Occurrence and identification of the Band-rumped Storm-Petrel (*Oceanodroma castro*) complex off North Carolina

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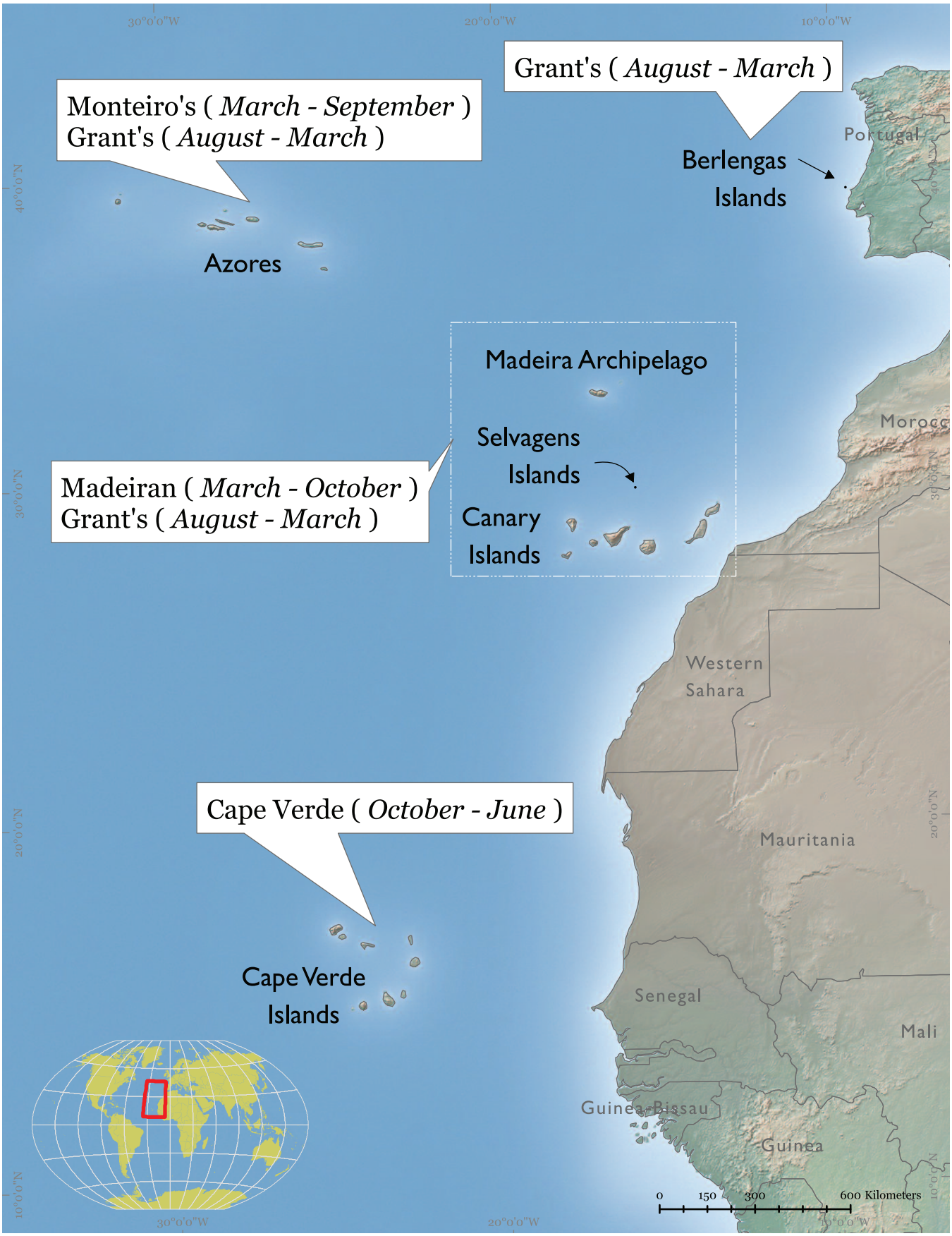
Figure 1. Type 1 (presumed Grant's) Band-rumped Storm-Petrel off Hatteras, North Carolina, 27 May 2009. A typical individual at this season, with obvious molt in the middle primaries (p1–p3 are new, p4 growing, p5 shed, and p6–p10 old; note that p10 on storm-petrels is distinctly shorter than p9, and often covered by it). *Photograph by Steve N. G. Howell.*

Abstract

This paper discusses seasonal occurrence patterns and provisional identification criteria for members of the Band-rumped Storm-Petrel (*Oceanodroma castro*) complex observed off North Carolina, where the authors studied and photographed this species extensively, 2007–2010. Recent published research on this complex indicates that it includes numerous taxa, perhaps as many as ten worldwide; in the past few years, several of these have been described as distinct species. Our study of molt in Band-rumped Storm-Petrels off North Carolina suggests that at least two types are present in pelagic Gulf Stream waters. We present evidence that most individuals observed are from a winter-breeding population, with a smaller number likely from a summer-breeding population. We infer that the larger and more numerous type corresponds to the undescribed winter-breeding population that nests from the Azores to the Canary Islands, which has been called Grant's Storm-Petrel, whereas the smaller and less numerous type may be the recently recognized Madeiran Storm-Petrel (*O. castro* sensu stricto), breeding from the Madeiran archipelago south to the northeastern Canary Islands. Just as these taxonomic arrangements and nomenclature are provisional, so the identifications discussed herein are tentative.

