, S., SCHULENBERG, T.S. & RODEWALD, A.D. 2020. A roadmap to identifying and filling shortfalls in Neotropical ornithology. *The Auk* 137: 1–17. doi:10.1093/auk/ukaa048

LEES, A.C., TÁVORA, A.F., TAVARES, M., TÁVORA, A. & COUTINHO, D. 2014. A second Sabine's Gull *Xema sabini* in Brazil. *Bulletin of the British Ornithologists' Club* 134:

163–164.

LI, H., FANG, L., WANG, X., YI, K., CAO, L. & FOX, A.D. 2020. Does snowmelt constrain spring migration progression in sympatric wintering Arctic-nesting geese? Results from a Far East Asia telemetry study. *Ibis* 162: 548–555. doi:10.1111/ibi.12767

LIN, C., NING, X., SU, J., LIN, Y. & XU, B. 2005. Environmental changes and the responses of the ecosystems of the Yellow Sea during 1976–2000. *Journal of Marine Systems* 55: 223–234. doi:10.1016/j.jmarsys.2004.08.001

LISOVSKI, S., GOSBELL, K., MINTON, C. & KLAASSEN, M. 2021. Migration strategy as an indicator of resilience to change in two shorebird species with contrasting population trajectories. *Journal of Animal Ecology* 90: 2005–2014. doi:10.1111/1365-2656.13393

LIU, J.Y. 2013. Status of marine biodiversity of the China Seas. *PLoS One* 8: e50719. doi:10.1371/journal.pone.0050719

LUTJEHARMS, J.R.E. 2006. The ocean environment off southeastern Africa: a review. *South African Journal of Science* 102: 419–426.

MADHUPRATAP, M., KUMAR, S.P., BHATTATHIRI, P.M.A. ET AL. 1996. Mechanism of the biological response to winter cooling in the northeastern Arabian Sea. *Nature* 384: 549–551. doi:10.1038/384549a0

MARQUES, P.A.M., SOWTER, D. & JORGE, P.E. 2010. Gulls can change their migratory behavior during lifetime. *Oikos* 119: 946–951. doi:10.1111/j.1600-0706.2009.18192.x

MCCLATCHIE, S., MIDDLETON, J.F. & WARD, T.M. 2006. Water mass analysis and alongshore variation in upwelling intensity in the eastern Great Australian Bight. *Journal of Geophysical Research* 111: C08007. doi:10.1029/2004JC002699

MINTON, C.L., WAHL, J.O., GIBBS, H.E., JESSOP, R.O., HASSELL, C.H. & BOYLE, A.D. 2011. Recoveries and flag sightings of waders which spend the non-breeding season in Australia. *Stilt* 59: 17–43.

MISSAGIA, R.V., RAMOS, J.A., LOUZAO, M., DELORD, K., WEIMERSKIRCH, H. & PAIVA, V.H. 2015. Year-round distribution suggests spatial segregation of Cory's shearwaters, based on individual experience. *Marine Biology* 162: 2279–2289. doi:10.1007/s00227-015-2762-1

MOTT, R. & CLARKE, R.H. 2018. Systematic review of geographic biases in the collection of at-sea distribution data for seabirds. *Emu - Austral Ornithology* 118: 235–246. doi:10.1080/01584197.2017.1416957

NAIR, P.V.R. & PILLAI, V.K. 1983. Productivity of the Indian Seas. *Journal of the Marine Biological Association of India* 25: 41–50.

NEWTON, I. 2008. *The migration ecology of birds*. London, UK: Academic Press.

OLSEN, K.M. 2018. *Gulls of the world: a photographic guide*. New Jersey, USA: Princeton University Press.

OLSEN, K.M. & LARSSON, H. 2004. *Gulls of Europe, Asia and North America*. London, UK: Christopher Helm, A&C Black Publishers Ltd.

