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The origins and temporal and spatial distribution patterns of non-local gulls in the Bay of Biscay

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ABSTRACT

The Bay of Biscay is an important non-breeding area for some Palaearctic gull species and populations. The aim of this work is to describe the spatial and temporal distributions of non-breeding gulls in the Bay of Biscay, and to identify their major areas of origin. With that goal, we analysed 6773 live sightings of colour-ringed gulls within the southeastern part of the Bay of Biscay during the 20 years 2000–19, relating to 2552 individuals of 10 species. Their distribution along the coast was not homogeneous, with numbers peaking in most cases from November to February, though some species were observed to peak around midsummer. Their origins comprised a wide geographical area encompassing western and eastern Europe; overall, the species can be divided into four groups by origin: northwestern France with Britain and Ireland, central western Europe (with a centroid in the Benelux region), eastern Europe, and the western Mediterranean.

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Migratory birds draw resources from broad geographical ranges during their lives, with their survival and reproductive output depending on conditions not only at their breeding areas but also along their migratory routes and at their wintering areas (Alerstam 1993, Newton 2008). Quantifying the spatial and temporal patterns of the distribution of migatory birds during the non-breeding season is therefore fundamental to all aspects of their biology and ecology, as well as to their conservation and management (Newton 2004).

The Bay of Biscay is an important non-breeding area for several Palaearctic gull species (Cramp & Simmons 1983, Obeso 1988, Malling Olsen & Larsson 2004). For instance, most of the central and western migrant populations of European Lesser Black-backed Gulls *Larus fuscus* pass through the Bay of Biscay on route to their winter quarters in Africa (Malling Olsen & Larsson 2004), or winter in the Bay itself (Molina 2009). Similarly, the Bay of Biscay is used as a wintering region by a significant fraction of the partially migrant western Mediterranean population of Yellow-legged Gull *L. michahellis* (Galarza *et al* 2012).

With the use of Darvic colour rings now widespread in many gull populations, new data are available to deepen our understanding of their migrations and use of space, among other issues (e.g. Arizaga *et al* 2010, Marques *et al* 2010, Carboneras *et al* 2013, Kralj *et al* 2014). These new data also permit researchers to estimate the breeding origins of gulls and gull assemblages in given areas, which can be important from management and conservation perspectives (Gerrard *et al* 1993, Oro & Martinez 1994, Jordi *et al* 2014).

The aim of this work is to describe the spatial and temporal distributions of non-breeding gulls in the Bay of Biscay, and to identify their major areas of origin. With that goal, we analysed data from colour-ringed gulls seen alive within the southeastern part of the Bay of Biscay during the 20 years 2000–19.

Material and methods

Sampling area and data collection

The data used in this work were collected within a relatively broad area in the southeast of the Bay of Biscay, extending from the Bay of Arcachon in France to the Cape of Ajo in the province of Cantabria (Figure 1).

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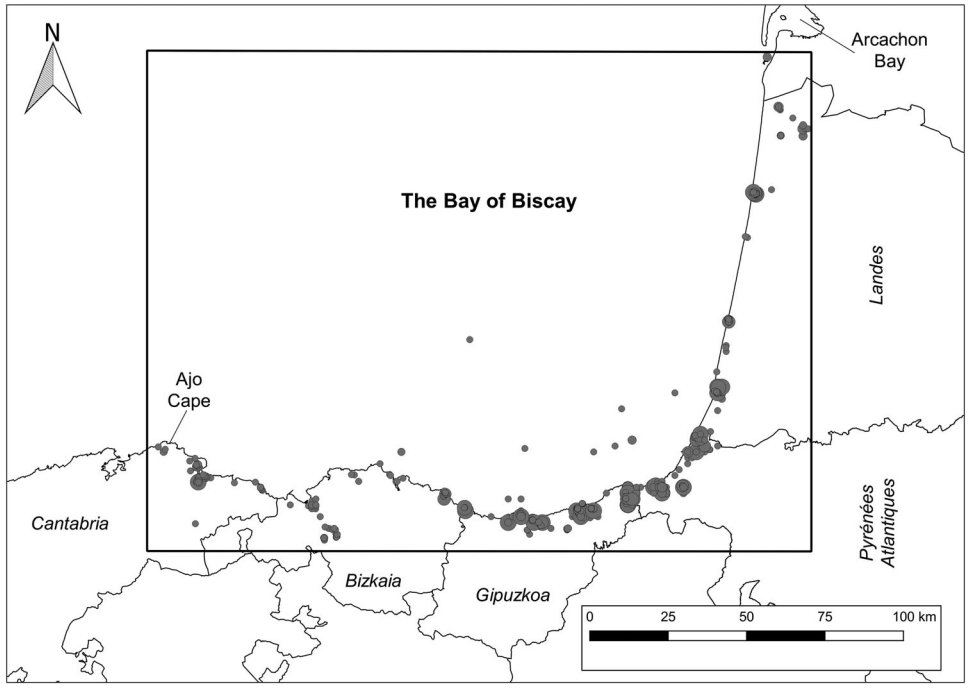

