FIELD SEPARATION OF CORY'S *CALONECTRIS BOREALIS* AND SCOPOLI'S *C. DIOMEDEA* SHEARWATERS BY UNDERWING PATTERN

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ABSTRACT

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Field separation of Cory's *Calonectris borealis* and Scopoli's *C. diomedea* shearwaters is notoriously difficult. Past, provisional research found that the most reliable method of separation is by underwing pattern. Here, we present a comprehensive study of the underwing patterns of both species from colonies and other locations in the eastern North Atlantic Ocean (Cory's Shearwater) and Mediterranean Sea (Scopoli's Shearwater). Data were derived from museum specimens, typed bycatch victims, and photographs of birds at colony, inshore by colony, and offshore in the Mediterranean. Results demonstrate that the large majority of Cory's/Scopoli's shearwaters are separable in the field, though overlapping features of the remainder are problematic. Improvements to the criteria for field separation will enhance studies of breeding limits, regional migration, and limits and variation in range, which, in turn, will highlight conservation needs of the two species.

Key words: Cory's Shearwater, Scopoli's Shearwater, *Calonectris* shearwater identification

INTRODUCTION

The genus *Calonectris* contains four species: Streaked Shearwater *C. leucomelas* (which breeds in the North Pacific, mainly on islands off Korea, Japan, and Taiwan), Scopoli's Shearwater *C. diomedea* (which breeds mainly in the Mediterranean Sea), Cory's Shearwater *C. borealis* (which breeds mainly on islands in the Northeast Atlantic Ocean), and Cape Verde Shearwater *C. edwardsii* (which is an endemic breeder of the Cape Verde Islands). In this study, we were concerned with the field separation of the cryptic pair Scopoli's Shearwater and Cory's Shearwater, only briefly considering the more easily recognised Streaked Shearwater and Cape Verde Shearwater. Background information is summarised in Appendix 1, available on the website).

Developments in field separation

Calonectris is a distinctive genus of large shearwaters that are relatively easy to separate in the field from the medium-sized *Ardenna* shearwaters. Unlike the latter diving shearwaters with their high wing loading, *Calonectris* shearwaters have the wing loading of surface-foraging shearwaters (Spear & Ainley 1997a), resulting in a more leisurely flight behaviour (Spear & Ainley 1997b). As well, *Calonectris* have a distinctive plumage aspect—a yellow or greyish/brownish bill, and a greyish-brown/brown hood, neck shawl, and upperside (Flood & Fisher 2020). The *Ardenna* shearwaters are generally much darker in color. Field separation of the Streaked Shearwater from other *Calonectris* shearwaters is relatively straightforward given, among other things, its browner upperside, more heavily marked white underwing-coverts, and uniquely white head that is variably streaked brown (Howell & Zufelt 2019, Flood & Fisher 2020). The separation of the Cape Verde Shearwater from the remaining two *Calonectris* shearwaters is moderately challenging, though reasonable views/photographs establish its longish, quite slender greyish/brownish bill (essentially yellow on Scopoli's and Cory's shearwaters), darker brown cap, smaller overall size, and quicker, more agile flight (Howell & Zufelt 2019, Flood & Fisher 2020). However, the field separation of Scopoli's Shearwater from Cory's Shearwater is notoriously difficult (Gutiérrez 1998, Howell & Patteson 2008, Flood & Fisher 2020).

Morphometric differences between Scopoli's and Cory's shearwaters have long been recognised (e.g., Bourne 1955, Cramp & Simmons 1977, Massa & Lo Valvo 1986, Granadeiro 1993, Porter *et al*. 1997, Thibault *et al*. 1997, Gómez-Díaz *et al.* 2006). These works are important, but they offer little help to field separation. The first serious attempt to distinguish the two species at sea concentrated on size and structure, upperside colouration, and underwing pattern (Gutiérrez 1998). Although most of these features are difficult to assess under field conditions (Howell & Patteson 2008, Fisher & Flood 2010, Campbell *et al.* 2013), underwing pattern is of great importance to field separation because it can be accurately recorded.

Gutiérrez (1998) studied Scopoli's Shearwaters from Spanish waters and Cory's Shearwaters from the Canary, Azores, and Madeiran islands. He noted that the under primaries of Cory's Shearwaters are mostly all dark, and the distal limit of white greater primary coverts forms a neat, rounded shape over the base of the under primaries. In contrast, the outer seven under primaries of Scopoli's Shearwaters typically have basal white 'tongues' of variable length in the inner web. The white tongues project beyond the distal limit of the white greater primary coverts into the dark under primaries. Individual tongues can be picked out with reasonable views/photographs, but at range they coalesce into a single white intrusion into the dark under primaries. The length of the tongues/depth of the intrusion varies significantly between individuals. The rounded shape at the distal limit of the white greater primary coverts typical of Cory's Shearwaters is lost in Scopoli's Shearwaters. Based on further at-sea data and the study of typed specimens, Gutiérrez (2005) noted greater variation in white tongues in Cory's Shearwaters and, based on this, offered criteria for the at-sea separation of Cory's and Scopoli's shearwaters.

Howell & Patteson (2008) agree on the importance of white primary tongues, as well as the variation that exists in Cory's Shearwaters, and they acknowledge that separating Scopoli's and Cory's shearwaters at sea is not as straightforward as noting the presence or absence of white primary tongues. They studied variation by field observation, examining museum skins, and other information. They found that Cory's Shearwaters with distinct white tongues in the outer primaries are not rare, though p10 is usually all dark or has only a small diffuse whitish area at its base beyond the distal limit of the white greater primary coverts. Howell & Patteson (2008) called for a detailed study, but for the interim they offered a scoring system by which to categorise birds as 'Cory's Shearwater, presumed Cory's Shearwater, Cory's Shearwater or Scopoli's Shearwater, or presumed Scopoli's Shearwater.' The decisive criterion is that presumed Scopoli's Shearwater must show distinct white tongues in three or more primaries, including p10. Based on this, Howell (2012) attempted to distinguish Cory's and Scopoli's shearwaters and thereby address their non-breeding status in the western Atlantic. Further, Robb *et al*. (2008) noted that Scopoli's Shearwaters typically have one dark mark/spot in the outermost greater primary covert, while Cory's Shearwaters often have a dark mark/spot in the two outermost greater primary coverts (i.e., one spot versus two spots).

