Status of Cory's Shearwater in the western Mediterranean

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Generally, Cory's Shearwater *Calonectris borealis* (hereafter *borealis*) breeds in the north-eastern Atlantic Ocean and Scopoli's Shearwater *C diomedea* (hereafter *diomedea*) in the Mediterranean Sea (BirdLife International 2018). Both species spend the non-breeding period primarily in the Atlantic, though *borealis* enters the southwest Indian Ocean (Ristow et al 2000, González-Solís et al 2007, Dias et al 2011, Reyes-González et al 2017). Recent evidence presented below shows that the breeding divide between *borealis* and *diomedea* lies in the western Mediterranean rather than at the Strait of Gibraltar, and that *borealis* regularly forages in small numbers off the Iberian Mediterranean coast. This paper presents and discusses the evidence, touches on hybridisation and introgression, and summarises criteria for at-sea and in-hand separation of *borealis* from *diomedea*. The aim is to improve current and future understanding of the status of *borealis* in the western Mediterranean.

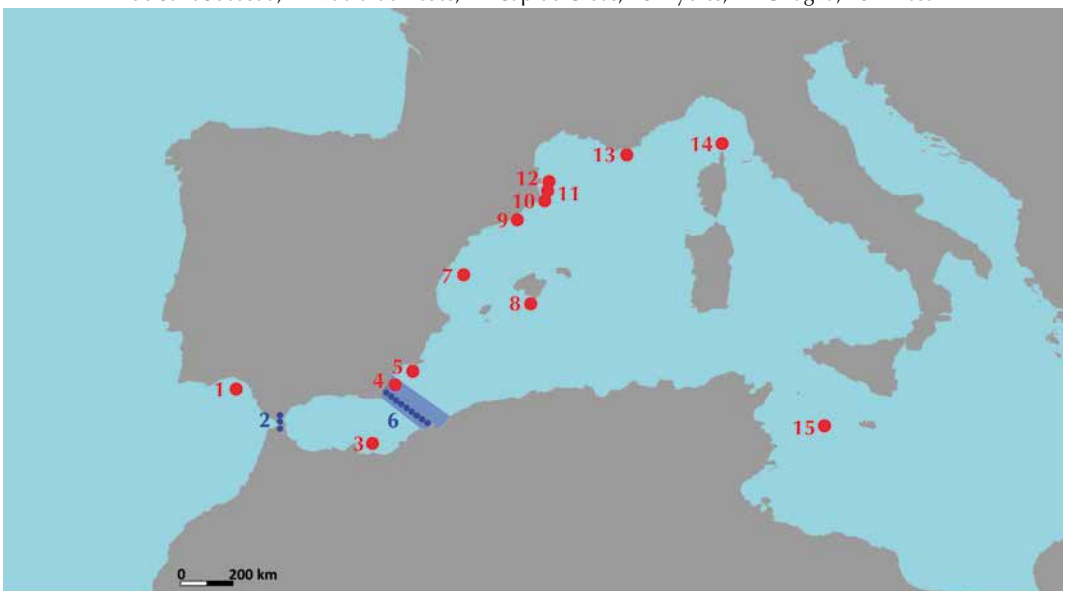
Breeding *borealis* in the western Mediterranean

The main breeding colonies of *borealis* are in the north-eastern Atlantic Ocean, ie, in the Azores, Berlengas, Canary Islands, Desertas, Madeira and Selvagens (BirdLife International 2018). It recently bred in Galicia in north-western Spain (Munilla et al 2016).

Two breeding sites were recently discovered in the western Mediterranean. First, a colony of c 10 breeding pairs was found on Isla de Terreros off the Almería coast, Spain (Gómez-Díaz et al 2009, Reyes-González et al 2017; figure 1). A genetic analysis of five individuals showed no evidence of hybridisation and a morphological study of 31 individuals supported their 'Atlantic identity' (Gómez-Díaz et al 2006). Also, a *Calonectris* species has been mentioned as breeding on nearby Isla Negra at 1 km distance from Isla de Terreros (Carboneras & Lorenzo 2004).