Background

The Band-rumped Storm-Petrel (*Oceanodroma castro*) complex consists of an unresolved number of taxa that breed on islands in tropi-



Map 1. Map of the eastern North Atlantic islands (often called Macaronesia), showing the breeding distribution and breeding season of Monteiro's, Grant's, Madeiran, and Cape Verde Storm-Petrels, as defined by Robb et al. (2008), in the major island groups. *Map by Kei Sochi.*

Figure 2. Type 2 (possible Madeiran) Band-rumped Storm-Petrel off Hatteras, North Carolina, 7 June 2009. Compare small-headed and slim build with the chunkier and slightly paler presumed Grant's in Figures 1 and 3. This individual has recently completed primary molt and might be taken for a fresh-plumaged juvenile. Note, though, the relatively faded and worn greater coverts compared to the newer and blacker secondaries, and the contrast between the fresher, blacker secondaries and the older, browner inner primaries. Other images show the outer primaries to be slightly fresher and blacker than the inners. On a juvenile, all of the wing feathers would be of the same age and show similar degrees of wear and fading. The narrow faded "hindcollar" indicates that some nape feathers have not yet been molted. The dusky median line on the uppertail coverts could indicate that some of the coverts are not fully grown, although such markings appear more typical of possible Madeiran than of presumed Grant's (see Figure 10). *Photograph by Steve N. G. Howell.*

Figure 3. Type 1 (presumed Grant's) Band-rumped Storm-Petrel off Hatteras, North Carolina, 26 July 2009. Compare the large-headed and bulky build of this individual with the slighter and darker possible Madeiran Storm-Petrel in Figure 2. This bird appears to have recently completed primary molt but may still be molting inner secondaries and some rectrices (possibly accentuating the apparent tail notch). *Photograph by Kate Sutherland.*

cal and subtropical latitudes of the Pacific Ocean and eastern Atlantic Ocean. In older North American literature, Band-rumped Storm-Petrel (hereafter often referred to as "Band-rump," indicating the entire complex) was known as Harcourt's or Madeiran Petrel (or Storm-Petrel or similar variants); the latter name is still widely used in Europe to refer to the complex. Until recently, the prevailing view based on morphology has been that Band-rumped Storm-Petrel showed limited geographic variation and was best considered a monotypic species (Austin 1952, Harris 1969). Recent studies of vocalizations and genetics, however, have disproved this view (Monteiro and Furness 1998, Friesen et al. 2007, Smith and Friesen 2007, Smith et al. 2007, Robb et al. 2008, Bolton et al. 2008). Some authors have further suggested, based on genetics, that the Band-rumped Storm-Petrel complex comprises an old lineage that is distinct enough from other storm-petrels to warrant a separate genus, *Thalobata* (Penhallurick and Wink 2004; but see Rheindt and Austin 2005).

In terms of regular North American occurrence, the North Atlantic populations of Band-rumped Storm-Petrel are almost certainly the ones responsible for records in eastern North America. Pacific populations of Band-rumps are not known to range near the waters of the U. S. West Coast, although vagrants are always a possibility. The most accessible treatment of North Atlantic types is that by Robb et al. (2008), who recognized four as breeding in the North Atlantic (Map 1); three of these have taxonomic standing at present. We follow this treatment here, while acknowledging that more work is needed on this complex and that there may not be full concordance between vocal and genetic data (Friesen et al. 2007, Robb et al. 2008). Likewise, our conclusions must be viewed as provisional and in some cases conjectural (Figures 1-3). We believe, however, that there is value to summarizing our observations as a starting point for discussion, and we encourage similar studies to be made elsewhere in the North American range of Band-rumped Storm-Petrel. In addition to the following four types, there are two or more Atlantic populations of Band-rumps breeding in equatorial and tropical southern latitudes on the islands of Ascension and St. Helena (Bennett et al. 2009), and birds possibly breeding on islets off São Tomé, in the Gulf of Guinea (Williams 1984).

Grant's Storm-Petrel (not formally described; see Robb et al. 2008) breeds widely from the Azores south and east to the Canary Islands; egg laying is mainly in October–November and young fledge mainly in March–April. The at-sea non-breeding range includes the Gulf of Mexico, based on a banded bird from the Azores recovered off Florida (Woolfenden et al. 2001).

Monteiro's Storm-Petrel (*O. monteiroi*; formally described in Bolton et al. 2008) breeds locally in the Azores; egg laying is in May–June and young fledge by early October. The at-sea non-breeding range is unknown; Bolton et al. (2008) suggest that the species may remain in the vicinity of its breeding grounds throughout the year, based on two late October and one mid-November records from the Azores.

Madeiran Storm-Petrel (*O. castro*) breeds from the Madeiran archipelago south to the northeastern Canary Islands; egg laying is mainly in June–July and fledging in mid- to late October. The at-sea range is unknown. A potential source of confusion, Bolton et al. (2008) call the winter-breeding Band-rumps (i.e., Grant's) in the Azores "Madeiran Storm-Petrel," the English name that Robb et al. (2008) give to this smaller, summer-breeding taxon.

Cape Verde Storm-Petrel (*O. jabejabe*) breeds in the Cape Verde Islands, where egg laying may occur mainly in October–November and February–May (Hazevoet 1995). This bimodal laying suggests that two seasonal populations could be involved, but no studies have been conducted that would reveal differences between them, and Robb et al. (2008) indicate that vocalizations sound similar from October through June. Hazevoet (1995) suggested that the species may be dispersive rather than truly migratory, and Band-rumps

that occur off western Africa may be of this species, but more research is needed in the Cape Verde Islands and on São Tomé.

Estimating the populations of nocturnal-breeding seabirds is notoriously difficult. Breeding populations for the above four types have been estimated at 3000-5000 pairs for Grant's, 250-300 pairs for Monteiro's, 2000-4000 pairs for Madeiran, and 1000 or so pairs for Cape Verde (Hazevoet 1995, Bolton et al. 2008, Robb et al. 2008). Given the frequency with which Band-rumps are seen off the East Coast and in the Gulf of Mexico, at least some of these numbers may be significant underestimates.

Molt Timing

On current knowledge, identification of the different types of Band-rumped Storm-Petrels known to breed in the eastern North Atlantic is feasible only with vocalizing birds on the breeding islands (Robb et al. 2008). Only very recently have authors begun to attempt distinguishing these types at sea, and the field identification criteria are still being developed (Robb et al. 2008). Even with good field studies and photographs, it may be the case that identification of some individuals, or indeed of some taxa altogether, will ultimately not be possible in the field.