Figure 1. The distribution of sightings data within the study area in the southeastern Bay of Biscay. The sizes of the circles are correlated with the number of sightings: the largest circles are for 10 records or more.

The data set was compiled from sightings of live gulls carrying rings with an alphanumeric code that allowed their individual identification at distance. A sighting record included a minimum of four fields of information: the code on the ring, the species, the date and the location coordinates. All these data were recorded over a period of 20 years (2000–19), by a variable number of observers that looked for ringed gulls, collectively throughout the annual cycle, but whose individual effort was unknown. Together with these sightings data, we also added the ringing data for each bird, including the same minimum of four fields, into our data set. The birds had been ringed mostly in breeding colonies, either as chicks or as adults. All the data used in this study were extracted from the portal www.colouring.eus.

Statistical analyses

Before analysis, the data set was reviewed to detect potential errors, such as apparently wrong sites or dates, or birds reported before they had been ringed. After this process, we limited analysis to include only those birds where the ring had been verified as well read and for which we had the complementary ringing data. Additionally, all data from Yellow-legged Gulls breeding locally within the region (Arizaga *et al* 2010, *2014*, Zorrozua *et al* 2020) were removed, to focus on birds ringed outside the study region. The local gulls are the subject of an intensive and specific project and their inclusion was beyond the scope of this work.

Because some individual gulls were observed on multiple occasions, we were careful to include each bird only once per unit of analysis, such as year, month or site.

For the statistical analysis of spatial distribution patterns, the study region was divided into three main zones: 'East', from Arcachon to Landes département; 'Southeast', including the Pyrénées Atlantiques département and the Gipuzkoa province; and 'Southwest', which encompass the provinces of Bizkaia and Cantabria (Figure 1). We considered each individual bird only once per zone. The percentage of the sightings data obtained in each zone will depend upon the sampling effort, but the effort was considered to be equal for all species in the same zone. Thus, for those seven species that had 10 or more sightings, we ran a chi-square test to see whether the proportion of sighting records varied between these three zones, using a contingency table of three columns for the zones and seven rows for species. Deviations from a uniform distribution pattern across columns were considered as evidence that one or more species were proportionally more abundant or scarcer in a zone. To detect where these deviations might have arisen, we looked at the standardised residual values from this contingency table; absolute values >3 were considered to indicate

significant deviation from the mean overall distribution pattern (Agresti 2002).

Regarding the region of origin for those gulls, we calculated the mean geographical location for every species, with a lack of overlap between 95% confidence intervals considered to reveal true, *a priori* differences in the main source region for those gulls observed in the Bay of Biscay.

We also ran a chi-square test to see whether the temporal distribution of sightings data varied between species. In this case, we considered each individual bird only once per month and we removed from this analysis the two species for which we only had one record (Figure 2).

Finally, in order to examine temporal trends in the number of sightings per month and year, the raw data were standardised by survey effort, measured as the number of survey days per site. This approach allowed us to account for potential change in the sampling effort among years or months.

We used for the analyses the software package PAST (Hammer *et al* 2001).

