ORIGINAL ARTICLE

Recent changes in distribution and plumage phenologies of the White-winged Tern (*Chlidonias leucopterus*) in the Middle East

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Abstract

Changes in species geographic distributions, including those of migration routes, stopover sites, and over-wintering grounds, may affect the phenology of breeding and moult. The White-winged Tern (*Chlidonias leucopterus*) is a long-distance migrant which breeds in Eurasia and winters in Africa and Australasia. This species is known in the Eastern Mediterranean and the Middle East mainly during the migration seasons although it also breeds locally in eastern Turkey and the Persian Gulf. However, in the last decade, there has been an apparent change in the winter distribution of this species, with increasing observations of individuals during December–February in the Middle East, many of them in breeding plumage. Using data collected from specimens stored at the Natural History Museum at Tring (UK), ringing data from Israel, the online database eBird, and accompanying Macaulay Library (Cornell Lab of Ornithology), we described these recent changes in the seasonal distribution and annual moult cycles. While the birds that breed in the north begin to replace their black body feathers immediately at the end of the breeding season, the birds described here displayed the black body plumage (breeding plumage) throughout the winter (December–February), a plumage pattern that is offset by seven to eight months from those of the northern-hemisphere breeding populations. This might suggest yet-to-be discovered local breeding in the Middle East in February–April. In such cases as this, we hypothesize that examination of plumage phenology may help researchers investigate the timing of as yet unknown breeding phenology.

Keywords Annual cycle · Geographic distribution · Moult · Phenology · Plumage

Zusammenfassung

Jüngste Veränderungen in der Verbreitung und Gefiederphänologie der Weißflügel-Seeschwalbe (*Chlidonias leucopterus*) im Nahen Osten

Veränderungen in der geografischen Verteilung der Arten, einschließlich der Zugrouten, Zwischenstopps und Überwinterungsgebiete, können sich auf die Phänologie von Brut und Mauser auswirken. Die Weißflügel-Seeschwalbe (*Chlidonias leucopterus*) ist ein Langstreckenzieher, der in Eurasien brütet und in Afrika und Australasien überwintert. Diese Art kommt im östlichen Mittelmeerraum und im Nahen Osten vor allem während der Zugzeiten vor, obwohl sie auch lokal in der östlichen Türkei und am Persischen Golf brütet. In den letzten zehn Jahren hat sich das Wintervorkommen dieser Art

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jedoch offensichtlich verändert, denn von Dezember bis Februar wurden vermehrt Individuen im Nahen Osten beobachtet, viele von ihnen im Brutkleid. Anhand von Daten aus dem Natural History Museum in Tring (UK), Beringungsdaten aus Israel, der Online-Datenbank eBird und der dazugehörigen Macaulay Library (Cornell Lab of Ornithology) haben wir diese jüngsten Veränderungen in der saisonalen Verteilung und den jährlichen Mauserzyklen beschrieben. Während die Vögel, die im Norden brüten, ihr schwarzes Körpergefieder unmittelbar nach Ende der Brutsaison zu wechseln beginnen, zeigten die hier beschriebenen Vögel das schwarze Körpergefieder (Brutgefieder) den ganzen Winter über (Dezember-Februar), ein Gefiedermuster, das sieben bis acht Monate von dem der Brutpopulationen der nördlichen Hemisphäre abweicht. Dies könnte auf noch nicht entdeckte lokale Bruten im Nahen Osten im Februar-April hindeuten. In solchen Fällen nehmen wir an, dass die Untersuchung der Gefiederphänologie helfen kann, den Zeitpunkt einer noch unbekannten Brutphänologie zu ermitteln.