Second, in the Chafarinas islands, Spain, close to the Moroccan Mediterranean coast, 20-30

FIGURE 1 Main locations in text: **1** Gulf of Cádiz, **2** Strait of Gibraltar, **3** Chafarinas islands, **4** Isla de Terreros and Isla Negra, **5** Palomas island, **6** Almería-Oran Oceanographic Front, **7** Islas Columbretes, **8** Cabrera, **9** Barcelona, **10** Cap de Sant Sebastià, **11** Badia de Roses, **12** Cap de Creus, **13** Hyères, **14** Giraglia, **15** Linosa



breeding pairs of *borealis* were found in a colony of 800-1000 pairs of *diomedea* (Reyes-González et al 2017). A pullus ringed on Selvagem Grande, Selvagens, in the north-eastern Atlantic on 6 October 1979 was found incubating on Congreso Island, Chafarinas, on 14 June 2005 (27 years old!) (by Isabel Afán and José Manuel Igual; Molina et al 2005). Biometrics of this individual and several more birds from the island corresponded with *borealis*. The proportion of *borealis* breeding in the Chafarinas colony increased from 6% in 2000 to 23% in 2010 with c 14% mixed pairs (Genovart et al 2013).

Breeding divide between *borealis* and *diomedea*

The Almería-Oran Oceanographic Front (hereafter AOOF) between Almería, Spain, and Oran, Algeria, is a salinity and heat driven current between two distinct water masses/habitats: ***1*** the north-eastern Atlantic Ocean, and ***2*** the oceanographic Mediterranean Sea (an evaporative semi-enclosed sea with relatively high salinity and heat) (Tintore et al 1988, Beckers et al 1997, L'Helguen et al 2002). Terreros and the Chafarinas, where *borealis* breed, lie on the margins and to the west of AOOF, respectively. The main colonies of *diomedea* are well to the east of AOOF, though Palomas island, at only c 60 km north-east of Terreros, so just to the east of AOOF, has 37-88 pairs of *diomedea* (Reyes-González et al 2017). Quite exceptionally, however, several pairs of *diomedea* have been breeding at Arcachon basin, Gironde, along the Biscay coast of south-western France (Mays et al 2006, Robb et al 2008). As evidence of the biogeographic importance of this AOOF boundary and Atlantic-Mediterranean distributions, Gómez-Díaz et al (2006, 2009) cite genetic studies on several species of crustaceans and molluscs from both sides of AOOF and demonstrate that this oceanic transition is an effective barrier to gene flow (Quesada et al 1995, Pannacciulli et al 1997). Accordingly, they identify AOOF as a divide between the breeding ranges of *borealis* and *diomedea*, thereby challenging the more conventional idea (eg, Borsa et al 1997, Bérubé et al 1998, Cagnon et al 2004) that the Strait of Gibraltar is the barrier (figure 1).

Records of *borealis* east of AOOF

Notwithstanding the above evidence, there is a growing number of well-documented records of *borealis* to the east of AOOF, either in or near *diomedea* breeding colonies, or at sea away from colonies.

Records in or near diomedea breeding colonies

Records of *borealis* in colonies of *diomedea* have been confirmed by a recovery of a *borealis* ringed as a pullus in one of the north-eastern Atlantic breeding colonies, or by genetic analyses, or by sound. Bretagnolle & Lequette (1990) and Robb et al (2008) showed that, in colonies, the two species can be separated by sound.

Spain

Islas Columbretes, Comunidad Valenciana The following four birds ringed as pullus on Selvagem Grande were recorded on Islas Columbretes, Valencia, in 1992-99. In 1992, a pair of *borealis* successfully raised a chick, but in 1993 the male disappeared and incubation failed. The female was present in 1994 as a non-breeder but was not found in subsequent years. In 1999, a female *diomedea* monitored as a breeder since 1993, though widowed in 1998, was in a burrow with a 7-year-old male *borealis*. The mixed pair did not breed in 1999, but successfully raised a chick in 2000. The female *diomedea* bred with a male *diomedea* in 2001. A *borealis* was captured in 1999, but its sex and reproductive status were not recorded (Sánchez & Martínez 1997, Martínez-Abraín et al 2002). In addition, in 2018 two *borealis* were found in mixed pairs with *diomedea*, while the colony size was 69 pairs that year (Servicio de Vida Silvestre 2018).

Cabrera, Balearic Islands On 23 May 2008, a male *borealis* was vocalising in a breeding colony of 94 pairs of *diomedea* (Miguel McMinn in litt).