Results

Overall, we collated 6773 sightings from 2552 individuals of 10 species (Figure 2): Slender-billed Gull *Chroicocephalus genei*, Black-headed Gull *C. ridibundus*, Audouin's Gull *Ichthyaetus audouinii*, Mediterranean Gull *I. melanocephalus*, Common Gull *Larus canus*, Great Black-backed Gull *L. marinus*, Herring Gull *L. argentatus*, Caspian Gull, *L. cachinnans*, Yellow-legged Gull and Lesser Black-backed Gull. The majority of the gulls were seen only once (n = 1636, 64%); at the other extreme, one Black-headed Gull was seen 127 times during 2015–19.

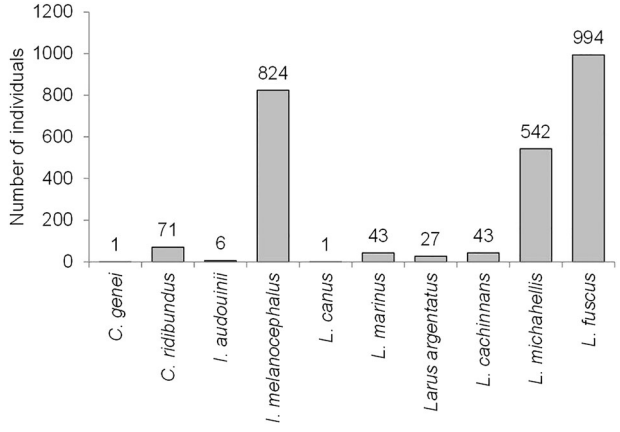

Figure 2. Frequency distribution of the number of individual colour-ringed gulls seen alive in the southeastern part of the Bay of Biscay during 2000–19. Species are in taxonomic order. Sample sizes include each bird only once for the entire sampling area.

Geographical distribution

The proportions of sightings data obtained from the three zones (Southwest, Southeast and East) were 8.6%, 66.0% and 25.4% respectively. This overall distribution pattern varied according to species (χ^2 = 310.6, df = 12, $P < 0.001$). In all species the majority of sightings were obtained in the Southeast zone (Table 1). Four species were detected to deviate from the overall ratio: Mediterranean Gull tended to be proportionally more abundant in the East and less common in the Southwest zone; Yellow-legged Gull, by contrast, tended to be proportionally less abundant in the East and more abundant in the Southeast; finally, Herring and Caspian Gulls were proportionally more abundant in the Southwest (Table 1).

The areas of origin of the colour-ringed gulls seen alive within the Bay of Biscay covered a broad geographical range, from Portugal to Ukraine, and from Algeria to Iceland and Norway (Figure 3, Table 2). The mean geographical site of origin differed between species, with a lack of overlaps of the 95% confidence intervals associated with these means (Figure 4). Overall, four main areas of origin could be identified: the Mediterranean Basin (Yellow-legged, Audouin's and Slender-billed Gulls), western Europe (Herring and Great Black-backed Gulls), central Europe (Lesser Black-backed and Mediterranean Gulls) and eastern Europe (Black-headed, Common and Caspian Gulls).

Independently of species, the majority of gulls were ringed as chicks (Table 3; birds coded as EURING 3

Table 1. Spatial distribution of sightings data for the gull species with more than 10 records. Percentages are shown, with the standardised residual values representing deviation from the overall pattern for all species pooled.

	Sample size	Southwest	Southeast	East
Black-headed Gull	73	6.8%	72.6%	20.6%
C. ridibundus		-0.5	+0.7	-0.8
Mediterranean Gull	982	3.0%	62.4%	34.6%
I. melanocephalus		-6.1	-1.4	+5.8
Great Black-backed Gull	51	19.6%	52.8%	27.6%
L. marinus		+2.7	-1.1	+0.3
Herring Gull *L. argentatus*	32	34.4%	56.2%	9.4%
		+5.0	-0.7	-1.8
Caspian Gull *L. cachinnans*	50	22.0%	50.0%	28.0%
		+3.3	-1.4	+0.4
Yellow-legged Gull	572	10.8%	87.1%	2.1%
L. michahellis		+1.9	+6.2	-11.1
Lesser Black-backed Gull	1062	10.8%	59.2%	30.0%
L. fuscus		+2.4	-2.7	+3.0
Overall	2822	8.6%	66.0%	25.4%