Nonetheless, because different types breed at different seasons, and because wing molt and breeding do not overlap appreciably, molt timing may provide a clue to the identity of adult Band-rumps seen off the East Coast. Storm-petrels have one complete molt per year, and their wing molt is often protracted over the five to seven months between breeding attempts. As in most birds, wing molt in storm-petrels starts with the innermost primary (p1) and proceeds sequentially outwards to the outermost primary (p10). Also as in many species, the short inner 2-3 primaries of storm-petrels may be shed almost synchronously and grow in fairly quickly (Howell 2010; Howell, unpubl. data). Based on observations off North Carolina in May–June, p5–p6 of Band-rumps can be shed while p4 is still growing, producing obvious gaps in the wing on many birds (Figures 1, 4). As p7 and p8 grow, the rate of old feather shedding slows, so that p8 and p9 are not shed before the adjacent feather is mostly grown, sometimes making it difficult to detect wing molt (Figures 5-8). We have seen very few birds with only p10 retained, and observations of several with p9 and p10 both growing (Figure 9) indicate that the outer 2 primaries can be molted in fairly quick succession. Molt of the secondaries starts with a group of middle feathers (and possibly the tertials), and the outer 4 secondaries (s1–s4) are not renewed until molt has progressed outward through the middle primaries. Tail molt in Band-rumps off North Carolina appears to occur during or following molt of the outer primaries (pers. obs.; Lee 1984), as occurs with Wilson's Storm-Petrel (*Oceanites oceanicus*) (Howell, unpubl. data).

Among populations of Band-rumped Storm-Petrel in the Azores, wing molt of both adult Monteiro's and adult Grant's starts toward the end of their respective breeding season and completes by the start of the next (Bolton et al. 2008). Thus, in breeding Monteiro's, primary molt spans early August to mid-May, mainly August–March. In breeding Grant's, primary molt spans late January–mid-October, with most birds molting during March–August. Consequently, adult Monteiro's are starting primary molt when Grant's are finishing it, and vice-versa. In terms of their breeding cycles, primary molt in Grant's and Monteiro's begins when chicks are well grown and ends before egg laying, which is similar to the relationship of wing molt and breeding in Leach's Storm-Petrel (*Oceanodroma leucorhoa*) and Ashy Storm-Petrel (*O. homochroa*) in California, whose molt spans roughly late August–early April (Ainley et al. 1976).

A complicating factor is that non-breeding immatures probably have a different molt schedule than breeding adults. In most tropical and subtropical tubenoses, and even in many temperate species, the wing molt of immatures usually starts 1-2 months earlier than that of breeding adults and also concludes earlier, because immatures are not involved in breeding activities.

For example, in Leach's Storm-Petrel, a species whose summer breeding season is similar to that of Monteiro's Storm-Petrel, year-old birds start their second prebasic wing molt in late May–June and complete it by early winter (Crossin 1974; Howell, pers. obs.). This offset in molt timing may also hold for summer-breeding Band-rumps. Thus, a provisional second prebasic molt schedule for Monteiro's would be starting in May–June and ending in October–December. If a similar off-

Figure 4. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 23 May 2009. Another typical individual. Compared to the bird in Figure 1, p4 is longer and p6 has also been shed. *Photograph by Steve N. G. Howell*.

Figure 5. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 30 May 2010. Another typical individual at this season, with p6 mostly grown, p7 shed, and p8-p10 old. Note the fine dusky bars on the white rump patch, typical of fresh plumage. *Photograph by Steve N. G. Howell*.

Figure 6. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 23 May 2009. As molt progresses farther out in the primaries, the feathers are shed more slowly and molt gaps become harder to detect; p8–p10, and their coverts, are yet to be shed. Also note the narrow paler hindcollar of faded old feathers. *Photograph by Steve N. G. Howell.*

Figure 7. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 28 June 2009. On this bird, only p9–p10 are still old, but at a distance it could appear full-winged and not in molt. ***Photograph by Kate Sutherland*****.**

Figure 8. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 7 June 2009. At a distance, this bird appeared not to be molting, but closer views show that p9-p10 are old. Careful examination reveals that the inner primaries, probably renewed three months or so before this photograph was taken, are subtly brown and faded relative to the newer and blacker middle primaries and outer secondaries, although this may not be apparent in this reproduction. ***Photograph by Steve N. G. Howell*****.**

Figure 9. Unidentified Band-rumped Storm-Petrel off Hatteras, North Carolina, 28 May 2009. The relatively advanced primary molt on this date, with p9–p10 growing, may indicate a winter-breeding bird (Grant's?) completing second prebasic molt, or an older bird of a summer-breeding population (cf. Figures 10-11). ***Photograph by Steve N. G. Howell.***

set occurs in winter-breeding populations, then Grant's may undergo their second prebasic wing molt mainly between December and June. We emphasize that these timings for immatures are conjectural, and that molt periods and molt duration can also be affected by seasonal and interannual differences in food supply, migration distances, and simply individual fitness and foraging experience.

Because Madeiran Storm-Petrel is a summer breeder (averaging about a month later than Monteiro's), its wing molt schedule is likely similar to or slightly later than Leach's (and Monteiro's?). Thus, wing molt may span September–June in adults, and perhaps July–January in first-years, with molt aligning progressively with adult timing during the subsequent immature years.

Given similar egg-laying regimes, molt timing in winter-breeding Cape Verde Storm-Petrels may be similar to Grant's, whereas spring-breeding Cape Verdes are likely to have a molt schedule more similar to Monteiro's, Madeiran, and nominate Leach's.

A further complication is that newly fledged young from winter-breeding populations are in fresh plumage at a time when adults of summer-breeding populations are also in fresh plumage, and the reverse applies to summer juveniles and winter-breeding adults. Moreover, year-old birds (as with first-summer Leach's in May–June) are likely to be full-winged but with fairly uniform, somewhat worn remiges, before they commence their second prebasic molt. Thus, although the presence of wing molt may be informative, absence of wing molt may not be.

Good photographs can help in evaluating the age of fresh-plumaged and full-winged birds (Figures 10-13). Juveniles have uniformly fresh flight feathers, although the secondaries can appear blacker than the primaries, depending on the angle of the light. In first-summer Leach's (and presumably in summer-breeding Band-rumps), the remiges appear fairly uniform, but the outer primaries (which are the most exposed feathers) can be somewhat worn or faded at the tips relative to the inners. Fresh birds of older age classes often show a subtle contrast between fresher and blacker outer secondaries and older and browner inner primaries (reflecting the time differential of when these feathers were molted). They can also show one or more points of contrast within the secondaries (between fresher and older feathers, especially between a blacker s4 and a browner s5) and a gradation in wear among the primaries from older and browner inners to newer and blacker outers (i.e., the reverse of worn juveniles).

To document molt timing, we photographed as many Band-rumped Storm-Petrels as we could off Cape Hatteras, North Carolina, during 2007–2010. Our largest samples are from late May to early June, when most pelagic trips were conducted (30 birds in 2007, 55 in 2008, 115 in 2009, 68 in 2010; Figure 14). We also scored wing molt on 43 individuals photographed from late July through mid-August, 2007–2009 (Figure 15).

