The Wilson Journal of Ornithology

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C. Scott Weidensaul,[1,5] Bruce A. Colvin,[2] David F. Brinker,[3] and J. Steven Huy[4]

Published by the
Wilson Ornithological Society

The Wilson Journal of Ornithology 123(2):373–377, 2011

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ABSTRACT.—Use of ultraviolet (UV) light, which causes porphyrin pigments in feathers of some birds to fluoresce, provides a simple, effective means of distinguishing multiple generations of flight feathers in owls. This permits easier and more accurate classification of age of adult owls. This lighting technique has been used extensively with Barn Owls (*Tyto alba*) and Northern Saw-whet Owls (*Aegolius acadicus*) and works well on a variety of owl species at night in the field, and should have wide applicability among owl researchers. The relative ages of the feathers can be easily distinguished by the intensity of fluorescence they exhibit when the ventral surfaces of primaries and secondaries are exposed to UV (black) light. This allows rapid and accurate assessment of molt and, in turn, the assignment of an age classification for the owl. *Received 10 August 2009. Accepted 9 January 2011.*

Feather molt among owls is complex but occurs in a relatively predictable sequence for an individual species, varying from complete or near-complete annual flight feather replacement in some species to a much lengthier process that may require 3 to 6 years (e.g., Great Horned Owl, *Bubo virginianus*). The replacement sequence of primaries and secondaries is relatively predictable, and it is believed possible to accurately assign age of individuals of some species to the third, and possibly fourth, year (Pyle 1997). However, distinguishing subtle differences between third- or fourth-generation feathers by looking for contrasts in wear and color can be difficult, especially at night under incandescent light.

Porphyrins are a large group of pigments characterized by nitrogen-containing pyrole rings including chlorophyll and, in animal blood, heme (McGraw 2006). Porphyrins are used by many birds to pigment eggshells in the oviduct, but 13 Orders of birds also use porphyrins as a plumage pigment, most notably owls, goatsuckers, bustards, and turacos (Gill 1995, McGraw 2006). Porphyrins are easily destroyed by exposure to sunlight, and are most abundant in new feathers; many of the so-called natural porphyrins also fluoresce brightly when exposed to ultraviolet (UV) light (Gill 1995). Most natural porphyrins contain iron, but several are based on copper, including turacoverdin, which produces intense green coloration in some turacos, two galliforms, and the jacanas (Dyck 1992); and turacin, responsible for magenta coloration in turacos (Gill 1995). Porphyrins were first isolated from bird feathers in the early 20th century, but their role in feather structure and function, and their synthesis with regards to plumage formation, remain largely unexplored (McGraw 2006).

In this paper, we describe a technique using UV fluorescence of porphyrins to more easily classify age of owls by examining flight feathers and molt patterns.

HISTORY

In 1982, Colvin was studying the interactions of Barn Owls (*Tyto alba*) and farm rodents by lacing non-toxic rodent baits with tetracycline, which would make rodent bones and teeth (collected from Barn Owl pellets) fluoresce under black UV light. Colvin was also trying to find easier ways to quickly distinguish molt limits among adult Barn Owl flight feathers, especially when working at night under weak incandescent light (e.g., a 6-volt flashlight). He subsequently tried both ''white'' and long-wave ''black'' hand-held fluorescent lights, discovering they both made molt patterns easier to see, because newly molted feathers have higher concentrations of porphyrins and fluoresce much more brightly, contrasting with weaker fluorescence in older feathers.

Colvin did not publish his findings and, for many years, the technique was used only by a limited number of researchers who had been

[1] 778 Schwartz Valley Road, Schuylkill Haven, PA 17972, USA.
[2] 32 Standish Road, Melrose, MA 02176, USA.
[3] Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, MD 21401, USA.
[4] 7012-A Summerfield Drive, Frederick, MD 21701, USA.
[5] Corresponding author; e-mail: scottweidensaul@verizon.net

associated with him or his colleagues in Ohio or New Jersey, working primarily with Barn Owls. In the mid-1990s, Brinker learned of the method from Scott Butterworth, then with the West Virginia Division of Natural Resources, and taught it to Huy, who began using black UV light in October 2000 on Northern Saw-whet Owls (*Aegolius acadicus*), netted for banding during autumn migration in Maryland. Brinker and Huy alerted Weidensaul, and all three used the technique extensively over the next several years to assign age to adult owls.