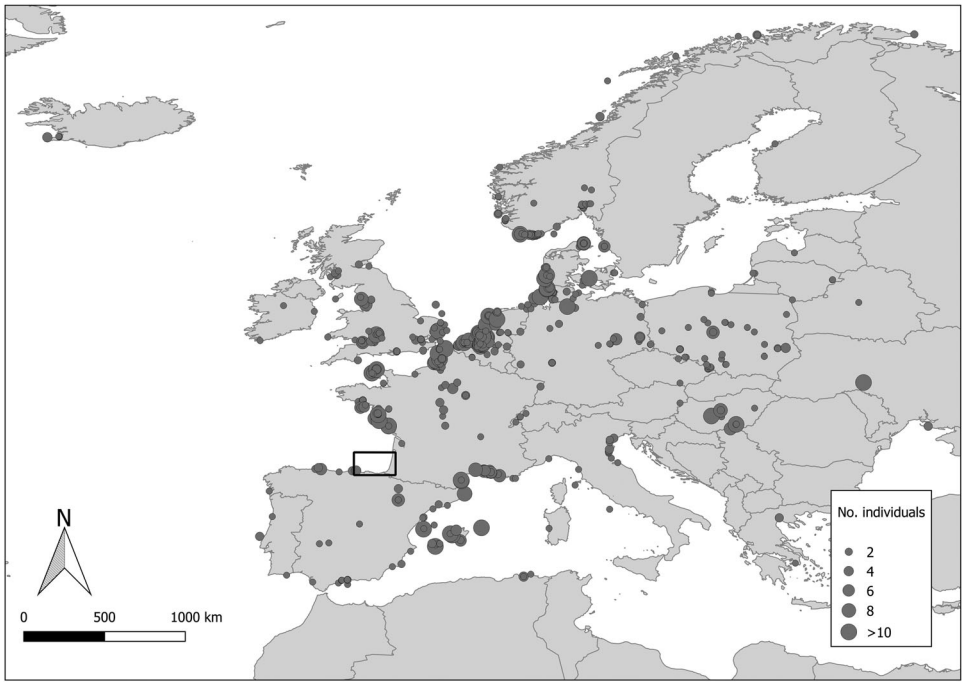

Figure 3. Ringing sites of colour-ringed gulls seen in the study area in the Bay of Biscay (boxed area).

were likely to have been ringed as chicks). Only three species had a relatively high proportion of birds ringed as adults (Black-headed Gull 44.4%, Mediterranean Gull 28.9%, and Lesser Black-backed Gull 25.6%). Most of these birds were ringed around the summer solstice, in their colony sites (Figure 5).

Temporal distribution

The number of individual gulls observed per year has increased during the study period (Figure 6). After 2000, we had an initial small increase from 2002 to 2004, when this number stabilised around a mean of *c.* 140 gulls seen per year up to 2013. From 2014 onwards, this annual value increased again up to 2019, when we reached 521 individuals, the maximum within the series. However, if the data are standardised by the sampling effort, this picture changes substantially (Figure 6). The observed pattern in this case suggests a fluctuating figure, with a mean of 1.6 gulls per survey day per site.

The four months around the winter solstice, November to February, accounted for 59.0% of the sightings data we compiled, when each bird is considered only once a month. By contrast, there were fewest sightings between April and June. This overall pattern did not change much once the raw data were corrected for survey effort (Figure 7). The main difference, when the effort had been accounted for, was the occurrence of a peak in March, and another one in September, with a relatively stable index of birds seen from September to January.

