SOOTY SHEARWATERS *PUFFINUS GRISEUS* IN THE NORTH ATLANTIC — MOULT STUDIES USING DIGITAL CAMERAS

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Received 25 May 2009, accepted 29 Dec. 2010

Studying moult in pelagic seabirds in a quantified manner is difficult, since moulting birds are largely at sea, away from the breeding grounds (Nelson 1980, Nettleship & Birkhead 1985). Birds found dead during beach patrols (Cooper *et al*. 1991) are often used for study, although such studies may be compromised by the fact that samples are small and may not be representative of the population. Digital photography of birds at sea, however, now offers the opportunity to quantify moult of flight feathers. As an example, I report on opportunistic observations of moulting Sooty Shearwaters *Puffinus griseus* in the Northeast Atlantic.

The study was carried out during a dedicated marine mammal survey of deep North Atlantic waters on board *R/V Mars Chaser*, from 5–30 July 2007, in the area west of Scotland and northwest Ireland, roughly between 52–61°N and 4–18°W. More than 3400 km of transects were covered in 290 h of observation, but attention could be paid to birds only during off-duty hours, and observations were thus limited and non-systematic.

Fig. 1. Moulting Sooty Shearwater, Rockall, 15 July 2005. The picture was taken with a Canon 300D camera with a telephoto zoom lens with focal length of 200 mm, aperture F5.0, ISO 400. In the left wing, primaries 1–5 have moult score 5 (new, fully grown), 6 = 4, 7 = 3, 8 = 2 and 10 = 0. Primary 9 is invisible, but cannot be anything else than score 1 or 2. The primary score in the right wing is virtually similar. The secondaries show at least two moulting centres (stepwise descendent moult), and the tail is also actively moulting. The variegated plumage on the back, rump, scapulars and upperwing is caused by old (rufous-brown) and new (dark brown) feathers. The white patches on the wings above the greater primary coverts are the bases of these coverts and possibly some downy feathers, visible because of the missing (growing) overlying median and lesser coverts. Photo Becci Jewel.

On 15 July we passed Rockall (57°35'48"N, 13°41'19"W), a rocky islet about 350 km west of the Scottish mainland. Here, a flock of about 500 Sooty Shearwaters was encountered, about half of which subsequently followed the ship for nearly an hour. The birds were photographed with digital cameras by several observers, and subsequent inspection showed that many were in active flight-feather moult (Fig. 1).

Sooty Shearwaters have a "normal" descendent primary moult (Cramp & Simmons 1977). Of 76 birds photographed well enough to see the primaries, 35 (46%) were in active primary moult. Primary moult was scored according to Ginn & Melville (1983) from the photographs of 27 individuals, all taken on 15 July. Of these, 15 were in active primary moult, with all 10 primaries visible in three birds, nine in three birds, eight in seven birds and seven in two birds. The moult scores of the invisible feathers were estimated. When a feather was hidden behind a covert, it was given a score 2. The resulting total moult score did not deviate more than three points from the real score.

The moult scores ranged from 32 to 43 (median 42). Twelve birds were definitely not actively moulting (moult score 0 or 50). Of the 12 birds not in moult, two were likely juveniles, as their plumage was very fresh, with no contrast in any visible feather tract (head, neck, back, rump, but especially upper wing-coverts and scapulars). The other birds had more variegated plumage, with a mixture of old and new feathers (Fig. 1) and were thus probably older. Among the birds in moult, two (10 birds), three (four birds) or four (one bird) primaries were growing at a time. The innermost growing primary was invariably almost fully grown (moult score 4).

Most Sooty Shearwaters sighted near Rockall still had yet to grow at least 10 "moult score points," equalling primaries 8–10 and representing almost 50% of the total primary mass (Cooper *et al*. 1991). The mean duration of a complete moult cycle is approximately 159 d (Cooper *et al*. 1991); hence, the "average" Sooty Shearwater in moult near Rockall had started its primary moult about 27 April and would finish it by 2 September. As Sooty Shearwaters can migrate quickly (Shaffer *et al*. 2006), this would seem to be well in time for them to reach their colonies in the South Atlantic. We cannot say whether the non-moulting birds had already moulted their primaries, or had yet to start moulting, although the latter seems unlikely.

Sooty Shearwaters washed ashore in South Africa had moulted their primaries between December and June (Cooper *et al*. 1991), the

majority in February–May, with a mean completion date of 10 June. Three birds moulting primaries in August were considered to be "outliers" and were excluded from their calculations. The authors assumed that the actively moulting Sooty Shearwaters in South African waters were "prebreeders and failed breeders."

Sooty Shearwaters commonly enter the North Atlantic after the breeding season (Cramp & Simmons 1977, Carboneras 1992), and as early as 30 years ago "concentrations on Rockall Bank and Faroese fishing grounds" were noted in late summer (Cramp & Simmons 1977). However, data on moulting individuals from the North Atlantic are surprisingly rare. A female found in western France on 1 November 1936 (Mayaud 1949) had a moult score close to 47, and only one of 603 individuals seen at sea on the Scotian Shelf off Atlantic Canada over 11 years was in moult (Brown 1988). Cooper *et al*. (1991) agreed with Brown (1988), who suggested that adult Sooty Shearwaters preferentially migrate into the North Pacific, whereas only "newly fledged juveniles [and] subadults that have already completed their moult before the start of migration" spend the austral winter in the northern Atlantic.

More probable than such a differential migrating route among age classes is a spatial segregation in wintering areas, with birds breeding in the South Pacific mainly migrating into the North Pacific (corroborated by Shaffer *et al*. 2006) and those of South Atlantic breeding grounds migrating into the North Atlantic. This is also supported by the few published records of ringing recoveries (see references in Cooper *et al*. 1991), with all occurring in the ocean of banding.

The recent opportunity to take numerous digital pictures of seabirds at sea and to scrutinize them afterwards on a computer screen gives unexpected opportunities for studying moulting seabirds. The use of digital cameras for up-close inspection of birds has already been described by Leary (2004) for waders, but as far as I know this is the first description of the use of digital photographs to study the moult of seabirds at sea.

ACKNOWLEDGEMENTS

I thank René Swift (University of St. Andrews, Scotland), the CODA-survey leader, and the captain and crew on the *R/V Mars Chaser*. Dr. Kelly MacLeod (University of St. Andrews, Scotland) was the overall organiser of CODA. My fellow observers generously shared their pictures with me. Becci Jewel is thanked for letting me use her picture. Steve Geelhoed commented on an earlier version.

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