This method has since been adopted widely by participants in Project Owlnet, a collaborative network of more than 100 owl migration banding sites, which annually band 8,000 to 15,000 Northern Saw-whet Owls (http://www.projectowlnet.org/). It has proven especially helpful in distinguishing after-second-year/after-third-year (ASY/ATY) adults, which are marked by the presence of three generations of feathers, a frequently subtle distinction that can be difficult to make in the field, at night, under artificial light. The recapture of marked, known-age owls in subsequent years has demonstrated that intensity of UV fluorescence in the flight feathers corresponds to the relative ages of the feathers themselves, and is consistent with accepted, age-linked molt sequences described in Pyle (1997). The importance of this technique lies in the ability it gives even inexperienced workers to quickly and easily distinguish molt limits in owls, and thus facilitate accurate age classification.

OBSERVATIONS

Use of UV light to read molt limits has proven successful in a variety of North American owl species. We primarily refer to Northern Saw-whet Owls, but given the assumed universality of porphyrins in owl plumages, this technique should be applicable to most, if not all, tytonids and strigids.

Colvin originally experimented with a variety of ''white'' fluorescent and long-wave ''black'' fluorescent lights, but most banders now use commercially available long-wave black UV light bulbs. Good results have been obtained with a 13–watt compact fluorescent blacklight (e.g., Feit Electric BPESL15T/BLB, available from on-line distributors) with a screw-in base for use in lamps taking household incandescent bulbs. There are a variety of handheld battery-powered lights (e.g., Arachnid A49 LED flashlight), powered by AA batteries, that are useful for field applications where 120v AC is not available.

The ventral surfaces of newly molted flight feathers fluoresce an intense magenta color with the UV light positioned ~15 cm away, brightest in the proximal third of the feathers, and fainter or absent from the distal third (Fig. 1). Underwing coverts fluoresce similarly. Porphyrins are generally reddish or brownish pigments, but the fluorescence is often brightest in areas that appear in natural light to be white or lightly tinged with pink.

Most individuals exhibit little fluorescence on dorsal wing surfaces, although it is unclear whether this is the result of rapid degradation of porphyrins in sunlight, or of limited deposition in those areas. Prior to widespread use of UV on the ventral wing surface, molt limits were evaluated using incandescent light to assess the differences in feather wear and sunlight-related fading on the dorsal surface of the feathers. These differences are often subtle and difficult to detect, making accurate assignment of age to owls more prone to error.

There is usually little fluorescence on the rectrices, except where the bases of the feathers are covered by coverts, even though Northern Saw-whet Owls undergo a complete and nearly simultaneous replacement of the tail during the prebasic molt (Collins 1961, Rasmussen et al. 2008). Tarsal and adult ventral down feathers glow with an especially bright, ruby-red color. A hatch-year (HY) Northern Saw-whet Owl, molting from its juvenal ''chocolate'' plumage in July in coastal Washington, had a mix of fluorescence on its underparts; the brown or fawn juvenal feathers exhibited no color under black UV light, while newly molted feathers glowed brightly (Jamie Acker, Dawn Garcia, and Stan Rullman; pers. comm.). The remiges showed a bright, even fluorescence, while the rectrices had no fluorescence at all. Northern Saw-whet Owl ventral contour feathers show almost no fluorescence in all ages and plumages.

HY Northern Saw-whet Owls captured in fall migration show an even fluorescence across the underwing surfaces, being most intense in the inner primaries and outer secondaries, and fading significantly across the innermost secondaries, which show little or no fluorescence (Fig. 1A). Second-year (SY) owls captured in fall, which have replaced outermost primaries and innermost secondaries (most often primaries 6–10 and