The temporal pattern varied between species ($\chi^2 = 1439.7$, $df = 77$, $P < 0.001$; Table 2, Figure 8). In particular, four species were observed to deviate from the overall general pattern: Audouin's Gull was the

Table 2. Standardised residual values from a species-by-month contingency table used to test whether the temporal distribution pattern varied by species. Absolute values >3 indicate that the species had an annual distribution of sightings data different from the one in Figure 7.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
C. ridibundus	-1.08	+0.05	-1.11	-1.40	+0.51	+0.96	+2.15	+0.89	+0.79	+1.44	-0.63	-0.25
I. audouinii	-1.04	-1.06	-0.87	-0.31	+3.56	+3.14	+4.68	+4.66	-0.65	-0.79	-1.13	-0.99
I. melanocephalus	+8.39	+10.66	+2.32	-3.49	-3.46	-2.94	-3.11	-6.44	-8.30	-7.64	-4.71	+2.58
L. argentatus	+0.46	-1.51	-0.80	+0.51	+0.87	+2.01	-0.99	-1.44	+0.21	0.53	+1.03	+0.32
L. marinus	+0.62	-0.65	-0.94	+1.75	+2.51	+2.83	+0.14	-0.77	-0.57	-1.56	+0.86	-0.14
L. cachinnans	+1.69	-0.74	-0.89	-0.89	-0.75	-0.84	-1.13	-1.65	-1.34	-1.84	+1.03	+3.09
L. michahellis	-6.55	-8.51	-7.06	+2.67	+4.30	+3.86	+6.35	+13.4	+13.47	+9.34	-3.55	-3.52
L. fuscus	-3.73	-3.60	+4.54	+1.56	-1.14	-1.76	-2.7	-4.12	-2.19	0.73	+7.67	-0.35

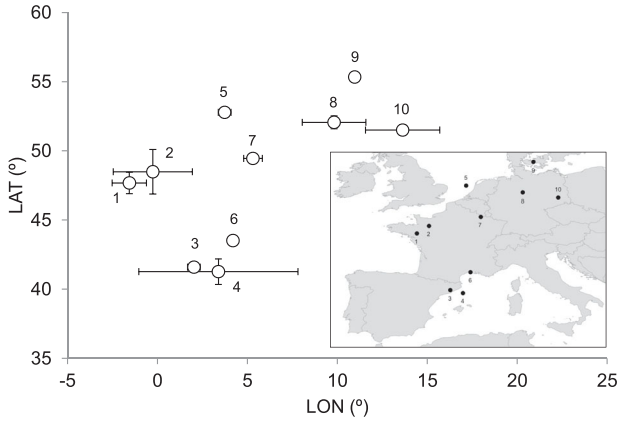

Figure 4. Mean geographical coordinates of ringing sites of the colour-ringed gulls seen in the Bay of Biscay, by species, with 95% confidence intervals, mapped in inset: 1 Herring; 2 Great Black-backed; 3 Yellow-legged; 4 Audouin's; 5 Lesser Black-backed; 6 Slender-billed; 7 Mediterranean; 8 Black-headed; 9 Common; 10 Caspian. Confidence intervals could not be calculated for single records of Slender-billed and Common Gulls.

Table 3. Ringing ages of the gulls seen alive in the Bay of Biscay during 2000–19. EURING 3 refers to birds ringed in their first year of life, either as chicks still near their nests or after fledging, away from the colony. EURING 4 refer to birds captured in or after their second year of life: most of these birds were coded EURING >8, representing adult birds captured as breeders in their colonies.

Species	Nestling	EURING 3	EURING 4	Unknown
Slender-billed Gull	1 (100%)	0	0	0
Black-headed Gull	30 (41.7%)	7 (9.7%)	32 (44.4%)	3 (4.2%)
Audouin's Gull	3 (75.0%)	1 (25.0%)	0	0
Mediterranean Gull	469 (55.3%)	126 (14.9%)	245 (28.9%)	8 (0.9%)
Common Gull	1 (100%)	0	0	0
Great Black-backed Gull	32 (72.7%)	12 (27.3%)	0	0
Herring Gull	21 (75.0%)	6 (21.4%)	0	1 (3.6%)
Caspian Gull	35 (79.5%)	7 (15.9%)	1 (2.3%)	1 (2.3%)
Yellow-legged Gull	334 (87.9%)	16 (4.2%)	32 (5.3%)	10 (2.6%)
Lesser Black-backed Gull	554 (54.9%)	184 (18.2%)	258 (25.6%)	13 (1.3%)