Introduction

The geographic distribution, including those of migration routes, stopover sites, and over-wintering grounds, affects the timing and strategy of important avian annual cycle events such as reproduction and feather moult (Barta et al. 2006, 2008; Kiat et al. 2019a, 2020; Jenni and Winkler 2020). The temporal and spatial changes in food resource availability are probably the primary factors influencing these events. Among many species, the availability of food may also affect the changes that occur in distribution throughout the annual cycle, specifically as related to migration (Newton 2010). The migration schedule in turn shapes the timing of breeding (Catry et al. 2013) and moult within the annual cycle (Conklin and Battley 2012; Kiat et al. 2019a). Therefore, changes in one component of the annual cycle may be the result of broader phenological changes in yearly events, as for example has been shown for those resulting from global warming (Saino et al. 2011; Kharouba et al. 2018; Tomotani et al. 2018; Kiat et al. 2019b). However, different mechanisms may reduce the long-term impact of these phenological changes. For example, when the timing of moult is altered due to annual cycle constraints, it may be performed at higher intensity to complete more quickly (Conklin and Battley 2012), or it may be suspended until better conditions for moult occur (Tonra and Reudink 2018; Kiat et al. 2019a; Pyle 2022a).

Many species breeding in the northern hemisphere migrate to southern regions, some of them crossing the equator to take advantage of the abundance and availability of food in the austral summer, which stands in contrast to resource availability during the same period in the boreal winter (Alerstam et al. 2003; Newton 2010). Some northern migratory species also have resident populations in the southern hemisphere, which breed at the same time that individuals from the northern populations are present to winter. Examples of such species are Great White Pelican (*Pelecanus onocrotalus*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Whiskered Tern (*Chlidonias hybrida*), and European Bee-eater (*Merops apiaster*; Billerman et al. 2022). Three species, Leach's Storm-Petrel (*Oceanodroma leucorhoa*), Barn Swallow (*Hirundo rustica*), and Cliff Swallow (*Petrochelidon pyrrhonota*), have recently begun breeding in their usual wintering grounds, in the southern hemisphere, far south of the typical and original breeding areas (Whittington et al. 1999; Garcia-Perez et al. 2013; Areta et al. 2021). These populations can reverse the direction of migration, wintering in the north (during the northern summer), changing the phenology of the annual cycle including that of moult timing by up to six months (Winkler et al. 2017; Areta et al. 2021).

The White-winged Tern (*Chlidonias leucopterus*) is a common summer visitor in Eurasia which migrates long distances to the wintering grounds in Africa, Southeast Asia, and Australia (Cramp 1985; Higgins and Davies 1996; Gochfeld et al. 2020). Like other terns, adult White-winged Terns have a breeding (definitive alternate) plumage which differs from the non-breeding (definitive basic) plumage. The breeding plumage typically occurs in April–July and includes a black head, body and scapulars, contrasting with a white rump, tail, and undertail coverts, whereas the non-breeding plumage typically occurs in October–February and is primarily pale grey above and white below (Gochfeld et al. 2020). White-winged Tern exhibits delayed plumage maturation, whereby first-year birds (in formative and first alternate plumages) remain in non-breeding or intermediate plumages through their first full summer at a year of age.

Adult marsh terns (genus *Chlidonias*), including White-winged Terns, moult their body feathers twice each year, resulting in the changes in appearance described above (Cramp 1985; Higgins and Davies 1996; Pyle 2008). Primaries can be moulted in up to three series, complete replacement accompanying the (definitive prebasic) moult into non-breeding plumage, a partial replacement of the inner 2–8 primaries accompanying the (definitive prealternate) moult into breeding plumage, and in some individuals an additional 1–3 inner primaries can be replaced during a third inserted (definitive presupplemental) moult (Pyle 2008). First-year birds also undergo a complete (preformative) moult including all primaries. Moult is a long-duration process over the annual cycle which rarely or only partially overlaps breeding or migration (Tonra and Reudink 2018; Jenni and Winkler 2020). Therefore, together with the fact that moulting is a relatively visible process, moult and plumage may help in understanding and interpreting distributional and phenological changes.