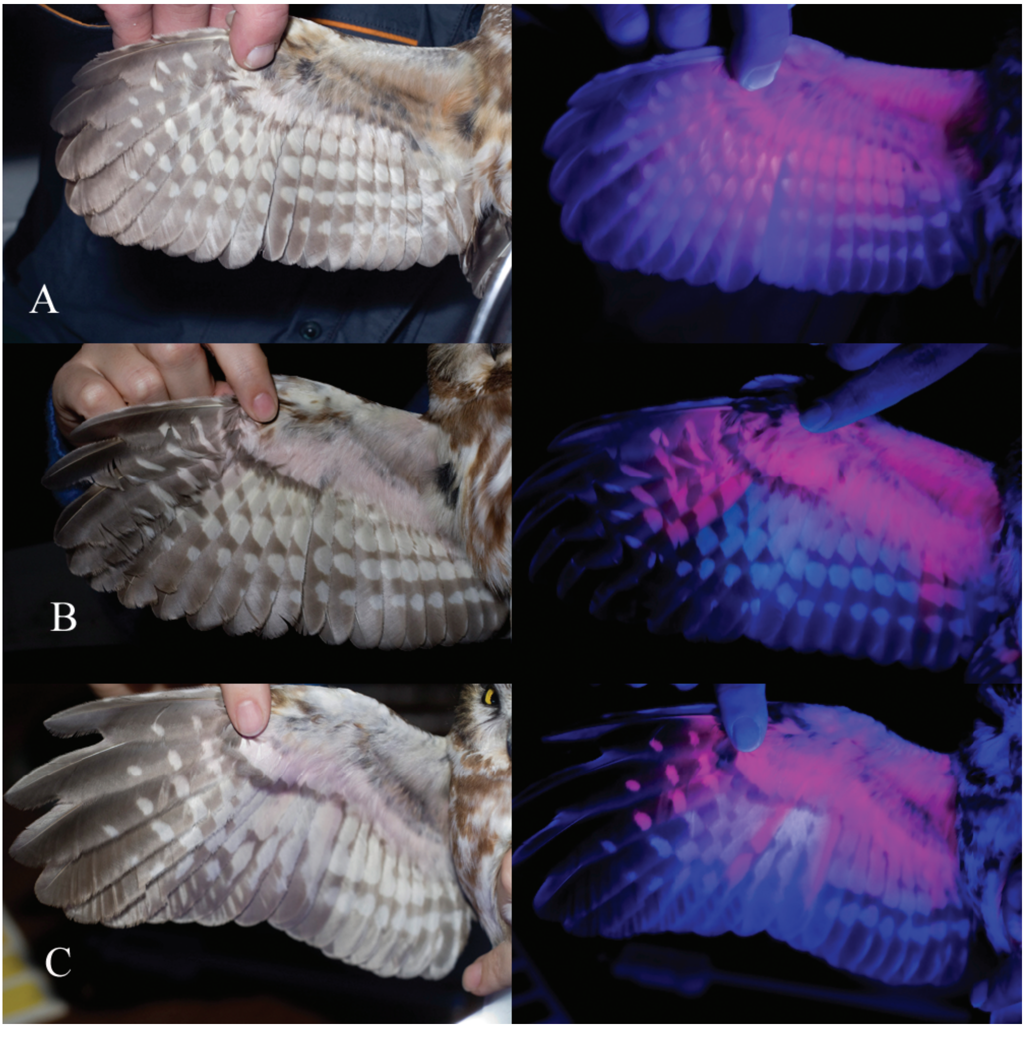

FIG. 1. Paired views of ventral surfaces of Northern Saw-whet Owl wings, photographed in October–November under visible light and ultraviolet light. Hatching-year (A) showing even fluorescence across all underwing surfaces; second-year (B) showing contrast between strong fluorescence on newly molted outermost primaries and innermost secondaries; and after-second-year (C) showing three generations of feathers, including chalky-white retained juvenal primaries 1–2 with no fluorescence. Photographs by Scott Weidensaul.

secondaries 8–12; DFB, unpubl. data), show a distinctive pattern of bright fluorescence in these areas, separated by a block of older retained juvenal feathers with relatively little fluorescence, limited to the base of the flight feathers (Fig. 1B). Owls showing a mix of old and new feathers, but not in the sequential block pattern of a SY (Fig. 1C), are classified as after-second-year (ASY), after Pyle (1997).

Extremely old feathers, presumably those at least 2 years of age, appear chalky or yellowish white under black UV light, evidencing no sign of fluorescence. Distinguishing third-generation feathers from second-generation feathers can be challenging, requiring significant experience on the part of the bander, particularly when working under artificial light at night. However, the difference under UV light is usually easily apparent, even to relatively inexperienced workers. Thus, use of UV light greatly improves the accuracy of age classification of Northern Saw-whet Owls.