France

Hyères The identification of 'a few' *borealis* breeding in a *diomedea* colony in Hyères was confirmed by genetic analyses (Gómez-Díaz et al 2009).

Giraglia, Corsica A number of *borealis* have been recorded in a *diomedea* colony of 31-40 pairs on Giraglia, Corsica (Thibault & Bretagnolle 1997, Cadiou et al 2004).

Italy

Linosa, Sicily On 16 May 1987, an 8-year-old female *borealis* ringed on Selvagem Grande as a pullus on 4 October 1978 was found in a *diomedea* colony on Linosa, Sicily (Lo Valvo & Massa 1988). The female *borealis* subsequently formed a mixed breeding pair with a male *diomedea* for two consecutive years (Corso 2005). On 11 August 2009, an adult male *borealis* ringed on Selvagem Grande as a pullus was found in a




193 Cory's Shearwater / Kuhls Pijlstormvogel *Calonectris borealis*, Xábia, Alicante, Spain, 7 May 2018 *(Victor Paris)*. Short whitish tongue basally on underside of p9 and at very base of p10 fits category 2/3 being presumed *borealis* (see main text). This individual has intermediate robustness fairly typical of *borealis* phenotype. **194** Cory's Shearwater / Kuhls Pijlstormvogel *Calonectris borealis*, Badia de Roses, Catalunya, Spain, 12 May 2007 *(Àlex Ollé)*. Classic *borealis* phenotype with under primaries all dark (category 1), relatively heavy density of dark markings in lesser and median underwing-coverts, and fairly robust bill. **195** Cory's Shearwater / Kuhls Pijlstormvogel *Calonectris borealis*, Cap de Creus, Catalunya, Spain, 28 May 2016 *(Guillem Saguer)*. Comments same as in caption of plate 194. **196** Cory's Shearwater / Kuhls Pijlstormvogel *Calonectris borealis*, Canó de Palamós, Catalunya, Spain, 23 May 2018 *(Ricard Gutiérrez)*. Comments same as in caption of plate 194, although overall somewhat more robust, suggesting male.

diomedea colony on Linosa, Sicily, with no report of breeding (Janni & Fracasso 2015). However, there is no evidence that hybrids were reared on Linosa.

Records away from diomedea breeding colonies

Spain

Xàbia, Alicante, Comunidad Valenciana One was photographed by Victor Paris at Xàbia, Alicante, on 7 May 2018 (plate 193).

Catalunya We know of five confirmed records and a number of *diomedea/borealis* documented with photographs: ***1*** Alt Empordà, off Badia de Roses, Girona, on 12 May 2007 (Àlex Ollé) (plate 194); ***2*** off Barcelona in July 2007 (José Manuel Arcos, in Gil-Velasco in press); ***3*** Alt Empordà, off Cap de Creus, Girona, on 28 May 2016 (Guillem Saguer) (plate 195); ***4*** three individuals off Barcelona on 30 May 2016 (José Manuel Arcos, in Gil-Velasco in press); ***5*** Baix Empordà, La Fonera, Canó de Palamós, off Cap de Sant Sebastià, Llafranc, Baix Empordà, Girona, on 23 May 2018 (RG et al) (plate 196); and ***6*** a number of unidentified *diomedea/borealis* photographed off Barcelona, Ebro delta, and Palamós are discussed in Gil-Velasco (in press).

TABLE 1 Measurements (mm) to assist in identification and ageing Cory's Shearwater *Calonectris borealis* and Scopoli's Shearwater *C diomedea* (Pyle 2008). Wing = length of wing in its natural curved position (not flattened); tail = distance between longest rectrix and point of insertion of two central rectrices; culmen = distance between tip of forehead feathering at base of bill and bill-tip, along ridge of culmen; bill depth = taken at distal end of forehead feathers; tarsus = distance from notch at end of lateral condyle of tibiotarsus, on back side of leg, to last tarsal scute on front of leg, at base of foot.

taxon	wing	tail	culmen	bill depth	tarsus
borealis (♂)	333-367	123-144	52-62	14.5-16.7	53-61
borealis (♀)	328-361	121-141	49-58	13.0-15.2	50-58
diomedea (♂)	323-355	120-135	48-54	12.0-14.6	49-57
diomedea (♀)	319-350	117-132	45-51	11.2-13.8	46-54

The occurrence of *borealis* in the western Mediterranean reflects findings of genetic studies. Isolation of Mediterranean populations occurred after Atlantic populations were established, probably after the last glacial period c 10 000 years ago (Rabouam et al 2000). Genetic studies from a number of Mediterranean and north-eastern Atlantic colonies revealed that the majority of individuals derived from their own basin (ie, Atlantic/Mediterranean), while short-range dispersal between colonies was not uncommon, and that there was occasional long-distance dispersal between basins, mainly from the Atlantic to the Mediterranean (Gómez-Díaz et al 2009, Genovart et al 2013). Results agree with capture-recapture data mentioned above (Gómez-Díaz et al 2009).