White-winged Tern is one of the Palearctic migrants for which a phenological change has been documented in

South Africa, affected by climate change, which includes an advanced departure from their South African non-breeding grounds (Bussière et al. 2015). Here we report on further recent changes in the annual phenology of White-winged Terns, which include wintering north of their typical non-breeding grounds, in south-eastern Europe, and parts of the Middle East (hereafter, 'the Middle East'; Fig. 1). We also report on observed changes in occurrence and timing of the breeding plumage in the boreal winter, and we offer explanations for this change in annual phenology.

Methods

We used three sources of information to assess changes in distributional and plumage phenology: (I) The Cornell Lab of Ornithology's online database eBird and Macaulay Library image catalogue (Sullivan et al. 2017; Fink et al. 2021; Pyle 2022b); (II) Specimens stored at the Natural History Museum at Tring (UK); and (III) White-winged Terns ringed in Atlit, Israel (32.69°N / 34.93°E) during the autumn migration in the years 2014–2022, as part of the project operated by BirdLife Israel and the Israel Nature and Parks Authority. Using eBird, we examined the change in presence and number of White-winged Terns in the Middle East during the boreal winter (December–February). The annual number of White-winged Terns recorded was calculated as the sum of maximum numbers of birds observed in eBird checklists at each site. Using images catalogued by the Macaulay Library, we characterized the White-winged Tern body plumage during the winter, in the Middle East and also in the typical African wintering grounds. We divided the plumage into three categories: (1) breeding black plumage, (2) moulting which includes a mix of black and white

feathers, and (3) non-breeding plumage which includes white and light grey feathers (includes first-year as well as adult birds).

For birds undergoing active primary moult, we recorded the progression using a moult scale of 0–5 for each feather (Ginn and Melville 1983; Table S1). Due to differences in the lengths of different primary feathers (Underhill and Joubert 1995), we measured the length of each primary feather on a sample of four specimens. The mean sum of the primary feather lengths in the White-winged Tern is 1063.3 ± 57.6 mm (Table S2), representing the total length of the primary feathers of a complete wing that is not undergoing active moult. We then used moult data to calculate primary moult score as a proportion of total primary length (mean value). The resulting score is a comparable value and represents the progress of the primary moult. Age of the birds in this group (birds with an active primary moult) as either first year or adult was determined by characteristics of the body plumage and flight feathers (Cramp 1985; Higgins and Davies 1996; Pyle 2008).

Statistical analysis

Using a linear model, we explored the relationship between year (continuous independent variable) and the number of White-winged Tern individuals wintering in the Middle East (dependent variable). Using Pearson's χ^2 test, we tested whether the White-winged Terns in the two areas, (1) the Middle East and (2) the typical African non-breeding areas of this species, differ in their plumage based on the three categories mentioned above (breeding plumage, moulting,