Most Band-rumps off North Carolina in May–June were in mid-primary molt, whereas a minority showed no signs of wing molt (Figure 14). The proportions of spring birds at different wing-molt stages were broadly similar in all four years, with about 80-90% showing molt of middle through outer primaries (usually with 3-5 old outer primaries remaining) and about 10-20% being full-winged or just completing molt of the outermost primary (Figure 14). The majority of late summer Band-rumps were completing wing molt or in fresh plumage (Figure 15), and thus appeared to represent a continuation of molt schedules noted in spring.

Of 28 non-molting Band-rumps seen in late May–early June, none of the 15 photographed well appeared to be a uniformly fresh juvenile (i.e., from a winter-breeding population). Further work is needed to establish whether juveniles from winter-breeding populations occur off North Carolina and when they might arrive. Three birds appeared to be uniform and slightly worn (Figure 12), similar to first-summer Leach's, and thus were likely year-old Band-rumps from summer-breeding populations. The other 12 full-winged birds were in fresh plumage and apparently had completed molt fairly recently, as would have soon been the case for 9 others that were concluding molt with growth of p10. These birds are discussed below.

Measurements and Plumage Criteria

Comparable measurements for all types of Band-rumps (that is, made by the same workers using the same methods) are unavailable (Table 1). Some measurements of Monteiro's and Grant's Storm-Petrels show statistically significant differences at the

Figures 10-11. Possible Madeiran Storm-Petrel off Hatteras, North Carolina, 21 May 2009. This bird is completing molt of its inner secondaries as well as p10 (apparent in other photographs). Note the contrast between fresher outer secondaries and faded inner primaries, and the subtle gradation from faded inner to fresher outer primaries (the apparent "step" between p7 and p8 represents an anomaly with p7, which is relatively short and brown). This bird might be a first-year Grant's Storm-Petrel, but we suspect it is more likely a non-breeding Madeiran Storm-Petrel (the squared tail would be atypical of Monteiro's). Black spots in the uppertail coverts may be more frequent in Madeiran than in Grant's (also see photograph on page 246 of Robb et al. 2008, which looks similar to Figure 10). Note how this individual's overall structure and plumage tones appear quite different in the two photographs, highlighting the dangers of relying on a single image for evaluating general structure. *Photographs by Steve N. G. Howell*.

population level, but all measurements also show considerable overlap (Monteiro and Furness 1998, Bolton et al. 2008; Table 1). Winter-breeding Grant's averages heavier, larger-headed, and larger-billed than summer-breeding Monteiro's and Madeiran (Bolton et al. 2008, Robb et al. 2008; Table 1), Monteiro's is relatively light-bodied but long-winged and long-tailed, and Cape Verde birds are relatively long-billed (Table 1).

One feature that has been suggested as possibly useful in the field is tail fork length, although this overlaps among types (Table 1). We have no measurements of tail fork for Cape Verde Storm-Petrel, but it may have a fairly squared tail tip (Robb et al. 2008), and thus could appear similar to Grant's. Good views are needed to evaluate tail fork, and apparent fork length varies greatly with angle of viewing, with how the tail is held, with the state of molt, and perhaps even with age (Figures 16-20). For example, the photographs of presumed Monteiro's at sea in Robb et al. (2008) show little evidence of a tail fork and look much like most Type 1 birds (see below) off North Carolina, which are ostensibly square-tailed.

As with taxa in the Leach's Storm-Petrel complex, however, conventional measurements (such as wing, tail, tarsus, and even tail fork) may not convey differences that are apparent when viewing birds in the field or even when comparing specimens (Figure 21). Off North Carolina in May–June, we frequently distinguish two types of Band-rumped based on molt timing and plumage state, in combination with overall structure and plumage pattern. Type 1 birds (in obvious wing molt) often appear slightly larger and bulkier, with a relatively large head, stout bill, and broad wings, whereas Type 2 birds (non-molting) often appear rather lightly built with a relatively small head, fine bill, and narrow wings (Figures 1-3). Type 2 birds typically appear blacker overall, which in May–June is often exaggerated in contrast to the faded brown or gray-brown of the more numerous Type 1 birds. This

Table 1. Comparative selected measurements (in millimeters, except for mass, in grams) for North Atlantic types within the Band-rumped Storm-Petrel complex. Methods probably differ somewhat between sources (e.g., wing length of Murphy likely unflattened chord, but flattened and perhaps straightened by other workers), and several sources unhelpfully provide only statistically significant means, with standard deviations. Values represent mean plus/minus standard deviation, with absolute range and sample size provided parenthetically when available.

	Grant's	Madeiran	Monteiro's	Cape Verde
Culmen	15.2±0.5[1] (n=76)	14.9±0.5[1] (n=86)	14.6±0.6[2] (n=221)	16.0[6] (15–17, n=12)
	15.0±0.5[2] (n=645)	14.7±0.6[4] (13.4–15.8, n=72)	14.6+0.6[3] (13.3–16.6, n=207)	
	15.0±0.5[3] (13.3–16.6, n=117)			
Wing	154.7±4.0[1] (n=76)	150.5±3.4[1] (n=86)	157.7±3.6[2] (n=226)	149.2[6] (142–157, n=12)
	157.6±3.2[2] (n=729)	150.6±3.5[4] (141–158, n=72)	159.2±3.6[3] (150–169, n=209)	
	158.4±3.5[3] (149–166, n=129)			
Tail	73.1±3.0[2] (n=647)	66.0±2.1[4] (62–71, n=72)	75.3±2.7[2] (n=217)	69.2[6] (64–74)
	72.4±2.5[3] (66–79, n=124)		74.7±3.3[3] (62–84, n=206)	
Tail fork	5.6±1.7[2] (n=70)	5-10[5] (n=10)	8.0±2.8[2] (n=128)	-
	3.5±1.5[3] (0–7, n=124)		7.8±2.3[3] (1–14, n=205)	
Mass	49.1±4.3[2] (n=662)	45.2±4.0[4] (35–55, n=72)	44.0±4.5[2] (n=206)	-
	47.3±3.1[3] (38.5–55.1, n=115)		44.6±4.0[3] (34.8–56.1, n=227)	

[1]Nunes 2000 (Desertas Islands, Madeira), [2]Monteiro and Furness 1998 (Azores), [3]Bolton et al. 2008 (Azores), [4]Robertson and James 1988 (Great Salvage Island), [5](British Museum specimens, Madeira), [6]Murphy 1924.