Our research into the separation of Cory's and Scopoli's shearwaters builds on these foundations by focusing on variation in three features of the underwing pattern: (1) visible white tongues in the inner web of the three outermost primaries, p8–p10; (2) marks/spots in the outermost two greater primary coverts gpc9 and gpc10; and (3) an additional feature, the degree of dark markings in the lesser secondary coverts (variation in the median and greater secondary coverts is relatively small). We published an interim summary of results based on a sample of 545 Cory's and 462 Scopoli's shearwaters (Flood & Fisher 2020). The results were promising, indicating that a large majority of Cory's/Scopoli's shearwaters are separable in the field, while overlapping features in the remainder were problematic. This article presents the details of the refined method, including challenges in measurement, thereby enabling researchers to replicate our study. We present results for 752 Cory's and 814 Scopoli's shearwaters, offering a detailed discussion of results, including intra-species variation, and we provide a clear guide to the field separation of these two species.

METHODS

We studied variation in the underwing pattern of Cory's and Scopoli's shearwaters in museum specimens, typed bycatch victims, birds at breeding colonies, birds flying 'inshore' in the immediate vicinity of a breeding colony (assumed from the colony), and birds in the Mediterranean Sea flying offshore away from colonies (assumed to be nearly all Scopoli's Shearwaters). We are aware that a small number of Cory's Shearwaters are proven to breed in the Mediterranean, mainly to the west of the Almería-Oran Oceanographic Front (AOOF), and hybridisation rarely occurs to the east of AOOF (Flood & Gutiérrez 2019). The potential impact of hybridisation on our results is raised in the discussion below. Offshore or pelagic *Calonectris* in the Atlantic did not form part of the study because Scopoli's Shearwaters are known to frequent the Atlantic range of Cory's Shearwaters twice a year during migration; passage overlaps part of the Cory's Shearwater breeding season, as the Cory's and Scopoli's shearwater breeding seasons differ by about one month (Reyes *et al*. 2017). This study includes representatives from most breeding island groups in the Mediterranean and the eastern North Atlantic (Figs. 1, 2).

Museum specimens of both species were studied at the American Museum of Natural History (New York, USA), Barcelona Museu de Ciències Naturals (Spain), Funchal Museu Historia Natural (Madeira Island, Portugal), and Tring Natural History Museum (UK). Jacob González-Solís (Barcelona University) gave access to genetically typed Scopoli's and Cory's shearwater bycatch victims. At our request, several researchers kindly took photographs of the underwings of live Scopoli's and Cory's shearwaters at study

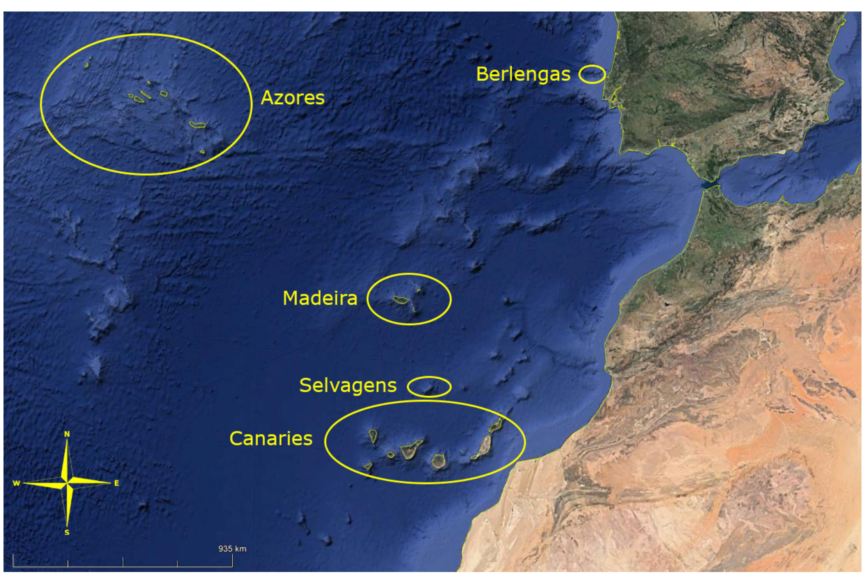

Fig. 1. Map showing island groups (circled) in the Northeast Atlantic Ocean sampled for Cory's Shearwater *Calonectris borealis*.

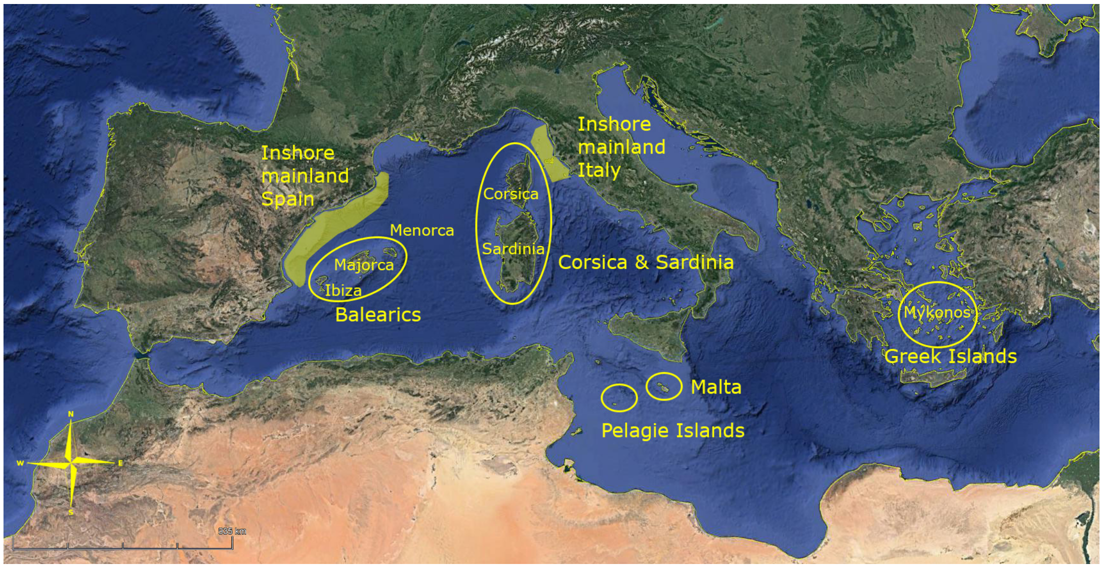

Fig. 2. Map showing island groups (circled) and inshore mainland regions (shaded) in the Mediterranean Sea sampled for Scopoli's Shearwater *Calonectris diomedea*.

colonies, and numerous people contributed photographs of birds in flight (see Acknowledgements). Photographs were eliminated if they were blurry, if contrast was poor, or if the angle of the underwing prevented accurate measurements.