DISCUSSION

This technique was developed for Barn Owls, and is described here primarily for Northern Saw-whet Owls. However, it appears to have wide applicability to many, if not all, species of owls. We and others have tested black UV lights on a variety of wild and captive North American owls, and all fluoresce. Eastern Screech-Owls (*Megascops asio*) exhibit a pattern and color almost identical to Northern Saw-whet Owls, as do Flammulated Owls (*Otus flammeolus*) (Jeff Smith, pers. comm.), while two captive adult Barred Owls (*Strix varia*) examined under black UV light showed a bright, violet-magenta fluorescence on newly molted remiges, but a complete absence on rectrices. Wild Barred Owls (classified as SY and ATY) examined in Washington State showed clear molt limits in the remiges with three generations easily visible in the ATYs (Jamie Acker, Dawn Garcia, and Stan Rullman; pers. comm.) A captive adult Great Horned Owl had weak fluorescence when initially examined, but a year later exhibited bright magenta fluorescence on newly molted remiges, perhaps a result of a stronger UV source. An unknown-age Northern Pygmy-Owl (*Glaucidium gnoma*) examined in August in Washington State exhibited bright fluorescence on the underwing coverts and faint fluorescence on the base of the remiges (Jamie Acker, Dawn Garcia, and Stan Rullman; pers. comm.).

An HY Long-eared Owl (*Asio otus*), found freshly killed by a larger raptor in early December, had an even distribution of pale lavender fluorescence only at the base of the flight feathers where they had been covered by coverts, but exhibited strong fluorescence on the down feathers of the tarsi and flanks. An HY Long-eared Owl captured in November had a similar pattern, while an AHY Long-eared Owl netted at the same time had distinct flight feather molt limits under black UV light with new feathers fluorescing brightly. The molt limits were difficult to detect on the same bird using incandescent light. The fluorescence was purple-red shading to dark purple, and no fluorescence was noted on the rectrices, contour feathers or dorsal surfaces.

One concern is the effect of exposure to UV light on the eyes of both owls and banders. Ultraviolet wavelengths can cause tissue damage, although the long wave (UVA, 400–315 nm) radiation produced by commercial black UV lights is considered the least damaging of the three wavelength categories of ultraviolet light, and is found in most light sources, regardless of type. However, UVA bulbs may emit trace amounts of more damaging UVB radiation (Stellman 1998). There appears to be little information suggesting that brief exposure to UVA light experienced during normal banding operations would be harmful to owls, but caution is warranted. We make an effort to shield the eyes of owls during UV examination, often by shading the bird with a hand, and keep exposure as brief as possible.

A growing number of bird taxa have been shown to see wavelengths of light in the UV range (Bennett and Cuthill 1994, Bowmaker et al. 1997, Wilkie et al. 1998, Cuthill et al. 2000), and UV reflectivity has proven important for some birds in mate selection (Hunt et al. 2001, Pearn et al. 2001, Arnold et al. 2002, Hausmann et al. 2003) and hunting (Viitala et al. 1995, Koivula and Viitala 1999).

Recent research suggests that many taxa that appear monomorphic in visible light may be highly dimorphic when viewed in the UV range (Andersson et al. 1998). A recent plumage survey of ~1,000 nonpasserine bird species showed distinctive ultraviolet reflectivity, suggesting this visual ability may be widespread (Mullen and Pohland 2007).

Fluorescence differs from reflectivity, but the presence of abundant pigment in owl plumage that fluoresces brightly prompts the question: can the owls see this color and, if so, might it have a social or behavioral role, such as in mate selection? The absence of visible fluorescence on dorsal surfaces, head or face of owls examined under black UV light argues against its use as a social signal, although the underwing surfaces where it is present would be observable in flight, such as during courtship rituals, and surfaces that reflect UV light may not fluoresce. The amount of UV light reflected by the moon is exceedingly low (the moon's albedo is just 0.038; Henry et al. 1995), and may be below the threshold for visual detection, although many owls are active at dusk and dawn, when UV intensity may be greater. However, examination of the eyes of the Tawny Owl (*Strix aluco*) suggests owls lack the ultraviolet-sensitive/violet-sensitive (UVS/VS) cone class associated with ultraviolet vision (Bowmaker and Martin 1978, Cuthill et al. 2000). Boreal Owls (*Aegolius funereus*), under experimental conditions, did not use ultraviolet markers to detect the presence of prey, as do diurnal raptors (Koivula et al. 1997). These factors in composite suggest ultraviolet fluorescence may not be a social cue, although further investigation is needed.

ACKNOWLEDGMENTS

The authors are grateful to D. H. Johnson, C. E. Braun, and an anonymous reviewer for their comments on an earlier draft of this manuscript. We thank Jamie Acker, Dawn Garcia, and Stan Rullman for sharing observations and photographs of fluorescence in Pacific Northwest owls and Jeff Smith for observations on Flammulated Owls.

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