Figure 12. Unidentified Band-rumped Storm-Petrel off Hatteras, North Carolina, 5 June 2010. The relatively uniform-looking but slightly faded remiges, the bleached, contrastingly pale upperwing band, and the broken-tipped outer rectrices (shown better in other images) suggest these are worn juvenile feathers, pointing to this being a first-year bird from a summer-breeding population, possibly a Madeiran Storm-Petrel (cf. Figures 19-20). *Photograph by Steve N. G. Howell.*

Figure 13. Unidentified Band-rumped Storm-Petrel off Hatteras, North Carolina, 28 May 2010, with Wilson's Storm-Petrel behind. This bird is still growing p10 and thus completing its prebasic molt into fresh plumage; other images show wear contrasts among the secondaries, confirming it is not a juvenile. Whether it is an "adult" from a summer-breeding population or a bird in second basic plumage from a winter-breeding population is unknown. *Photograph by Steve N. G. Howell.*

difference is not due simply to fresh versus worn plumage, however, for in late summer, when Type 1 birds have molted into fresh plumage, they still appear slightly paler and grayer overall. Interestingly, such differences in structure and plumage tones recall those between the smaller and darker summer-breeding Townsend's Storm-Petrel *O.* [*leucorhoa*] *socorroensis* and the larger and paler winter-breeding Ainley's Storm-Petrel *O.* [*leucorhoa*] *cheimomnestes* in the eastern Pacific (Howell et al. 2010).

Based on a small sample studied in spring 2007 off North Carolina, Howell provisionally considered that molting Band-rumps comprised birds in more advanced wing molt, with a shorter white rump "band," and birds in less-advanced wing molt, with a longer white rump band (photographs published in Robb et al. 2008, p. 236). However, our samples of 2008 through 2010 do not support a correlation between the extent of the white band and primary molt timing. Given the great variation in rump pattern exhibited by the single subspecies of Leach's Storm-Petrel in the North Atlantic (Flood 2009), perhaps it is unsurprising that any given type of Band-rump could also be quite vari-

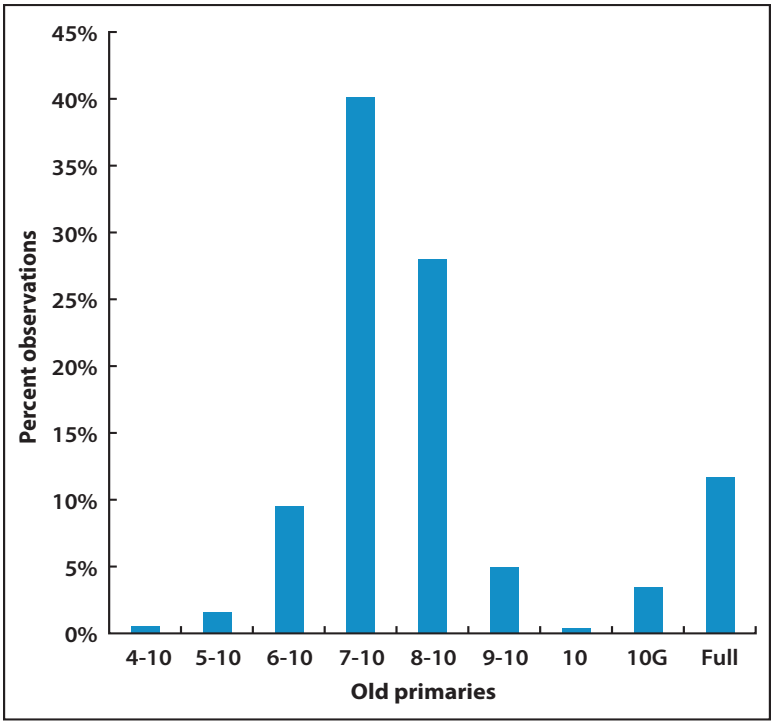


Figure 14. Percentages of 268 Band-rumped Storm-Petrels at different stages of primary molt off North Carolina, 21 May–7 June (2007 through 2010); *10G* indicates p10 still growing; *Full* indicates that all primaries appeared full-grown, with molt completed. Note the break in distribution into two groups: presumed winter breeders with mid-primary molt, and possible summer breeders in fresh plumage or completing molt with growth of p10. All years are combined in the figure, but the bimodal division was apparent in each year.

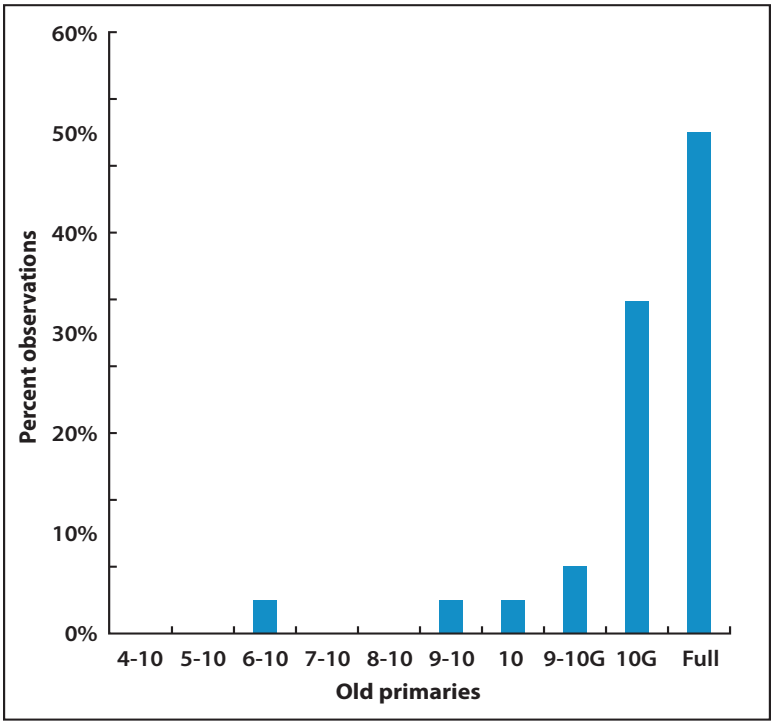


Figure 15. Percentages of 30 Band-rumped Storm-Petrels at different stages of primary molt off North Carolina, 25 July to 17 August (2007-2009); *9-10G* indicates p9 and p10 both growing, *10G* indicates p10 still growing; *Full* indicates that all primaries appeared full-grown, with molt completed, though one bird observed in mid-August appeared to have p1 shed; see text. Note how molt of presumed winter breeders (about 90% of individuals represented) progresses from the late May–early June period (see Figure 14) to the late July–mid-August period.

able, although average differences may occur between types. For example, the Type 1 birds tend to have broader rump bands than Type 2 birds and less often have scattered black spots in the white (black spots on 15% of 35 Type 1 birds in mid-primary molt, versus on 70% of 14 fresh Type 2 birds), but there is overlap in these features. Moreover, black spots surrounded by white may sometimes simply reflect incompletely grown tail coverts, which could be expected on birds completing their molt.