Measurement techniques and scoring methods were established (see below). Museum skins and bycatch corpses were measured/scored in the hand. Live birds were photographed in the hand at the colony or in flight at sea. Photographs were magnified to minimise errors and measured/scored on a flat 32-inch computer screen. A ringer's metal ruler was used for measurements (working to the nearest mm). Multiple photographs of an individual were used, where possible, to improve confidence in measurements/scores. Light management in Adobe Photoshop was employed to enhance features. We measured/scored photographs independently and compared our results. Results that disagreed were rechecked and reconciled. We did not reach agreement in about 5% of cases, and these cases were eliminated from the study.

Under primaries (p)

We studied the outer three primaries, which are the most accessible primaries in museum specimens and are the most visible in the field and in photographs (tongues, when present, are found mainly in p3–p10). The length of the visible white tongue of a primary was measured from the tip of its greater covert to the farthest-most point of the white tongue (B in Fig. 3). The length of the visible primary was measured from the tip of its greater covert to the tip of the primary (A in Fig. 3). The length of each tongue was calculated as a percentage of the length of the primary (B divided by A) and was recorded using the categories 0%, 1%–5%, 6%–10%, 11%–15%, etc (from hereon, the categories respectively are referred to as 0%, 5%, 10%, 15%, etc). Categorisation gave clear quantitative variation in each species and facilitated comparison between species.

Issues

Not all primary tongues were solid white. Some faded into mottled white, some were largely mottled, and some were broken. It was such cases where our results disagreed. In the process of reconciliation, we opted for the shorter measure that excluded weakly mottled ends to tongues that were difficult to measure in photographs and impossible to assess at sea. In addition, photographs of some under primaries suffered from light reflection (e.g., flash at night, strong light during the day, variation in reflectivity of under primaries due to the age of feathers). This was particularly problematic with highly reflective fresh under primaries, such as those of pre-fledging juveniles (under primary surfaces of adults, toward the end of the breeding season, tend to be worn and less reflective). If light enhancement did not define the tongues, then the photograph was eliminated from the study.

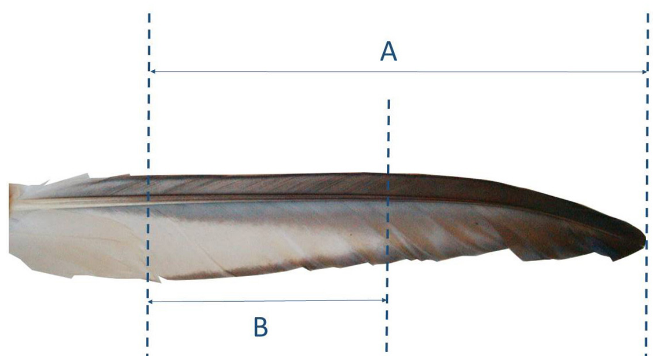

Fig. 3. Method for measuring the length of the visible white tongue in an under primary. 'A' is the total length of the visible under primary, from the tip of the greater primary covert to the tip of the primary. 'B' is the length of the visible white tongue, from the tip of the greater primary covert to the farthest-most point of the white tongue. The length of each tongue is calculated as a percentage of the length of the visible primary (B divided by A) and is recorded using the categories 0%, 1%–5%, 6%–10%, 11%–15%, etc. Shown is a primary feather of a Scopoli's Shearwater *Calonectris diomedea* bycatch victim off Catalonia, Spain, Mediterranean Sea (Photo: Ricard Gutiérrez).

TABLE 1
Sample of Cory's Shearwaters *Calonectris borealis* from the eastern North Atlantic by source and by island group[a]

Island group	Sample	Museum	At colony	By colony
Azores Islands	187 (26.2%)	62 (33.2%)	10 (5.3%)	115 (61.5%)
Canary Islands	186 (26.1%)	35 (18.8%)	0 (0%)	151 (81.2%)
Selvagens Islands	138 (19.3%)	15 (10.9%)	41 (29.7%)	82 (59.4%)
Madeiran Islands	196 (27.5%)	24 (12.2%)	1 (0.5%)	171 (87.3%)
Berlengas Islands	7 (0.9%)	0 (0%)	0 (0%)	7 (100%)
All island groups	714	136 (19.1%)	52 (7.3%)	526 (73.6%)

[a] The column 'Sample' breaks down the total sample into island groups and gives, in brackets, the percentage of the sample represented by each island group. Three other columns break down the sample for each island group into sources (museum specimens, live birds at breeding colony, and birds flying inshore by breeding colony) and give, in brackets, the percentage of the island group sample represented by each source.

Samples

Of 752 Cory's Shearwaters studied from the eastern North Atlantic breeding colonies during the breeding season, under primaries were accessible or visible on 714 of them (total sample): 136 museum specimens (all collected at breeding colony), 52 live birds at colony (photographed in the hand), and 526 flying inshore by colony. These came from five island groups: 187 from Azores, 186 from Canary, 138 from Selvagens, 196 from Madeiran, and seven from the Berlengas islands (Fig. 1, Table 1).

Of 814 *Calonectris* shearwaters from the Mediterranean Sea during the breeding season, under primaries were accessible or visible on 768 of them (total sample): 63 museum specimens (47 collected at colony), 34 typed bycatch victims (Genovart *et al*. 2013), 29 at colony (photographed in the hand), 150 inshore by colony, and 492 away from colony. These came from numerous islands groups and inshore mainland waters: 52 inshore Ibiza (Balearic Islands, Spain), 46 inshore Majorca (Balearic Islands), 14 inshore Menorca (Balearic Islands), nine inshore Corsica and Sardinia, 38 at colony Pelagie Islands (Italy), 51 inshore Malta, 14 inshore Greek islands (mainly Mýkonos Island); and away from colony, 484 inshore mainland Spain (mainly Catalonia), 43 inshore mainland Italy (mainly Tuscany), and 17 at various locations (Fig. 2, Table 2).

Under greater primary coverts (gpc)

Dark marks/spots that occur in the outermost two greater primary coverts were initially scored from 1 to 5: score 1, no mark/spot in either gpc9 or gpc10; score 2, a mark/spot in one web of gpc10; score 3, a larger mark/spot across both webs of gpc10; score 4, as score 3 plus a mark/spot in one web of gpc9; score 5, as score 3 plus a large mark/spot across both webs of gpc9.