ORBEN, R.A., O'CONNOR, A.J., SURYAN, R.M., OZAKI, K., SATO, F. & DEGUCHI, T. 2018. Ontogenetic changes in at-sea distributions of immature short-tailed albatrosses *Phoebastria albatrus*. *Endangered Species Research* 35: 23–37. doi:10.3354/esr00864

PARRINI, R. & CARVALHO, C.E.S. 2009. Primeiro registro de *Xema sabini* (Charadriiformes: Laridae) para o Brasil. *Atualidades Ornitológicas* 151: 53.

PEBESMA, E. 2018. Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10: 439–446. doi:10.32614/RJ-2018-009

PÉRON, C. & GRÉMILLET, D. 2013. Tracking through life stages: adult, immature and juvenile autumn migration in a long-lived seabird. *PLoS One* 8: e72713. doi:10.1371/journal.pone.0072713

PHILLIPS, R.A., SILK, J.R.D., CROXALL, J.P., AFANASYEV, V. & BENNETT, V.J. 2005. Summer distribution and migration of nonbreeding albatrosses: individual consistencies and implications for conservation. *Ecology* 86: 2386–2396. doi:10.1890/04-1885

PORTFLITT-TORO, M., MIRANDA-URBINA, D. & LUNA-JORQUERA, G. 2018. Specimen record confirms broad-billed prion *Pachyptila vittata* presence in Chilean waters. *Marine Ornithology* 46: 69–70.

PRIYONO, B.E. & SUMIONO, B. 1997. The marine fisheries of Indonesia, with emphasis on the coastal demersal stocks of the Sunda shelf. In: SILVESTRE, G. & PAULY, D. (Eds.) *Status and management of tropical coastal fisheries in Asia*. ICLARM Conference Proceedings. Manila, Philippines: International Centre for Aquatic Resources Management.

QASIM, S.Z. 1977. Biological productivity of the Indian Ocean. *Indian Journal of Marine Science* 6: 122–137.

QUIÑONES, J., MANRIQUE, M. & ARATA, J. 2021a. Occurrence of Black-browed Albatross (*Thalassarche melanophris*) in southern Peru provides clues on their northern limit. *Ornithology Research* 29: 50–55. doi:10.1007/s43388-021-00043-4

QUIÑONES, J., ROMERO, C. & ZAVALAGA, C. 2021b. Vessel survey observations confirm wintering dispersion of northern giant-petrel (*Macronectes halli*) juveniles in southern-central Perú; what is their origin? *Notornis* 68: 76–85.

R DEVELOPMENT CORE TEAM. 2019. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: The R Foundation for Statistical Computing.

ROBIN, R.S., KANURI, V.V., MUDULI, P.R., RAJKUMAR, J.S.I. & PALANISAMI, S. 2010. Vertical distribution of biological characteristics and phytoplankton community structure in the shelf waters off southwest coast of India. *International Journal of Current Research* 8: 16–34.

SCALES, K.L., MILLER, P.I., HAWKES, L.A., INGRAM, S.N., SIMS, D.W. & VOTIER, S.C. 2014. On the Front Line: frontal zones as priority at-sea conservation areas for mobile marine vertebrates. *Journal of Applied Ecology* 51: 1575–1583. doi:10.1111/1365-2664.12330

SI, Y., XU, Y., XU, F. ET AL. 2018. Spring migration patterns, habitat use, and stopover site protection status for two declining waterfowl species wintering in China as revealed by satellite tracking. *Ecology and Evolution* 8: 6280–6289. doi:10.1002/ece3.4174

SILVA, A.C., SANTOS, M.L.S., ARAUJO, M.C. & BOURLÈS, B. 2009. Observações hidrológicas e resultados de modelagem no espalhamento sazonal e espacial da pluma de água Amazônica. *Acta Amazonica* 39: 361–370. doi:10.1590/S0044-59672009000200014

SINCLAIR, J.C. 1981. Eight previously unreported seabirds at Marion Island, Indian Ocean. *Ardea* 69: 217–218.

SREENIVASAN, P.P., PRAVEEN, J., PRINCE, M. & KARUTHEDATHU, D. 2013. Sabine's Gull *Xema sabini* from Puthankadapuram, Kerala, India: a first record for South Asia. *Indian Birds* 8: 97–99.