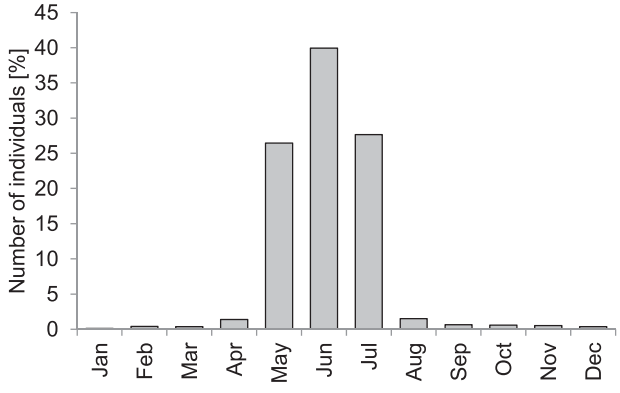

Figure 5. Ringing months for colour-ringed gulls seen alive in the Bay of Biscay, species pooled, shown as proportions of the grand total.

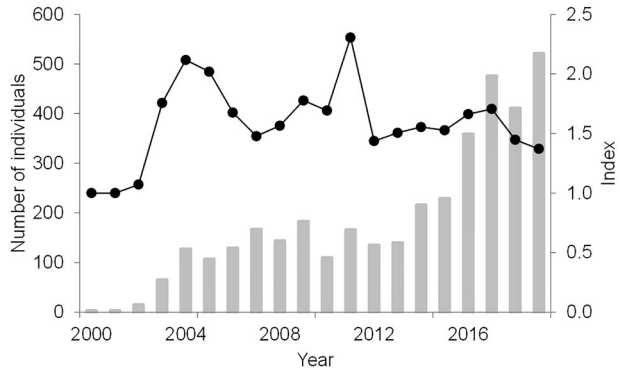

Figure 6. Number of colour-ringed gulls seen alive in the Bay of Biscay during 2000–19 (shaded bars). On the 'Index' axis, the data have been standardised for survey effort, measured as the number of survey days per site in each year (solid line).

species that differed most clearly, appearing within the region only in late spring and summer, with a peak in August; Mediterranean Gull deviated slightly, with proportionally more observations during the first two months of the year; Yellow-legged Gull, by contrast, showed proportionally more observations from mid-spring to mid-autumn, but fewer from mid-autumn to March; finally, Lesser Black-backed Gull tended to be proportionally less abundant during the first months of the year and more so in March and November.

Discussion

This is the first detailed study of the sightings data of non-local colour-ringed gulls for the Bay of Biscay. Previous studies using similar data were much more limited in scope (e.g. Arizaga 2019). The number of sightings varied substantially between species. Thus,

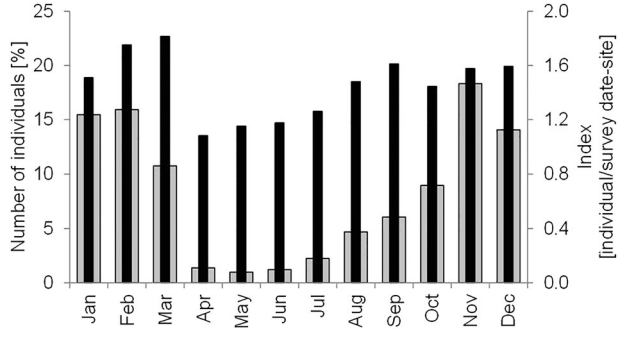

Figure 7. Monthly distribution of colour-ringed gulls of all species seen alive in the study area during 2000–19, excluding locally breeding gulls: shaded bars, raw data as proportions of the grand total: solid bars, index, after standardising for survey effort, measured as the number of survey days per site in each month.