Issues

Many museum specimens are old, a number are tatty, and some have poorly arranged or missing coverts so that we were unable

TABLE 2
Sample of *Calonectris* from the Mediterranean Sea by source and by location[a]

Location	Sample	Museum	Bycatch	At colony	By colony	By mainland
Balearics	112 (14.6%)	21 (18.8%)	0 (0%)	0 (0%)	91 (81.2%)	0 (0%)
Corsica/Sardinia	9 (1.2%)	7 (77.8%)	0 (0%)	0 (0%)	2 (22.2%)	0 (0%)
Pelagie Islands	38 (5%)	2 (5.3%)	0 (0%)	29 (76.3%)	7 (18.4%)	0 (0%)
Malta	51 (6.6%)	4 (7.8%)	0 (0%)	0 (0%)	47 (92.2%)	0 (0%)
Mýkonos Island	14 (1.8%)	11 (78.6%)	0 (0%)	0 (0%)	3 (21.4%)	0 (0%)
Mainland Italy	43 (5.6%)	6 (14.0%)	0 (0%)	0 (0%)	0 (0%)	37 (86.0%)
Mainland Spain	484 (63%)	4 (0.8%)	34 (7.0%)	0 (0%)	0 (0%)	446 (92.2%)
Other	17 (2.2%)	8 (47.1%)	0 (0%)	0 (0%)	0 (0%)	9 (52.9%)
All locations	768	63 (8.2%)	34 (4.4%)	29 (3.8%)	150 (19.5%)	492 (64.1%)

[a] The column 'Sample' breaks down the total sample into island groups, inshore mainland Italy and Spain, and other locations, and gives, in brackets, the percentage of the sample represented by each location. Five other columns break down the sample for each location into sources (museum specimens, typed bycatch victims, live birds at breeding colony, birds flying inshore by breeding colony, and birds foraging inshore by the mainland) and give, in brackets, the percentage of the location sample represented by each source.

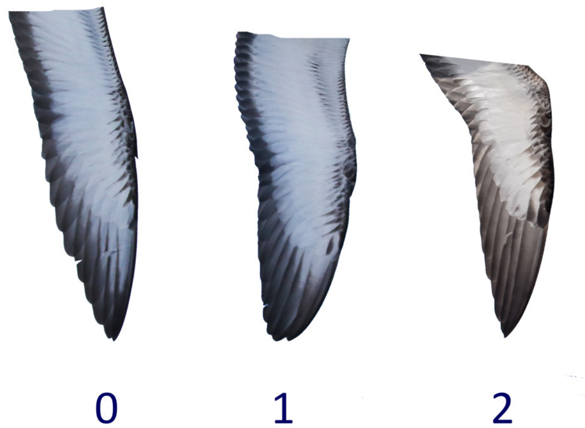

Fig. 4. Illustration of marks/spots in the greater primary coverts gpc9 and gpc10 of Cory's Shearwater *Calonectris borealis* and Scopoli's Shearwater *C. diomedea*: 0. No dark mark/spot. 1. One dark mark/spot in gpc10. 2. A dark mark/spot in gpc9 and gpc10. Left and centre, Scopoli's Shearwater off Catalonia, Spain, Mediterranean Sea (Photo: Matxalen Pauly). Right, Cory's Shearwater off Porto Santo Island, Madeiran Islands, Northeast Atlantic Ocean (Photo: Kirk Zufelt).

to score them. In field conditions, assessing spots/marks in the greater primary coverts is not always straightforward, even with a series of photos. The wings of birds in flight are highly mobile and some actions cause the greater primary coverts to compress like a concertina, making scoring difficult. On occasions, our score for a bird changed across photographs; most typically, scores changed between score 2 or score 3, and score 4 or score 5. For this reason, we adopted a simpler scoring method: score 1, no mark/spot; score 2, one mark/spot; and score 3, two marks/spots, where a mark/spot may be large or small (Fig. 4).

Samples

Of 752 Cory's Shearwaters from the eastern North Atlantic, greater primary coverts were accessible or visible on 592 of them (the sample): 26 museum specimens, 46 at colony (photographed in the hand), and 520 flying inshore by colony. Of 814 *Calonectris* shearwaters from the Mediterranean Sea, greater primary coverts were accessible or visible on 710 of them (the sample): 27 museum specimens (14 collected at colony), 32 at colony (photographed in the hand), 150 inshore by colony, and 501 away from colony.

Under lesser secondary coverts (lsc)

Dark markings in the lesser secondary coverts were chosen over dark markings in the lesser primary coverts because secondary coverts are more visible in the field/photographs and primary coverts are often obscured on birds in the hand (Fig. 5). Also, scoring primary and secondary coverts complicated matters. The quantity of dark markings was scored from 1 to 6, from minimal to maximal, respectively. The quantity, rather than the pattern of dark markings, was studied because the patterns were too numerous be useful. A