STENHOUSE, I.J., EGEVANG, C. & PHILLIPS, R.A. 2012. Trans-equatorial migration, staging sites and wintering area of Sabine's Gulls *Larus sabini* in the Atlantic Ocean. *Ibis* 154: 42–51. doi:10.1111/j.1474-919X.2011.01180.x

STEWART, K.R., LEWISTON, R.L., DUNN, D.C. ET AL. 2010. Characterizing fishing effort and spatial extent of coastal fisheries. *PLoS One* 5: e14451. doi:10.1371/journal.pone.0014451

SULLIVAN, B.L., WOOD, C.L., ILIFF, M.J., BONNEY, R.E., FINK, D. & KELLING, S. 2009. eBird: A citizen-based bird observation network in the biological sciences. *Biological Conservation* 142: 2282–2292. doi:10.1016/j.biocon.2009.05.006

SUMAILA, U.R., ALDER, J. & KEITH, H. 2006. Global scope and economics of illegal fishing. *Marine Policy* 30: 696–703. doi:10.1016/j.marpol.2005.11.001

SUNOKO, R. & HUANG, H.-W. 2014. Indonesia tuna fisheries development and future strategy. *Marine Policy* 43: 174–183. doi:10.1016/j.marpol.2013.05.011

SUSILOWATI, I., BARTOO, N., OMAR, I.H. ET AL. 2005. Productive efficiency, property rights, and sustainable renewable resource development in the mini-purse seine fishery of the Java Sea. *Environment and Development Economics* 10: 837–859. doi:10.1017/S1355770X0500255X

TEW KAI, E. & MARSAC, F. 2010. Influence of mesoscale eddies on spatial structuring of top predators' communities in the Mozambique Channel. *Progress in Oceanography* 86: 214–223. doi:10.1016/j.pocean.2010.04.010

THIEBOT, J.B., CHEREL, Y., TRATHAN, P.N. & BOST, C.A. 2012. Coexistence of oceanic predators on wintering areas explained by population-scale foraging segregation in space or time. *Ecology* 93: 122–130. doi:10.1890/11-0385.1

THIEL, M., MACAYA, E.C., ACUÑA, E. ET AL. 2007. *The Humboldt current system of northern and central Chile*. In: GIBSON, R.N., ATKINSON, R.J.A. & GORDON, J.D.M. (Eds.) *Oceanography and Marine Biology – an annual review.* Vol. 45, 1st Edition. Boca Raton, USA: CRC Press. doi:10.1201/9781420050943

UETA, M., ANTONOV, A., ARTUKHIN, Y. & PARILOV, M. 2002. Migration routes of Eastern Curlews tracked from far east Russia. *Emu - Austral Ornithology* 102: 345–348. doi:10.1071/MU01003

VAN BEMMELEN, R., BØRGE, M., HANSSEN, S.A. ET AL. 2017. Flexibility in otherwise consistent non-breeding movements of a long-distance migratory seabird, the long-tailed skua. *Marine Ecology Progress Series* 578: 197–211. doi:10.3354/meps12010

WARD, T.M., MCLEAY, L.J., DIMMLICH, W. ET AL. 2006. Pelagic ecology of a northern boundary current system: effects of upwelling on the production and distribution of sardine (*Sardinops sagax*), anchovy (*Engraulis australis*) and southern bluefin tuna (*Thunnus maccoyii*) in the Great Australian Bight. *Fisheries Oceanography* 15: 191–207. doi:10.3354/meps12010

WILLEMS, T., DE BOER, M.N. & SAULINO, J.T. 2017. Offshore surprises: new at-sea bird records for Suriname (2013–2015). *Revista Brasileira de Ornitolologia* 25: 190–205.

WOLFSON, D.W., FIEBERG, J.R. & ANDERSON, D.E. 2020. Juvenile Sandhill Cranes exhibit wider ranging and more exploratory movements than adults during the breeding season. *Ibis* 162: 556–562. doi:10.1111/ibi.12786