Further work based upon birds of known species is needed to elucidate any differences in structure, plumage, or flight manner that could aid in at-sea identification.

Which Band-rumped Storm-Petrels occur off North Carolina?

While today we take for granted the occurrence of Band-rumped Storm-Petrels over warm, deep waters off the East and Gulf coasts, it was not until the pioneering work of birders and of researchers such as David Lee and others in the early 1980s that Band-rumps were found to be a regular component of the North American avifauna (Lee 1984, Haney 1985). Most North American records fall between April and September, and Band-rumps occur regularly off the East Coast north at least to the Carolinas, as well as through the Gulf of Mexico west to Texas (Lockwood and Freeman 2004).

Records off North Carolina are known from mid-May through late August (Lee 1984, Patteson and Sutherland 2009). Although Band-rumps might also occur earlier in May (and even in April), few trips to the Gulf Stream are conducted at these times; Haney (1985) detected the species as early as 29 April off Florida's Atlantic coast. The largest numbers occur from mid-June through mid-August, when upwards of 20 individuals and exceptionally as many as 234 (6 August 2000; Davis 2001) can be seen on a day trip. Although Band-rumps are undocumented in North Carolina's offshore waters after August, Haney (1985) detected the species through 4 September off Florida, and there are later specimens for Florida, including one as late as 6 December (Stevenson and Anderson 1994; see below). There are also many September records from inshore waters and inland locations in the eastern United States, e.g., 30-70 individuals from sites in North Carolina, Virginia, the District of Columbia, New Jersey, Pennsylvania, and possibly New York following Hurricane *Isabel* in 2003 (Davis et al. 2004) and 8 between North Carolina, Virginia, and Pennsylvania after Tropical Storm *Ernesto* in 2006 (Davis et al. 2007). For such storm-related birds, the points of entrainment are obviously unknown, and the birds may well have been swept up from points southward. Conceivably, onshore and inshore September records represent different taxa than those collected and observed from May through August off North Carolina: September tropical cyclones frequently develop around the Cape Verde Islands, thus the term "Cape Verde hurricanes."

Which Band-rumps occur off North Carolina? Given our assumptions about molt timing in the different types (outlined above), it follows that Type 1 Band-rumps off North Carolina are on a winter-breeding molt schedule, as has been suggested for molting birds in the Gulf of Mexico (Woolfenden et al. 2001, Bolton et al. 2008). Specimen data (Lee 1984) and our observations later in the year indicate that most Band-rumps off North Carolina complete their primary molt in July–August, in accord with the return of winter breeders to their colonies in August–September. So would these winter breeders be Grant's, or Cape Verde, or both?

The relative proximity and abundance of Grant's Storm-Petrel as a breeding bird, and specimen confirmation that this type occurs in the Gulf of Mexico, suggests that most Band-rumps visiting North Carolina waters are more likely to be Grant's (our Type 1). While it is possible that Cape Verde Storm-Petrels occur off North Carolina, their identification at sea, as with Grant's, is not yet possible. It may be that this Cape Verde Storm-Petrel does not normally range as far north and west as North American waters, which appears to be the case with Cape Verde Shearwater (*Calonectris edwardsii*), for instance, which appears to be extremely rare in North American waters. Because we can neither rule in Grant's with certainty, nor rule out Cape Verde Storm-Petrel (or even the presence of both), our treatment of winter breeders off North Carolina remains hypothetical. Moreover, juveniles from winter-breeding populations could occur in North American waters, though we are not aware of any records, which will require good-quality photographs or in-hand examination. Preparation of the 15 North Carolina specimens taken at sea indicated

Figure 16. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 2 June 2009. Compare the even-edged or slightly rounded spread tail with the partially closed tail a second later, in Figure 17. This individual's wing molt is slightly asymmetrical, with four old primaries remaining on the right wing, five on the left. ***Photograph by Steve N. G. Howell.***

Figure 17. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 2 June 2009. The same bird as Figure 16, a second later, showing how the slightly closed and concave tail can appear slightly notched. ***Photograph by Steve N. G. Howell.***

Figure 18. Presumed Grant's Storm-Petrel off Hatteras, North Carolina, 27 May 2009. The apparent tail notch shown by this bird may simply reflect the angle from which the slightly closed, concave tail is viewed. ***Photograph by Steve N. G. Howell.***

Figure 19. Unidentified Band-rumped Storm-Petrel off Hatteras, North Carolina, 21 May 2007. This individual really does seem to have a distinctly notched tail, with the outer rectrices appreciably longer than the inners. Although its wing-molt timing fits with Grant's, could some immature Monteiro's (which have the deepest tail notch of North Atlantic Band-rumpeds) be molting at this time? This and the bird in Figure 20 are the only two molting spring birds we have photographed with a distinct tail fork. *Photograph by Steve N. G. Howell*.

Figure 20. Unidentified Band-rumped Storm-Petrel off Hatteras, North Carolina, 30 May 2010. This distinctive-looking individual stands out as having relatively narrow wings and a deeply forked tail, which are shown well in a series photographs from different angles and not simply artifacts of this single photograph or of tail molt. A tail fork this pronounced may rule out Grant's and point to Monteiro's. Might first-summer Monteiro's molt earlier than first-summer Madeiran (cf. Figures 12 and 19)? As is so often the case, more work is needed. *Photograph by Steve N. G. Howell*.