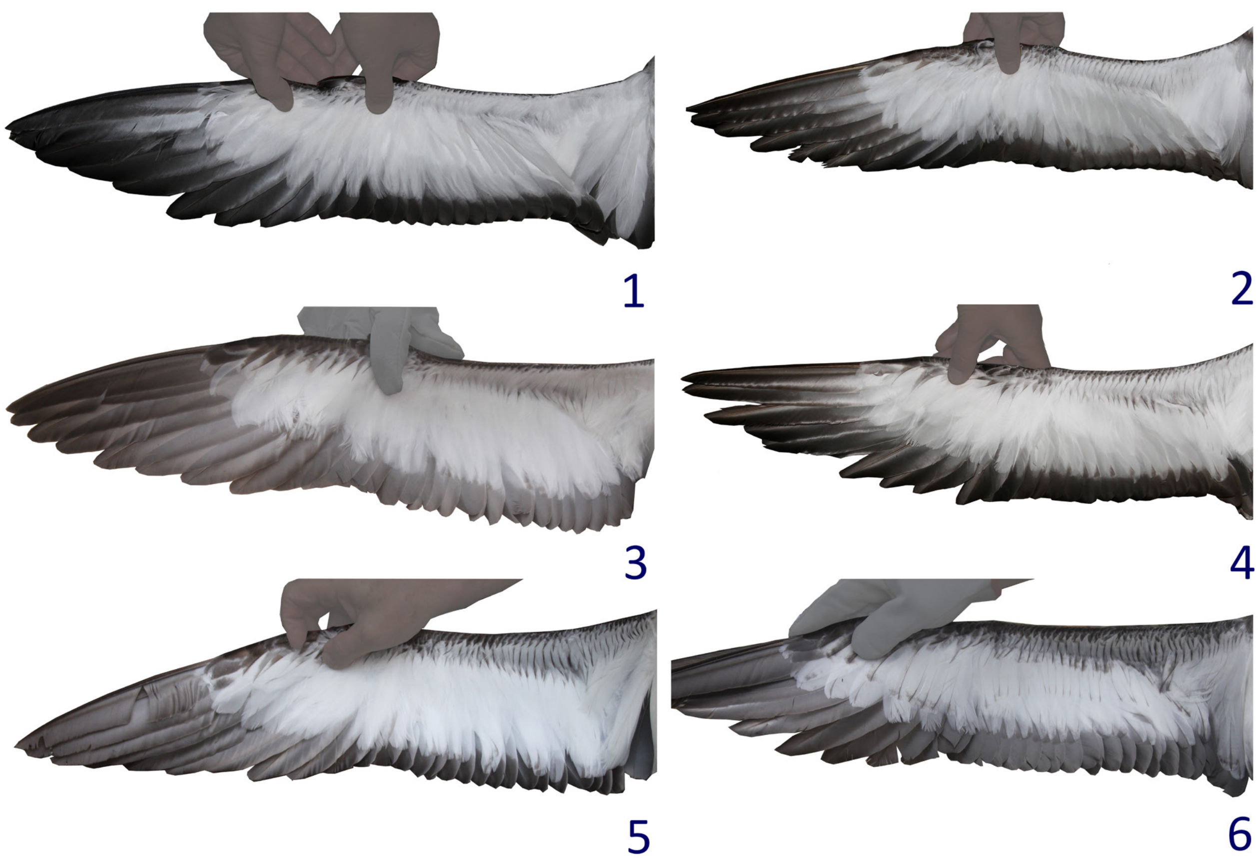

Fig. 5. Variation in underwing lesser secondary coverts of Cory's Shearwater *Calonectris borealis* and Scopoli's Shearwaters *C. diomedea*, showing progression from score 1, minimal markings, to score 6, maximal markings (a recommended standard to maximise consistency). 1, 2, and 4, Scopoli's Shearwaters, Linosa Island, Pelagie Islands, Italy, Mediterranean Sea (Andrea Corso); 3, 5, and 6, Cory's Shearwaters, Selvagem Grande Island, Selvagem Islands, Northeast Atlantic Ocean (Photo: Frank Zino).

composite set of six photographs represented the six scores and provided a standard by which to maximise consistency (Fig. 5).

Issues

The wings of museum specimens are usually fixed, making the lesser secondary coverts inaccessible. Scoring was somewhat subjective, and despite the pre-established standard and discussion there remained occasional disagreement. Cases were eliminated where disagreement was not resolved.

Samples

Of 752 Cory's Shearwaters from the eastern North Atlantic, lesser secondary coverts were accessible or visible on 551 of them (the sample): 45 at breeding colony (photographed in the hand) and 506 flying inshore by colony. Of 814 *Calonectris* shearwaters from the Mediterranean Sea, lesser secondary coverts were accessible or visible on 672 of them (the sample): 32 at breeding colony (photographed in the hand), 144 flying inshore by colony, and 496 flying at sea away from colony.

RESULTS AND DISCUSSION

Under primaries

Cory's Shearwater

Regarding the prevalence of white tongues in the under primaries p8–p10, across all sources and island groups, about 74.5% (*n* = 532) of the sample (*n* = 714) lacked a white tongue in p8–p10 and showed the 'classic' Cory's Shearwater's neat, rounded shape at the distal limit of the white greater primary coverts (Tables 3, 4). About 97.5% (*n* = 696) lacked a white tongue in p10. (See Appendix 2, available on the website, for length patterns in p8 and p9 when p10 = 0.)

The 2.5% (*n* = 18) of birds with a white tongue in p10 are from 10 museum specimens and eight birds inshore by colony from mixed locations (Table 3). Lengths of the white tongues in p10 fell into the following categories: 5% (*n* = 6), 10% (*n* = 3), 15% (*n* = 5), 20% (*n* = 3), and 40% (*n* = 1). The single bird with a tongue length in p10 greater than 20% was considered an outlier (a museum specimen, confirmed to be Cory's Shearwater by DNA, details in Flood & Fisher 2020, p. 138).

Aside from the small sample of seven from the Berlengas Islands, the percentage of the sample with a white tongue in p10 differed between island groups and ranged from 0.5% of the sample from the Madeiran Islands to 4.4% of the sample from the Selvagens Islands (the percentage of the sample with a white tongue in p10 was also relatively high in samples from the Azores Islands at 3.7%). The percentage of the sample with a white tongue in one or more of p8–p10 also differed between island groups and ranged from 19.6% of the sample from the Selvagens Islands to 33.7% of the sample from the Azores Islands (Table 4).

Scopoli's Shearwater

Regarding no white tongue (score 0%) in the under primaries p8–p10, across all sources and island groups, of the total sample (*n* = 768), eight (1%) scored 0% and showed the 'classic' Cory's Shearwater's neat, rounded shape at the distal limit of the white greater primary coverts: seven from inshore mainland Spain (Catalonia) and one from inshore Balearic Islands (Ibiza; Tables 5, 6).

None of the 63 museum specimens (47 collected at colony) scored 0% in p8–p10 and only three (4.8%, all collected at colony) scored 0% in p10. None of the 34 typed bycatch victims scored 0% in p8–p10 or in p10, and the shortest set of tongues in p8–p10 was 25%, 35%, and 20%. None of the 29 live birds photographed at colony on Linosa Island (Pelagie Islands) scored 0% in p8–p10 and only two (6.9%) scored 0% in p10 (Table 5).

Of 150 birds photographed inshore by colony, one (0.7%) scored 0% in p8–p10 and one (0.7%) scored 0% in p10. Of 492 birds photographed inshore by the mainland, seven (1.4%) scored 0% in p8–p10 and 35 (7.1%) scored 0% in p10: 34 from inshore mainland Spain (7%) and one from inshore mainland Italy (2.3%). In total, 41 (5.3%) of the sample of 768 scored 0% in p10 (Table 6).

The percentage of the Cory's Shearwater sample with a white tongue in p10, and in one or more of p8–p10, was greater in

TABLE 3
Cory's Shearwaters *Calonectris borealis* from the eastern North Atlantic with white tongues (all categories) in the under primaries by source: museum specimens, live birds at colony, and birds flying inshore by colony[a]

Source	Sample	p8–p10	p10
Museum	136	55 (40.4%)	10 (7.4%)
At colony	52	6 (11.5%)	0 (0.0%)
By colony	526	121 (23.0%)	8 (1.5%)
Total	714	182 (25.5%)	18 (2.5%)

[a] The column 'Sample' gives the sample size for each source. The column 'p8–p10' gives the number of birds and in brackets is the percentage of the source sample with a white tongue in one or more of p8–p10. The column 'p10' gives the number of birds and in brackets is the percentage of the source sample with a white tongue in p10.