Fig. 1 Map of the area tested for the presence of White-winged Terns in the winter (December–February), defined here as the 'Middle East', although this area includes parts that are not included in the Middle East in its common definition, for example, south-eastern Europe. The yellow circles indicate main or important new non-traditional wintering sites in the studied period (2010–2022) which demonstrate the spatial distribution pattern described
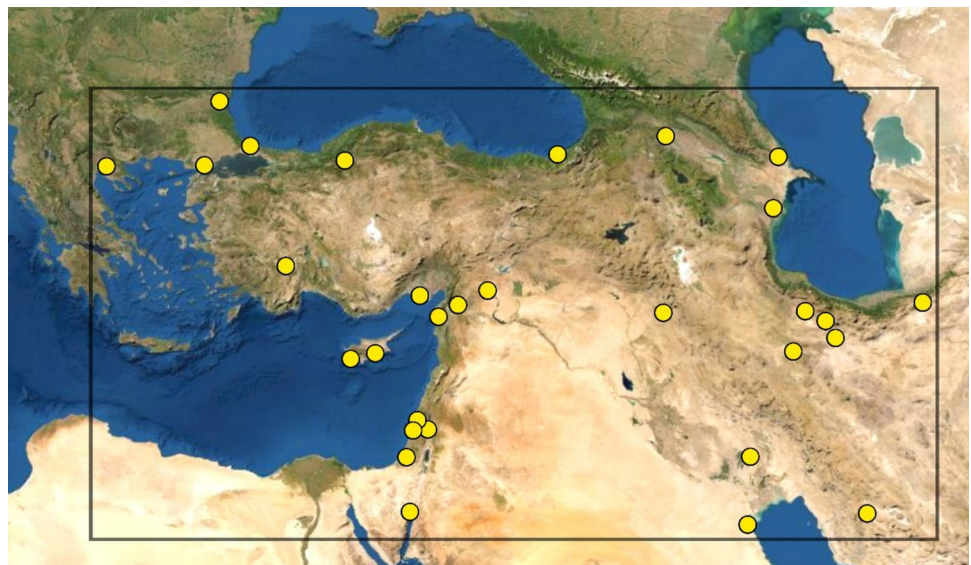
and non-breeding plumage). The analysis (two-tailed, critical $\alpha = 0.05$) was performed using *R* (version 4.1.2).
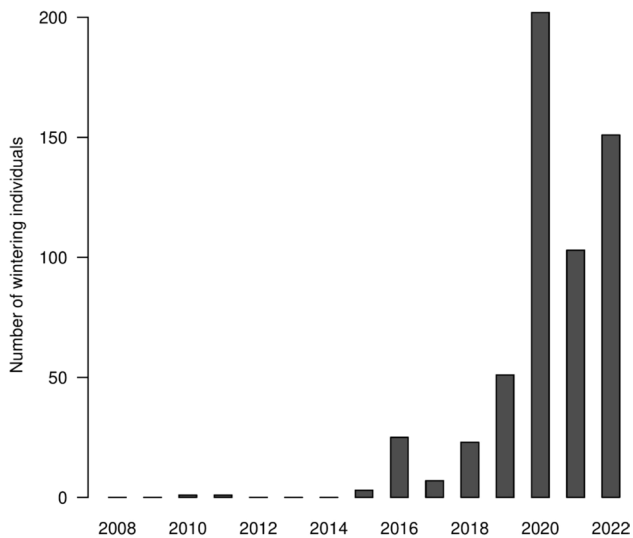

Fig. 2 The increase in the annual reported number of White-winged Terns recorded in the Middle East during the winter. The value shown for each year refers to January–February of the current year and the last 16 days of the previous year (December 16–31). The presence of White-winged Terns during the winter increased significantly ($P = 0.007$) since 2014 with a record of more than 200 individuals in 2020

Results

The presence of White-winged Terns in the Middle East (as defined in Fig. 1) during the boreal winter (December–February) increased significantly from 2014 to 2022, from no wintering individuals in 2014 to 100–200 birds in the winters of the last three years (2020: 202 birds, 2021: 103 birds, 2022: 151 birds; $F_{1,7} = 13.83$, $R^2 = 0.66$, $P = 0.007$; based on eBird database; Fig. 2). Until 2015, only two winter sightings were recorded with no more than one bird per year. As expected, most of the adult and first-year birds that were sampled from the typical wintering areas of Africa in December–February (1898–2022) were in non-breeding plumage (97.0%; $n = 372$ birds), whereas, in contrast, 94 of 96 (97.9%) of the birds that were sampled from in the Middle East (December–February, 2017–2022) were adults in full breeding plumage (Figs. 3 and 4). The remaining two individuals included one that had begun the ensuing (prebasic) moult and was categorized as moulting (Fig. 4c) and a first-year bird in typical first-winter (formative) plumage for this date (Fig. 4d).