Origin of *borealis* foraging off the Iberian Mediterranean coast

The origin of *borealis* foraging off the Iberian Mediterranean coast is yet to be determined. Records off Catalunya were near or over submarine canyons where nutrient-rich upwellings support a thriving food chain including top marine predators such as cetaceans and seabirds. *Calonectris* shearwaters have well-developed olfactory glands sensitive to dimethyl sulphide released when zooplankton graze on phytoplankton (Dell'Ariccia et al 2014). Their strong sense of smell increases the chance of finding such food-rich areas. Data logger studies show that petrels repeatedly return to a single food-rich location while breeding (eg, Madeiros 2012).

Records of *borealis* off the Catalunya and Valencia regions occurred mainly in May (one in July) which coincides with the *Calonectris* incubation period (Sánchez & Martínez 1997). Studies of *borealis* from the Canary Islands revealed that non-incubating partners foraged at 1584±725 km with a duration of 7.11±2.86 days (Navarro & González-Solís 2007); *diomedea* from Zembra, Tunisia, foraged at 51.7-1919 km with a duration of 0.7-8 days in 2013 season, while they foraged between 6.5 and 1883.9 km with a duration of 0.7 to 8 days in 2012 season (Gremillet et al 2014). This means that, for example, Alicante and Girona are well within the range of *borealis* colonies on Terreros and the Chafarinas. However, GPS loggers deployed on adult *borealis* from Terreros (three birds, 20 trips, 7426 waypoints) and the Chafarinas (one bird, two trips, 1332 waypoints) showed them foraging to the west of AOOF, with some from Terreros reaching the Gulf of Cádiz (Reyes-González et al 2017). Interestingly, a few tracked *diomedea* breeding on Palomas island only c 60 km north-east of Terreros foraged in the opposite direction to the south-west and north-east.

Therefore, *borealis* recorded off the Iberian Mediterranean coast could be breeders from east of AOOF, although of course we cannot exclude non-breeding birds. Reyes-González et al (2017) showed that *diomedea* from the Balearic Islands exploit waters off Catalunya and Valencia throughout the breeding season, intensively during chick-rearing. Any *borealis* breeding in the Balearic Islands are likely to follow suit. The single record in May of a male *borealis* on Cabrera could be one of several *borealis* there. Foraging *borealis* from Hyères, France, may also be involved, or perhaps individuals from locations yet to be discovered. All studies to date involve adult breeders and the publications cited do not mention the presence of pre-breeding immature birds.

At-sea and in-hand identification criteria

Borealis and *diomedea* are among the most challenging of species pairs to separate. It is likely that *borealis* has been overlooked among *diomedea* in the western Mediterranean and in *diomedea* colonies. At-sea separation of *borealis* and *diomedea* has been widely debated and is summarised below (eg, Granadeiro 1993, Gutiérrez 1998, Camphuysen & van der Meer 2001, Howell & Patteson 2008, Robb et al 2008, Fisher & Flood 2010, Gil-Velasco in press). Essential biometric data for in-hand identification is given in table 1 (see also

197 Scopoli's Shearwater / Scopoli's Pijlstormvogel *Calonectris diomedea*, Canó de Palamós, Catalunya, Spain, 23 May 2018 *(Ricard Gutiérrez)*. Fairly typical *diomedea* phenotype, with white tongues on all primaries (category 5), and fairly clean underwing-coverts, although with intermediate robustness. **198** Scopoli's Shearwater / Scopoli's Pijlstormvogel *Calonectris diomedea*, Canó de Palamós, Catalunya, Spain, 23 May 2018 *(Ricard Gutiérrez)*. As bird in plate 197 but with even cleaner underwing-coverts.