TABLE 4
Cory's Shearwaters *Calonectris borealis* from the eastern North Atlantic with white tongues (all categories) in the under primaries by island group[a]

Location	Sample	p8–p10	p10
Azores Islands	187	63 (33.7%)	7 (3.7%)
Canary Islands	186	45 (24.2 %)	4 (2.2%)
Selvagens Islands	138	27 (19.6%)	6 (4.4%)
Madeiran Islands	196	45 (23.0%)	1 (0.5%)
Berlengas Islands	7	2 (28.6%)	0 (0.0%)
Total	714	182 (25.5%)	18 (2.5%)

[a] The column 'Sample' gives the sample size for each island group. The column 'p8–p10' gives the number of birds and in brackets is the percentage of the island sample with a white tongue in one or more of p8–p10. The column 'p10' gives the number of birds and in brackets is the percentage of the island sample with a white tongue in p10.

TABLE 5
***Calonectris* from the Mediterranean Sea with no white tongue in the under primaries by source: museum specimens (47 collected at colony), typed bycatch victims, live birds at colony, birds flying inshore by island colony, and birds foraging inshore by mainland[a]**

Source	Sample	p8–p10	p10
Museum	63	0 (0%)	3 (4.8%)
Bycatch	34	0 (0%)	0 (0%)
At colony	29	0 (0%)	2 (6.9%)
By colony	150	1 (0.7%)	1 (0.7%)
By mainland	492	7 (1.4%)	35 (7.1%)
Total	768	8 (1%)	41 (5.3%)

[a] The column 'Sample' gives the sample size for each source. The column 'p8–p10' gives the number of birds and in brackets is the percentage of the source sample that scored 0% in p8–p10. The column 'p10' gives the number of birds and in brackets is the percentage of the source sample that scored 0% in p10.

TABLE 6
***Calonectris* from the Mediterranean Sea with no white tongue in the under primaries by location[a]**

Location	Sample	p8–p10	p10
Balearics	112	1 (0.9%)	2 (1.8%)
Corsica/Sardinia	9	0 (0%)	1 (11.1%)
Pelagie Islands	38	0 (0%)	3 (7.9%)
Malta	51	0 (0%)	0 (0%)
Mýkonos Island	14	0 (0%)	0 (0%)
Mainland Italy	43	0 (0%)	1 (2.3%)
Mainland Spain	484	7 (1.5%)	34 (7%)
Other	17	0 (0%)	0 (0%)
Total	768	8 (1%)	41 (5.3%)

[a] The column 'Sample' gives the sample size for each location. The column 'p8–p10' gives the number of birds and, in brackets, the percentage of the location sample that lacked a white tongue in p8–p10. The column 'p10' gives the number of birds and in brackets is the percentage of the location sample that lacked a white tongue in p10.

museum specimens than the other two sources; in addition, this result for p8–p10, for example, exceeded expected proportions in the sample ($\chi^2 = 23.04$, $P < 0.01$; Table 3). Plausible explanations for this deviation from expectation are the greater visibility of short tongues when handling museum specimens, tongues covered by greater primary coverts in life that are revealed when coverts of dead specimens are displaced, or both. Thus, we anticipate that, in photographs of Cory's Shearwaters in flight, evidence of a white tongue in p10 will be rarer than 2.5% and evidence of a white tongue in one or more of p8–p10 will not be as frequent as 25.5% (i.e., less than percentages for the total sample, which includes museum specimens).

Results for the Mediterranean *Calonectris* sample were likely influenced, to some degree, by the presence of a small number of Cory's Shearwaters known to occur in the western Mediterranean (Flood & Gutiérrez 2019). Their frequency of occurrence has not been established. For this reason, we analysed the part of the sample that was known to be, or was extremely likely to be, Scopoli's Shearwater: genetically typed bycatch victims ($n = 34$), museum specimens collected at colony ($n = 47$), and live birds photographed at colony on Linosa Island ($n = 29$; Table 5). None of these 110 birds scored 0% for p8–p10, providing solid evidence that the 'classic' Cory's Shearwater all-dark under primaries is not found in Scopoli's Shearwaters. Based on this finding, eight birds photographed in flight with 'classic' Cory's Shearwater under primaries were assumed to be Cory's Shearwaters and were removed from further analysis: seven from inshore mainland Spain, apparently a foraging zone favoured by Cory's Shearwaters, and one from inshore Ibiza (reducing the Mediterranean sample to 760 birds).

In addition to the eight presumed Cory's Shearwaters, 41 birds lacked a white tongue in p10 (5.4% of 760; sample of 768 less eight presumed Cory's Shearwaters): 34 inshore mainland Spain (7.1% of 477; sample of 484 less seven presumed Cory's Shearwaters), two Balearic Islands (1.8% of 111; sample of 112 less one presumed Cory's Shearwater), three Pelagie Islands (7.9% of 38), one Sardinia (11.1% of nine), and one inshore mainland Italy (2.3% of 43; Table 6). The decisive criterion by which to separate Cory's and Scopoli's shearwaters, given by Howell & Patteson (2008), is that presumed Scopoli's Shearwaters must show distinct white tongues on three or more primaries, including p10, which would exclude our 41 birds and designate them 'Cory's Shearwater or Scopoli's Shearwater.' It is improbable that all 5.4% of the total sample for the Mediterranean were Cory's Shearwater, so Cory's Shearwater and Scopoli's Shearwater probably occur with intermediate characters, and provisionally we propose that Scopoli's Shearwater rarely occurs without a white tongue in p10 (although further research is required).

The occurrence of Cory's Shearwater with a white tongue in p10 is rare, probably < 2.5% of birds. When present, the tongues are short, with 17 of 18 tongues falling in the range 5%–20% of the length of the visible primary (with one outlier at 40%). The occurrence of Scopoli's Shearwater without a white tongue in p10 is apparently rare, probably about 5.3% of birds, while the majority have a white tongue in p10 that is > 20% of the length of the visible primary, which accounts for at least 67% of birds. So, it is highly likely that a bird with p10 = 0% is a Cory's Shearwater, and it is almost certain that a bird with p10 > 20% is a Scopoli's Shearwater, making p10 of crucial importance to species separation.

The probability of a Cory's Shearwater having a white tongue in p9 was 22.7% ($n = 162$) with a tongue length up to 65% of the length of the visible primary, and the probability of having a white tongue in p8 was 17.9% ($n = 128$) with a tongue length up to 50% of the visible primary. Thus, for Cory's and Scopoli's Shearwaters, the frequency of occurrence and overlap in length of a white tongue in p9 and p8 was substantial, rendering them of no apparent value for species separation. (Appendices 2 and 3 document patterns in p9 and p8 found in Cory's Shearwaters without a white tongue in p10.)