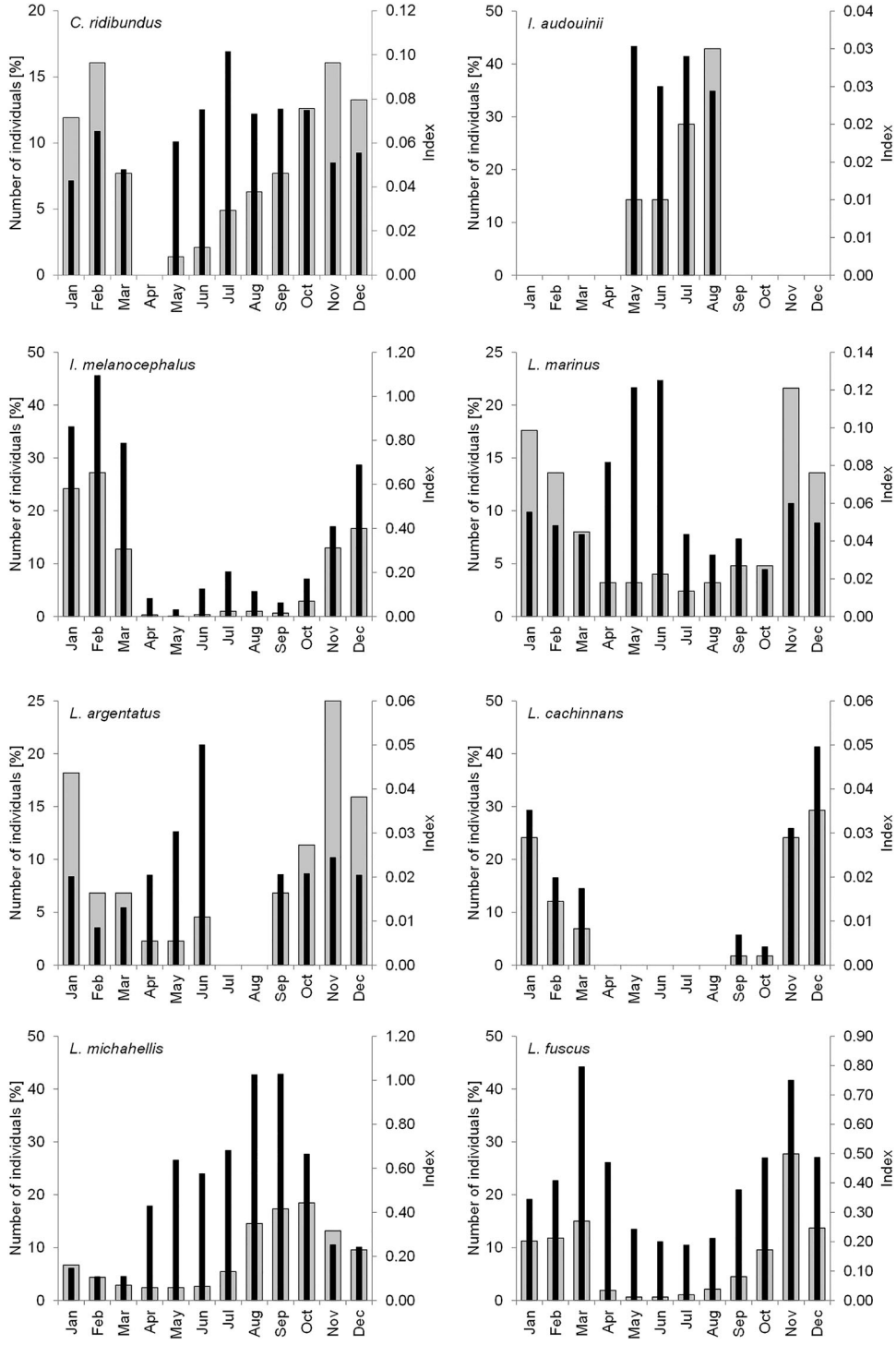

Figure 8. Monthly distribution of each colour-ringed gull species seen alive in the study area more than once during 2000–19. Conventions are as in Figure 7.

Lesser Black-backed and Mediterranean Gulls accounted respectively for 38% and 32% of the colour-ringed gulls seen within the survey region. In contrast, we obtained single sightings for Slender-billed and Common Gulls. Although these figures might be correlated with the real population size of each species within the region (JA, unpublished; www.ornitho.eus), they cannot be taken as a proxy of gull abundance, because unequal ringing effort between years, zones of origin and species could result in biased overall proportions relative to the real abundance of each species. We tried to discover the numbers of gulls colour-ringed by year and zone, but the information was not available for most

projects; therefore, we were unable to correct our figures for ringing effort.