Randi et al 1989, Granadeiro 1993, Gómez-Diaz et al 2006, Pyle 2008).

Plumage

The single most though not totally reliable characteristic, based on current understanding, is the pattern on the underside of the outer primaries, ie, the extent of white/whitish basal tongues running up the inner webs (Gutiérrez 1998, 2005, Howell & Patteson 2008). This can be estimated with good views or from reasonable quality photographs. In the clearest guidance to date, Howell & Patteson (2008) divide the under primary variation into five categories: ***1*** all dark = *borealis*; ***2*** short whitish tongue p10 = presumed *borealis*; ***3*** whitish tongue p9 = presumed *borealis*; ***4*** whitish to white tongues on two or three under primaries among p8-10 = *diomedea*/*borealis*; and ***5*** distinct white tongues on three or more primaries including p10 = presumed *diomedea* (cf plate 193-198). We are currently reviewing this feature by analysing many 100s of *borealis* and *diomedea* museum skins, birds in hand at colonies, and photographs of birds around colonies.

Further differences in the underwing pattern lend support to identification. Most often *diomedea* has a large dark mark in the outermost greater primary covert; *borealis* has a large dark mark in the outermost two greater primary coverts (Robb et al 2008), though some *borealis* are like typical *diomedea* and vice versa (museum specimens pers obs). *Diomedea* has variable though typically lightly marked fairly clean-looking white primary and secondary lesser and median coverts; *borealis* on average has variable although somewhat denser markings in these coverts, but reverse cases occur.

There are further subtle differences in plumage as *diomedea* has a paler head and mantle, less grey throat, and paler and not so uniformly patterned upperwing. However, these characteristics are rarely helpful given variable effects of feather age and light on the contrast and colours (eg Campbell et al 2013).

Size and structure

Both *borealis* and *diomedea* show a size/robustness cline from west to east. Western birds typically are amongst the largest, with the deepest and longest bills (Randi et al 1989, Gómez-Diaz et al 2006). It follows that *borealis* on average is a larger and more robust bird than *diomedea*. Shearwaters exhibit sexual dimorphism with males on average larger and most robust, and age-related differences with juveniles on average smaller and least robust. Hence, on average adult male *borealis* is the largest and most robust, and juvenile female *diomedea* the smallest and least robust, while intermediates of the two species overlap. Estimating size and robustness at sea will result in a safe identification only in fairly extreme cases (Granadeiro 1993).

In summary, identification of some *borealis* and *diomedea* at sea or in hand is possible when considering: ***1*** under primary patterns; ***2*** minimal/maximal examples of size/robustness (ideally precise measurements in the hand); and ***3*** a combination of 1 or 2 above and other supporting features.

Inevitably, some birds cannot be identified, even with good views and photographs. This may be due to variation within *borealis* and *diomedea*, though may also be the result of hybridisation and introgression. For example, in a sample of 159 *borealis*/*diomedea* Gómez-Díaz et al (2009) found one bird that was genetically *borealis* breeding in the Mediterranean showing a *diomedea* phenotype, and one bird genetically *diomedea* breeding in the Atlantic showing a *borealis* phenotype. Hybridisation and potential for introgression pose a knotty problem for at-sea separation of *borealis* and *diomedea*, in particular in the western Mediterranean where hybridisation is known to occur. Further research is underway. For now, positive identification is best limited to 'classic' cases described above.

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Samenvatting
Status van Kuhls Pijlstormvogel in westelijk Middellandse Zeegebied Dit artikel bespreekt de status van Kuhls Pijlstormvogel *Calonectris borealis* in het westelijke Middellandse Zeegebied. Nieuwe gegevens tonen dat de scheiding tussen het broedareaal van Kuhls en de nauw verwante Scopoli's Pijlstormvogel *C diomedea* in het westelijke deel van de Middellandse Zee ligt en niet in de Straat van Gibraltar. Kleine aantallen Kuhls foerageren regelmatig langs de Spaanse oostkust en er zijn enkele gevallen van gemengde broedparen van Kuhls en Scopoli's in het westelijke Middellandse Zeegebied. Dit artikel presenteert en bespreekt deze nieuwe gegevens, gaat kort in op hybridisatie en genetische introgressie en vat de criteria samen voor de herkenning van Kuhls en Scopoli's, zowel in de hand als op zee.

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