Figure 21. Specimens of Band-rumped Storm-Petrel of undetermined identity collected off North Carolina, housed at North Carolina Museum of Natural Sciences (NCSM), Raleigh. From left to right, NCSM 9536 (male, 5 July 1983; wing molt completed, tail molt completing), NCSM 10369 (female, 31 July/9 August 1984; p9-p10 growing), NCSM 13860 (female, 21 June 1985; p8–p10 old), and NCSM 13861 (male, 24 June 1985; p8–p10 old). Besides its different molt schedule, note how the left-hand skin (possibly Madeiran) appears smaller and blacker than the other three (presumed Grant's). *Photograph by Steve N. G. Howell*.

Table 2. Specimens of Band-rumped Storm-Petrel recovered on land in North America, in chronological order[†]

Location	Date	Source (and/or specimen number)
Navy Yard Bridge, DC	Aug 1893	Palmer 1897
Capitol Hill, DC	Aug 1893	Palmer 1897
Morgan County, IN	Jun 1902	Butler 1906
Ottawa, ON[1]	Aug 1933	Taverner 1934a, 1934b
Hidalgo County, TX[2]	Jun 1954	Oberholser 1974
Monroe County, FL	Oct 1958	Sprunt 1963
Kleberg County, TX	Jul 1968	*fide* M. Lockwood [TAMU-K 299]
Kleberg County, TX	Jun 1969	*fide* M. Lockwood [WWF 1908]
Escambia County, FL	Aug 1969	Stevenson and Anderson 1994
Carteret County, NC	Jun 1972	Fussell 1974
Charleston County, SC[3]	Jun 1972	Shuler 1973
Sevier County, TN[4]	Sep 1975	Eller 1976 [USNM 52639]
Brazoria County, TX	Jul 1976	Brooks and Arnold 2003
Pinellas County, FL	Oct 1977	Stevenson and Anderson 1994
Nueces County, TX	May 1989	*fide* M. Lockwood [CWC 12440]
Escambia County, FL	Jul 1991	Woolfenden et al. 2001 [tissue; FMNH]
Anderson County, KY	Jul 1994	Palmer-Ball 1996
Polk County, NC	Aug 1994	Davis 1995
Escambia County, FL	May 1997	Woolfenden et al. 2001 [at FMNH]
Escambia County, FL	May 1997	Woolfenden et al. 2001 [at FMNH]
Escambia County, FL	Jul 1997[5]	*contra* Woolfenden et al. 2001 [GEW 5939]
Beaufort County, SC	Jun 1999	W. Post, pers. comm. [ChM 1999.02.061]
Norfolk County, ON	Jul 2000	Crins 2003 [ROM 67110]
Escambia County, FL	Apr 2004	UF 44558 (includes skeleton)
Nelson County, VA	Sep 2004	Day 2005
Franklin County, KY	Aug 2005	Monroe et al. 2006
Escambia County, FL[6]	Apr 2006	Steadman 2006
Pinellas County, FL	Aug 2008	B. Anderson, pers. comm. [not accessioned]

[†]This list does not include discarded or lost specimens, skeletons, or the many birds observed alive in association with tropical cyclones; a well-documented sight record of a Band-rumped Storm-Petrel from 14 June 1984 at Lake Mitchell, Bexar County, Texas (Lasley and Sexton 1985) shows no obvious meteorological connection (as is true of the Indiana specimen and several from western Florida).
[1]This bird was preserved both as specimen (CMNAV 25668) and skeleton (CMNAV S716).
[2]In addition to this preserved specimen from 25 June, two others were noted from the same location on this date.
[3]Lee (1984) notes that this specimen (ChM 1972.37) strongly resembles the 5 July North Carolina specimen (NCSM 9536) in molt and in overall size and weight, thus possibly also a candidate for Madeiran Storm-Petrel (*O. castro* sensu stricto), not yet verified in North America. See NCSM 9536 in Figure 21, at left.
[4]One 26 September specimen preserved; two further individuals were found "dead or dying," also in the Great Smoky Mountains National Park, on 24 and 25 September; however, these carcasses were buried (C. Sloan, pers. comm.).
[5]Woolfenden et al. (2001) give the year as 1991 for this specimen, but tag data indicate that 1997 is correct (R. Bowman, R. Boughton, pers. comm.). This bird wrecked during Hurricane *Danny* (Pranty 1998).
[6]A 13 April 2003 specimen from Escambia County (Pranty 2003) cannot be located at present (T. Webber, pers. comm.).

that not one was a juvenile (Lee 1984), a finding that agreed with Howell's review of the plumage of these specimens.

What of the 10-20% of spring birds off North Carolina that are in fresh plumage or completing wing molt? Are these from summer-breeding populations? Given that thousands of Cory's Shearwaters (*Calonectris* [*diomedea*] *borealis*) from summer-breeding populations in the eastern Atlantic occur in summer off North Carolina, as well as non-breeding Leach's Storm-Petrels and Manx Shearwaters (*Puffinus puffinus*), it would not be surprising if small numbers of Madeiran and Monteiro's Storm-Petrels occurred as well. While the known breeding population of Monteiro's is small, it is surely much larger than that of Swinhoe's Storm-Petrel (*O. monorhis*) in the North Atlantic; there have been four summer records of Swinhoe's off North Carolina in recent years (Patteson et al. 2009).

As with non-breeding Leach's Storm-Petrels, Madeiran and Monteiro's off North

Carolina in May–June would likely comprise worn juveniles (some perhaps starting primary molt) and fresh-plumaged older birds, perhaps including some still completing molt in May–June. Based upon larger population size, it seems more likely that summer-breeding Band-rumps off North Carolina in spring (our Type 2) would be mainly Madeiran. The photograph of a presumed Madeiran in Robb et al. (2008) matches well many of the Type 2 birds we see off North Carolina (cf. Figure 10).

A possible complication is that some immature Grant's (and Cape Verdes) might complete their first wing molt in May–June, when non-breeding adult Madeiran (and Monteiro's) could also be completing wing molt. For any individual bird, distinguishing between a year-old Grant's (or winter-breeding Cape Verde) and an older Madeiran (or Monteiro's) may not be possible. Thus, fresh-plumaged birds in May–June could include both first-year Grant's Storm-Petrels (which may be slightly larger, bulkier, larger-headed, stouter-billed, and paler overall; Figures 1, 3) as well as adult and first-summer Madeiran Storm-Petrels (which may be slightly smaller, lighter in build, smaller-headed, finer-billed, and darker overall; Figure 2).