The number of sightings varied geographically within the region, but this may have been due to the unequal sampling effort, with more observers in the Southeast zone. Therefore, rather than focusing on raw proportion values, the key aspect here is to assess how a species compared to the mean values in an area, when pooled for all species. Thus, the East was observed to host a proportionally higher number of Mediterranean Gulls than expected, as did the Southeast for Yellow-legged Gull and the Southwest for Herring and Caspian Gulls.

The temporal distribution shows clear seasonal fluctuations in sightings, which occurred mostly from November to February. However, standardised data show a slightly different temporal pattern. Overall, most individual birds were found during September to March, though a few species did not fit with this general pattern. Deviations could be attributed to those species which come from the Mediterranean region, either during their post-breeding dispersal before migrating to Africa (e.g. Audouin's Gull) or to make a short winter visit within the region, with most birds returning to their areas of breeding or origin well before midwinter (e.g. Yellow-legged Gull; Galarza *et al* 2012). It must be also acknowledged that some of the decrease in sightings detected around the summer was due to a decreasing survey effort during this period, mediated in part by the summer vacation period but also by the lower abundance of gulls in summer, which may have discouraged many birdwatchers from going out in search of ringed gulls.

That 64% of the gulls were seen only once suggests that most remained for just a day or a few days within the region, which would therefore be classed as mostly a stopover or resting area and not a final winter destination. This conclusion is compatible with a recent study based on counts during the winter period (JA, unpublished), where the numbers of gulls wintering were observed to be considerably smaller in the southeastern Bay of Biscay than along the coast of northern Iberia (e.g. Molina 2009).

The increasing quantity of sightings data during the final years (Figure 6) seems to be an artefact since, when the raw data are corrected for survey effort, the trend is relatively stable, though with some fluctuations. Thus, the increase observed in the raw data is linked directly to increasing birdwatching effort within the region, where reading colour rings on gulls is becoming ever more popular among birdwatchers. Overall, this figure highlights the very relevant role of citizen science for the success of many colour-ring projects and the importance of accounting for survey effort when interpreting results from raw sightings data.

The southeastern Bay of Biscay receives gulls from several regions of origin across Europe. Given that most individuals were ringed either as chicks or as adults at their breeding sites, our sightings data truly reflect the origin of the non-breeding gulls found in the Bay of Biscay. Non-breeding gulls could be separated into three main groups , according to their migratory behaviour and ecology: those appearing during post-breeding or post-fledging dispersal, migratory ones and wintering ones (Figure 8). The first group would include birds dispersing from their breeding or hatching areas, seen mostly in summer, before starting to migrate to their wintering areas. An example of this behaviour may be Audouin's Gull, a species that winters between southern Iberia and Senegambia (Oro & Martinez 1994, Malling Olsen & Larsson 2004), but that has some records in the Bay of Biscay in summer (Figure 8). Previous research confirms that those summering are mostly first-year individuals that move randomly from their Mediterranean colonies, before the autumn migration (Oro & Martinez 1994). In other cases, the Bay of Biscay is used as a stopover region, where the birds would stay from hours to weeks. The temporal patterns from Figure 8 show that this can be the case of individuals of several species, like Lesser Black-backed Gull, which shows two clear peaks of passage in autumn and spring. Finally, some species seem to use the Bay of Biscay primarily as a wintering area, as may be the case with Caspian Gull.

Overall, we must note that more than one of the three strategies shown here could be found in a single species. For instance, it is clear that some Lesser Black-backed Gulls use the Bay of Biscay on route to winter grounds situated between Portugal and western Africa (Klaassen *et al* 2012, Shamoun-Baranes *et al* 2017), whilst other birds overwinter there. Overall, therefore, the Bay of Biscay is a key region for the conservation of several Western Palaearctic gull populations, either because they overwinter or because they pass through and make a stopover within the region. Future research should quantify the proportion of individuals of each population that pass through and, probably more importantly, overwinter in this region.

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