None of the 96 White-winged Tern individuals sampled during the boreal winter in the Middle East were undergoing active primary moult. In contrast, examination of the typical moult strategy in live birds ($n = 19$) and museum specimens ($n = 48$) indicated that adults begin the first moult series in late summer and early autumn, mainly during July
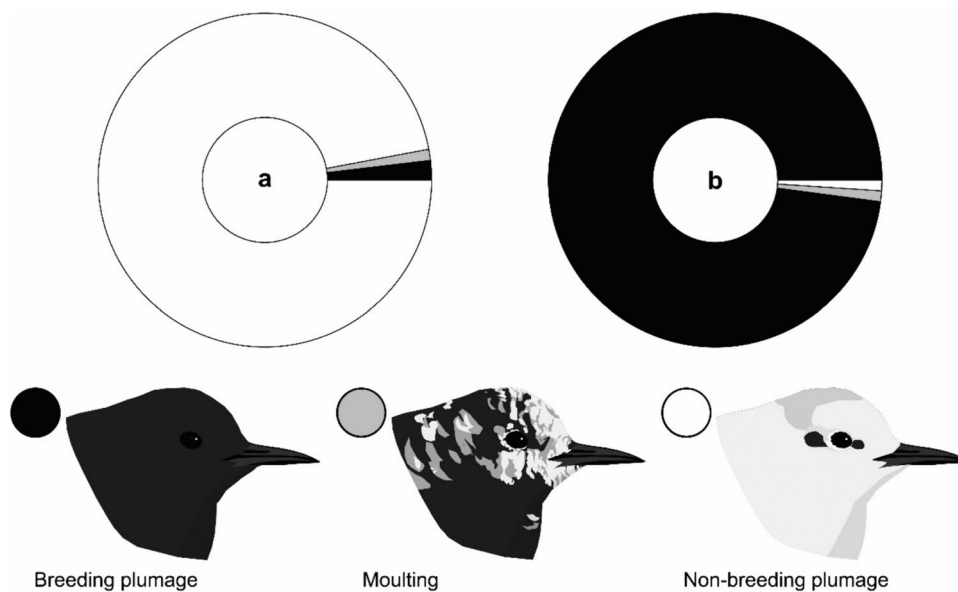

Fig. 3 A significant difference in White-winged Tern plumages between the two areas tested, (**a**) the typical African non-breeding areas of this species, and (**b**) the Middle East (see Fig. 1). Most of the individuals that were tested in the Middle East (December–February), north of the typical wintering areas, were adults in full breeding plumage (97.9%; $n = 96$ birds), while during the same period in the African non-breeding area, most of the individuals were in non-breeding plumage (97.0%; $n = 372$ birds; $\chi^2 = 417.02$, df = 2, $P < 0.001$; Pearson's χ^2 test). These results show that the new wintering in the Middle East (**b**) includes individuals with an unusual plumage, in relation to the season, and as recorded in the traditional breeding sites of the species (**a**)

Fig. 4 White-winged Terns photographed recently during December–February in the Middle Eastern study area. **a** Adult in breeding (definitive alternate) plumage, Tirat-Zvi Fishponds, Beit She'an Valley, Israel, 4 December 2020. Breeding body plumage is fully developed, primaries include three waves of replacement, P_7–P_{10} (basic), P_3–P_6 (alternate), and P_1–P_2 (supplemental). **b** Adult in breeding plumage, Hazore'a Fishponds, Yizre'el Valley, Isreal, 25 December 2020. Breeding body plumage is fully developed, primaries include two waves of replacement, P_7–P_{10} (basic), P_1–P_6 (alternate). **c** Adult in breeding plumage that may have initiated moult into winter (basic) plumage, Doğanpınar Sulama Göleti, Gaziantep, Turkey, 1 February 2020. Breeding body plumage is fully developed although moult into winter plumage appears to have initiated. **d** First-year bird in first-winter (formative) plumage, Kfar Ruppin Fishponds, Beit She'an Valley, Isreal, 8 January 2018. Typical first-winter plumage; primary moult (preformative) had proceeded to P_7 and then was suspended. Photos cropped and used by licence agreement from the Cornell Lab of Ornithology's Macaulay Library: (**a**) Niv Bessor, ML285425501; (**b**) Micha Mandel, ML291356401; (**c**) Göktuğ Güzelbey, ML206616461; (**d**) Giora Leitner, ML81168081