Interestingly, of the 15 Band-rumped specimens at the North Carolina Museum of Natural Sciences, one from 5 July is in fresh plumage, thus out of sync with the other birds, as noted by Lee (1984; Figure 21). This specimen is also smaller overall and darker than the others and has a narrower white rump patch; whether it is a first-year Grant's or an older Madeiran might be determinable through genetic analysis. Based on the incongruity of this specimen with the others in the North Carolina collection, Lee (1984) wrote: "A larger series of western North Atlantic birds would be useful, but these specimens strongly suggest that two or more breeding stocks occur off the North Carolina coast."

Genetic analysis of North American specimen material would be of interest; the number of specimens from North America has more than doubled in the decades since Lee's research. In North American museum collections, at least 28 individual Band-rumped Storm-Petrels taken on land are now represented in collections (Table 2), mostly salvaged following the passage of tropical cyclones that make landfall and move inland (cf. Clapp et al. 1982); in two cases, tissue samples and their associated round skins are held at different institutions. Peterson (1980) also lists inland records of Band-rumped Storm-Petrels from Montana and Québec, but these appear to be in error (J. Marks, P. Bannon, pers. comm.). North American specimens taken at sea—in addition to the 15, plus one skeleton, at the North Carolina Museum of Natural Sciences—now include 27 from Louisiana's pelagic waters at the Louisiana State University Museum of Natural Science (all with associated tissue samples; D. Dittmann, pers. comm.); one in the National Museum of Natural History, a bird that was found on the deck of a research vessel anchored 115 kilometers east of Rehoboth, Delaware 14 August 1975 (Paxton et al. 1976; USNM 567674); one collected about 32 kilometers south of the Pensacola, Florida area 31 May 1993 (Woolfenden et al. 2001); one, noted above, that was caught by a fisherman off Pensacola, Florida 27 April 1998 and found to have been banded by Luis Monteiro on Praia Islet in the Azores in 1993 (Woolfenden et al. 2001; round skin is GEW 5940; associated tissue specimen is FMNH 395937, D. Stotz, pers. comm.); and one taken about 56 kilometers off Cape San Blas, Gulf County, Florida, on the late date of 6 December 1958 (Stevenson and Anderson 1994). Other specimens preserved as skeletons include one taken off Dare County, North Carolina 24 August 1985 (GEW 5797; R. Boughton, pers. comm.) and a partial skeleton from Mustang Island, Nueces County, Texas 14 May 1989 (TCWC 12877; B. Marks, pers. comm.).

There are two specimen records of Band-rumped Storm-Petrel that have been published but for which the specimens are no longer extant. One from Chambersburg, Pennsylvania (April 1912; Sutton 1927, Todd 1940) has been lost (McWilliams and Brauning 2000); and a specimen found in poor condition along the Lake Erie shoreline in Pennsylvania (February 1998; McWilliams 1998) was confirmed by David Lee and others as Band-rumped but apparently later discarded (G. McWilliams, pers. comm.). All Band-rumped Storm-Petrels salvaged as a result of tropical cyclones, or oil spills, could help to shed light on which types occur in North American waters; all should be deposited in museum collections whenever possible, including as tissue samples.

Exceptions and Conclusions

Only three individuals we have photographed off Hatteras are far enough outside the patterns described above to warrant specific comment. One on 22 May 2007 still had p4-p10 old, with p1 growing and p2–p3 shed (Figure 22). This may have been an early molting first-year bird from a summer-breeding population, or perhaps a late-molting adult from a winter-breeding population. Unfortunately, the photographs are not clear enough to allow objective evaluation of potential wear contrasts among the flight feathers, and the age of this bird is unknown.

Figure 22. Unidentified Band-rumped Storm-Petrel off Hatteras, North Carolina, 22 May 2007. This bird is growing p1 and has shed p2–p3, but p4–p10 are old and look fairly brown and uniformly worn, suggesting faded juvenile feathers. However, the photograph is not good enough to determine feather generations and wear gradients. Thus, whether this is an early molting first-year bird from a summer-breeding population, or a late-molting Grant's Storm-Petrel, or perhaps even a Cape Verde Storm-Petrel, remains unknown. ***Photograph by Steve N. G. Howell.***

Figure 23. Unidentified Band-rumped Storm-Petrel off Hatteras, North Carolina, 16 August 2009. This bird appears to have shed p1 on both wings and the contrast between blacker secondaries and paler primaries indicate it is not a first-year. If this bird really were starting primary molt in fall (a sharper image is needed to be certain), then its distinctly forked tail and broad white rump band suggest Monteiro's Storm-Petrel. ***Photograph by Steve N. G. Howell.***

Another, on 27 July 2007, was in mid-primary molt, with p6–p10 old, a molt stage similar to that of several presumed first-summer Leach's Storm-Petrels observed at the same season. We suspect this was a first-summer bird from a summer-breeding population, although the photograph is not good enough to confirm age.

An individual on 16 August 2009 appeared to have shed p1 on both wings, and the contrast between blacker secondaries and paler

primaries suggests it was not a first-year bird (Figure 23). If this bird were starting primary molt in fall, it would likely be a summer-breeding bird older than one year. Its distinctly forked tail, fairly stocky build, and large white rump band are all points that suggest Monteiro's Storm-Petrel rather than Madeiran, but its identity must remain conjectural. Late summer seems like the best time to readily pick out non-Grant's based on molt timing, and further observations are especially needed in July–September.

In summary, over 99% of the Band-rumped Storm-Petrels we see in May–June off North Carolina fall into two groups based on molt timing. Type 1 birds (80-90% of the total birds) are in obvious wing molt and presumably from winter-breeding populations, most likely Grant's Storm-Petrel. Type 2 birds (10–20% of birds) are not molting or are just completing wing molt. Within these non-molting birds are both fresh-plumaged and slightly worn individuals that we ascribe provisionally to a summer-breeding population, most likely Madeiran Storm-Petrel. Fresh-plumaged spring birds may also include individuals from a winter-breeding population, most likely Grant's Storm-Petrel, that have recently completed their second prebasic molt, and perhaps also recently fledged juveniles. Monteiro's and Cape Verde Storm-Petrels may also occur, but much more work is needed on establishing identification criteria.

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