Based on our findings, we propose the following modification to the criteria given by Howell & Patteson (2008): (1) presumed Scopoli's Shearwater must have a distinct white tongue in p10 > 20%; (2) presumed Cory's Shearwater must lack white tongues in p8–p10; and (3) the 5%–20% categories for p10 are best treated as Cory's/Scopoli's Shearwater unless support criteria indicate otherwise (see below).

Underwing greater primary coverts

We investigated variation in the dark marks/spots in gpc9 and gpc10 of 592 Cory's Shearwaters from the eastern North Atlantic. None lacked a mark/spot in gpc9 and gpc10, 52.5% (*n* = 311) had a single, generally large, dark mark/spot in gpc10, while 47.5% (*n* = 281) had two small/large dark marks/spots that were generally large in gpc10 (Fig. 6). We investigated 710 *Calonectris* shearwaters from the Mediterranean Sea. About 4.4% (*n* = 31) apparently lacked a dark mark/spot in gpc9 and gpc10, 94.5% (*n* = 671) had a single, generally large, dark mark/spot in gpc10, and 1.1% (*n* = 8) had two small/large dark marks/spots that were generally large in gpc10 (Fig. 6).

The single most important observation for greater primary covert scores is that 'classic' Scopoli's Shearwaters have a single dark mark/spot in gpc10, with only a small percentage showing a second dark spot/mark in gpc9 or apparently no dark mark/spot in gpc9 or gpc10 (Fig. 6). However, about one-half of Cory's Shearwaters have a single dark mark/spot in gpc10, while the remainder have a dark mark/spot in gpc9 and gpc10. Accordingly, a marginal case where p10 = 20% may only be considered a Scopoli's Shearwater if it has a single dark mark/spot in gpc10 or no dark mark/spot in gpc9 and gpc10.

Underwing lesser secondary coverts

We investigated variation in the quantity of dark markings in the underwing lesser secondary coverts of 551 Cory's Shearwaters from the eastern North Atlantic. About 76.6% (*n* = 422) scored 3 or 4 (the two central scores), 17.2% (*n* = 95) scored 5 or 6 and had dark-looking lesser secondary coverts, and 6.2% (*n* = 34) scored 1 or 2 and had clean-looking lesser secondary coverts (Fig. 7). We investigated 672 *Calonectris* shearwaters from the Mediterranean Sea. About 50.1% (*n* = 337) scored 3 or 4 (the two central scores), 0.8% (*n* = 5) scored 5 or 6 and had dark-looking lesser secondary coverts, and 49.1% (*n* = 330) scored 1 or 2 and had clean-looking lesser secondary coverts (Fig. 7). On average, Scopoli's Shearwaters had more lightly-marked lesser secondary coverts than Cory's Shearwaters and vice versa (Fig. 7).

Body size and build

An additional factor in judging a marginal case of a Cory's versus Scopoli's shearwater is the size and build of the bird, although there is much overlap between these two species, principally between female Cory's Shearwater and male Scopoli's Shearwater. Examples of 'extremes' in build (bill, head, neck, body, and wings) are given in Flood & Fisher (2020). Judgement of size and build in the field and in photographs is problematic, and only the extremes are appropriate indicators for marginal cases. Biometrics of a bird in the hand could be decisive (e.g., see Biometrics in Pyle 2008).

CONCLUSIONS

In our sample, only Cory's Shearwaters occurred with all dark visible under primaries p8–p10. Apart from one Cory's Shearwater outlier, only Scopoli's Shearwaters had a white tongue in under primary p10 that was greater than 20% of the length of the

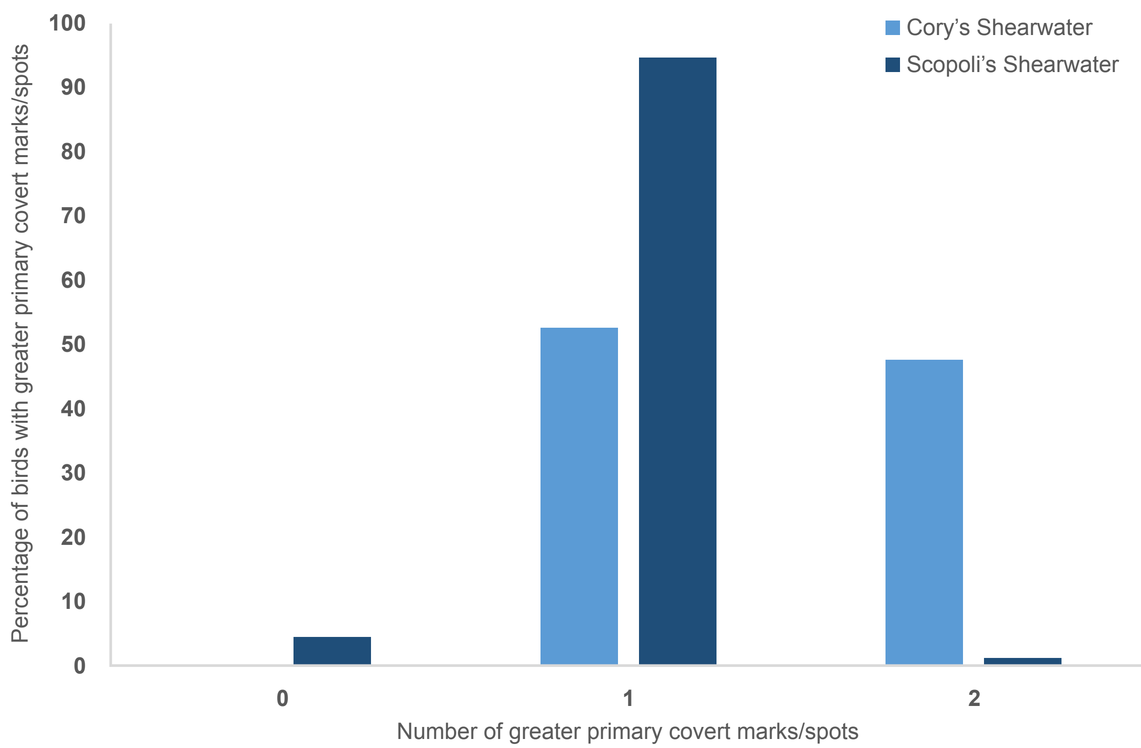

Fig. 6. Occurrence of dark marks/spots in the underwing greater primary coverts gpc9 and gpc10 in Cory's Shearwater *Calonectris borealis* and Scopoli's Shearwater *Calonectris diomedea*. Score 0: No dark mark/spot. Score 1: One dark mark/spot in gpc10. Score 2: A dark mark/spot in gpc9 and gpc10.