(June–August; Fig. 5), before arriving at the wintering areas in Africa. The moult of this series can be suspended for migration and ends in the second half of winter (mainly January–April). The second primary moult series begins in the mid-winter (mainly December–February) and is arrested before all primary feathers moulted (Fig. 4a-b). The first-year birds that were recorded moulting in the African wintering areas typically moulted from November of the first year to May of the second year (sometimes into summer) and usually completed replacement of all primaries. Thus, the birds found in the Middle East in December–February displayed moult and plumage cycles different than those observed during the same period in historic wintering areas.

Discussion

The results described here indicate a delay relative to a normal moult cycle of at least seven to eight months in the moult cycle of adult White-winged Terns occurring during December–February in the Middle East, an area where this species apparently has not been regularly recorded at this time of the year until recently. Shirihai et al. (1996) reviewed the wintering status of this species in Israel and mention only one verified winter report in the second half of the twentieth century. The European (and west Asian) populations of this species are not known to have wintered in this region in recent decades, certainly not regularly as has been the case in recent years. The year-over-year increase described here in the number of wintering individuals may be slightly biased as a result of an increase in observer effort and usage of the eBird platform (Sullivan et al. 2017). However, the value used is the maximum number of birds observed at each site, which is expected to be slightly affected by an increase in the number of reported checklists in eBird. In addition, our result is not expected to show a linear relationship with effort, especially not in a wintering population which normally shows stability in relation to migratory populations. The general pattern regarding the change in the distribution of this species, which is also supported by the authors' personal field experience and literature (Shirihai et al. 1996; Gochfeld et al. 2020), is unequivocal.

There is as of yet no known documentation for breeding on the African wintering grounds, although we have
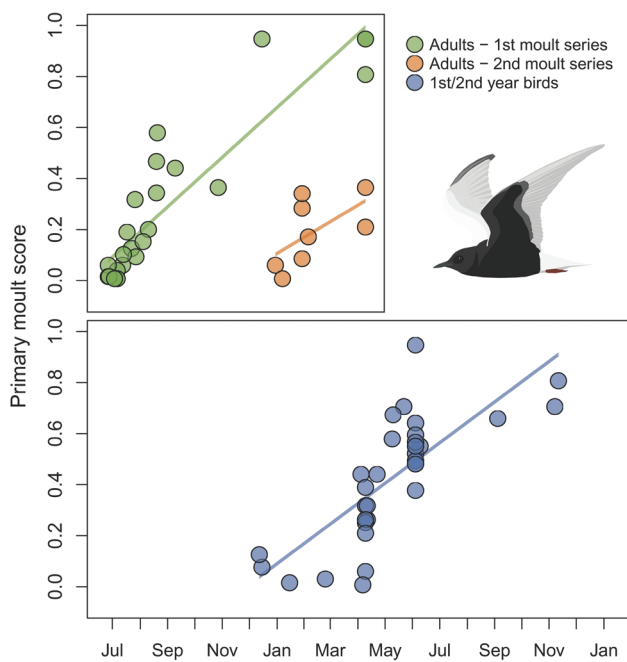
Fig. 5 Increase in the primary moult scores (normalized by feather lengths) among adult (*n* = 33 birds) and first-/second-year (*n* = 34 birds) White-winged Terns wintering in Africa. The individuals depicted in this figure are typical of the population breeding in Eurasia and wintering in Africa, undergoing traditionally known moult and plumage cycles. In contrast, individuals that winter recently in the Middle East avoided primary moulting during December–February

located documentation for a small percentage of individuals in breeding plumage at this time (boreal winter in Africa, *e.g.* ML213262401 in Ethiopia on 9 February 2020, and ML415437421 of two birds in Uganda on 1 February 2022), suggesting the possibility of breeding during the austral summer. Furthermore, the eastern population of White-winged Tern, which breeds in central and eastern Asia and winters in southern Asia and Australia (Higgins and Davies 1996; Gochfeld et al. 2020), includes records from New Zealand during the boreal winter in breeding plumage during the austral summer (December–February) and four cases of breeding have been recorded in New Zealand, from 1917 to 2015 (Higgins and Davies 1996; Pierce 2022). We refer to such birds, whose physiology, breeding cycle, and plumages are geared to the southern hemisphere, as birds undergoing a 'southern-cycle strategy'. This thus represents a fourth species, along with Leach's Storm-Petrel, and Barn and Cliff Swallows, of transequatorial migrants known to have begun or to show occasional breeding in the wrong hemisphere.

The reasons why such southern-cycle birds are increasing in the Middle East during the boreal winter are not clear. One possibility is an expansion of the breeding range during the boreal summer, outside of historical breeding areas to the Middle East, as may have occurred recently in Iraq

and western India (Salim et al. 2012; Gochfeld et al. 2020; Solanki et al. 2022). Another possibility is increased breeding in unknown areas north of the tropical region in Africa and birds originating from this putative population migrating north in austral winter, similar to the situation with Barn Swallows that moved to breed in South America and migrate north post-breeding (Garcia-Perez et al. 2013; Winkler et al. 2017). However, under such a scenario we might expect to see more worn first-year birds (in first alternate plumage) in the Middle Eastern sample during December–February. The one first-year individual we did record (Fig. 4d) was in typical first-winter (formative) plumage and may have been a bird of northern origins wintering farther north than usual.

The birds that breed in the north begin to replace their black body feathers immediately at the end of the nesting season, while the birds described here (with the exception of one individual) displayed the black body plumage (breeding plumage) throughout the December–February period. This pattern therefore may be the result of an advancement in the phenology of the annual cycle by seven to eight months, rather than six months (as would be expected for southern-cycle birds), explaining the near lack of initiation in body moult within our sample. Had these birds bred during the austral summer in Africa and migrated north to the Middle East, we would expect them to have commenced body moult by December–February. The moult recorded here for White-winged Terns wintering in the typical areas in Africa, by contrast, is similar to the pattern and timing described for this species in the literature (Higgins and Davies 1996; Van Der Winden and Nesterenko 2003; Fullagar et al. 2013).

Little is known about processes leading to pigment deposition in feathers of bird species that alter their appearance between breeding and non-breeding plumages, although it is suspected to be regulated by a-melanocyte-stimulating hormones (Lin et al. 2013). Presumably such hormonal processes are regulated by light regimes, as birds found in the opposite hemisphere appear to rapidly adjust their plumage patterns to those of the wrong hemisphere, often being offset by six months. Such was the case with the southern-cycle White-winged Terns in Africa and New Zealand mentioned above, as well as long-staying vagrants in Australia from the northern hemisphere such as Laughing Gulls (*Leucophaeus atricilla*), or southern-hemisphere species such as Kelp Gull (*Larus dominicanus*) found in North America (Higgins and Davies 1996; Jiguet et al. 2012). Plumage appearance patterns may also be affected by an offset between hormones controlling moult cycles with those that control pigment deposition on feathers (Pyle 2013). We propose that the intermediate-level light regimes found in our sample area of the Middle East may have resulted in annual plumage patterns offset by seven to eight months from those of the northern hemisphere and that this might suggest yet-to-be discovered local breeding in the Middle East, perhaps in

February–April as opposed to December–February. In this case, therefore, examination of plumage phenology may help determine as yet unknown breeding phenology. Such changes in breeding, moult, and migration phenology could be related to global climate change, as has been documented to a lesser extent for many species (Halupka and Halupka 2017; Tomotani et al. 2018; Romano et al. 2023), and in any case will provide opportunities to study interactions between breeding, moult, and light regimes within the annual cycles of birds.

Data availability statement The data that support the findings of this study are available at https://osf.io/23tj7/.

Declarations

Conflict of interest The authors declare no conflicts of interest.

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