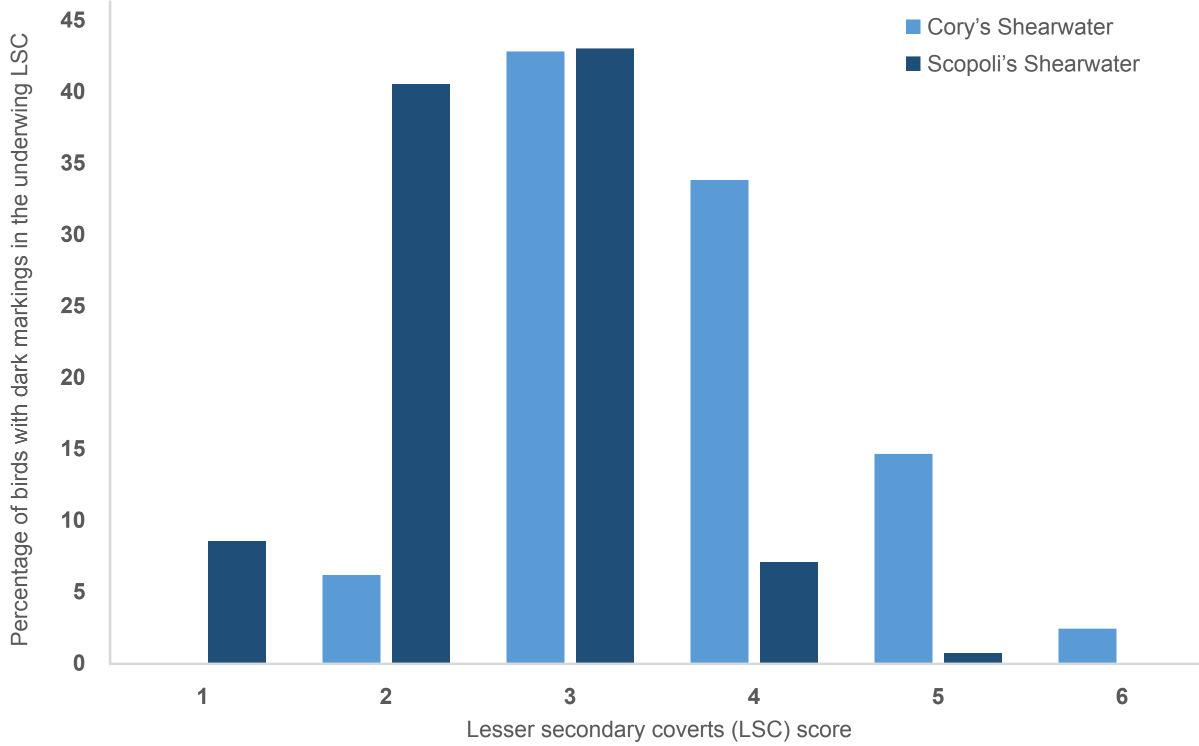

Fig. 7. The extent of dark markings in the underwing lesser secondary coverts of Cory's Shearwater *Calonectris borealis* and Scopoli's Shearwater *Calonectris diomedea*. Score 1 (minimal markings) to Score 6 (maximal markings).

visible primary. An 'overlap range' for tongues in p10 occurred in categories 5%–20%—a range for p10 that was shared by up to 2.5% of Cory's Shearwaters and by about 31.8% of Scopoli's Shearwaters. For measurements that fall in the 20% category, support criteria may help to decide 'Scopoli's Shearwater' or 'Cory's/Scopoli's Shearwater', and for measurements that fall in the 5% category, support criteria may help to decide 'Cory's Shearwater' or 'Cory's/Scopoli's Shearwater'.

There are three support criteria: (1) for the greater primary coverts, the great majority of Scopoli's Shearwaters show just one dark mark/spot in gpc10; (2) on average, Cory's Shearwaters have denser dark markings in the lesser secondary coverts (also reflected in the lesser primary coverts), giving a darker- or dirtier-looking underwing than Scopoli's Shearwaters, and vice versa; and (3) the largest and most heavily built (adult male) Cory's Shearwaters are outside of the range of Scopoli's Shearwaters, while the smallest and most lightly built (juvenile) female Scopoli's Shearwaters are outside of the range of Cory's Shearwaters.

Thus, it is possible to distinguish, at sea, most Cory's Shearwaters and Scopoli's Shearwaters using the following criteria:

1) Under primary pattern: Cory's Shearwater if under primaries p8–p10 lack white tongues.
2) Under primary pattern: Scopoli's Shearwater if a white tongue in p10 > 20% of length of the visible primary.
3) Under primary pattern: Cory's/Scopoli's shearwater if a white tongue in p10 = 5%–20%. Identification to species requires strong backing from support criteria or is best left as Cory's/Scopoli's shearwater.
4) Support for Cory's Shearwater: mark/spot in gpc9 and gpc10, lesser secondary covert score > 3.
5) Support for Scopoli's Shearwater: no mark/spot in gpc9 and gpc10, or one mark/spot in gpc10, lesser secondary covert score < 3.
6) Support for Cory's Shearwater: maximal size and robustness (robust bill, blocky head, bull-neck, heavily built body, broad wings).
7) Support for Scopoli's Shearwater: minimal size and robustness (slim bill, small head, narrowish neck, lightly built body, narrowish wings).

We recommend the following further studies: (1) DNA test Scopoli's Shearwaters at colony to confirm or refute the proposition that some Scopoli's Shearwaters lack a white tongue in p10. If so, document age (fledgling, breeding adult, other); (2) DNA test a sample of *Calonectris* in the Mediterranean with p10 in the 0–20% categories, including presumed Cory's Shearwaters without white tongues in p8–p10, to determine if these birds are pure or hybrid Cory's/Scopoli's shearwater; (3) investigate the scale of hybridisation and introgression between Cory's and Scopoli's shearwaters in the Mediterranean and the impact on the underwing pattern.

Improvements to the criteria for field separation of Scopoli's and Cory's shearwaters will assist studies of their breeding limits, regional migration, and limits and variation in range, which, in turn, will highlight their conservation needs. Tracking the distribution of Scopoli's and Cory's shearwaters has revealed broad patterns of migration and range limits. Genetic studies have proven that hybridisation occurs in the Mediterranean Sea. However, tracking and genetic studies deal with a small sample of birds and are costly.

The improved separation criteria described above will enable field observers to study larger samples at low cost.

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