Marking Techniques 13

Daniel E. Varland
Rayonier, 3033 Ingram Street, Hoquiam, WA 98550 U.S.A.

John A. Smallwood
Department of Biology & Molecular Biology,
Montclair State University, Montclair, NJ 07043 U.S.A.

Leonard S. Young
1640 Oriole Lane Northwest, Olympia, WA 98502-4342 U.S.A.

Michael N. Kochert
USGS Forest and Rangeland Ecosystem Science Center,
Snake River Field Station, 970 Lusk Street, Boise, ID 83706 U.S.A.

INTRODUCTION

In this chapter we describe techniques for marking raptors for visual identification beginning with a discussion of considerations involved in designing and conducting a marking program. We identify and describe permanent markers that can be used safely and effectively on raptors, including conventional leg bands, colored leg bands, leg markers, and wing markers. We then discuss temporary marking techniques (e.g., paints, dyes, feather imping). Avian marking techniques unsuitable for raptors are not addressed in this chapter but are described by Young and Kochert (1987). These include, but are not limited to, neck collars, nasal saddles and discs, and grafting feathers to the skin.

CONSIDERATIONS IN DESIGNING AND CONDUCTING A MARKING PROGRAM

Selecting Markers

Careful planning is imperative before applying markers, and biologists need to consider many important points before selecting a marker type (Marion and Shamis 1977, Ferner 1979, Barclay and Bell 1988, Nietfeld et al. 1996, Silvy et al. 2005). These include: (1) marker effect on the individual (Will affixing the marker cause pain and stress? Will the marker influence behavior? Will it decrease survival? Will it affect breeding?), (2) marker durability and longevity (Will the marker chosen last for the duration of the study, given both the subject bird's ability to remove or damage it and environment wear and tear?), (3) distance at which marked individuals may be identified and ease of identification (How close can the subject birds be approached for marker identification and to what extent will vegetation impede identification?), (4) need for identifying individuals versus a group, (5) ease in obtaining and, if required, assembling the marker, (6) ease of applying the marker, (7) marker cost, (8) the likelihood that the marker will interfere with other studies or raise public concerns, and (9) the likelihood that the marker will be approved for use by regulatory authorities.

Biologists should be fully aware of the effects that marking may have on the birds they intend to capture and mark (Murray and Fuller 2000). When there is doubt about the effects or effectiveness of a marking technique, trials with captive birds may be in order. Captive studies allow researchers to observe markers and birds at close range, and performance of the marker and its effects on marked individuals can be evaluated.

Developing a Marking Protocol

Careful planning will help ensure that marking objectives are accomplished. Planning a marking program necessarily involves developing a marking protocol or adopting one that already is in place. Although protocols will differ depending on the needs of different species, several basic guidelines should be followed for any protocol to be effective. (1) The protocol should be as simple as possible; usefulness of the marking technique should not be diminished by too complicated a scheme. (2) The protocol should meet the needs of all aspects of the study. (3) The protocol should be effective over the lifetime of the study. (4) The protocol should take into account the species' entire range. (5) Species that appear similar (e.g., Golden Eagles [*Aquila chrysaetos*] and subadult Bald Eagles [*Haliaeetus leucocephalus*]) should be treated as one marking "unit" and should be governed by a common protocol. (6) Techniques that are confused easily (e.g., wing markers and wing streamers) should be treated similarly and should be governed by a common protocol. (7) The Bird Banding Offices that have oversight in the region where the work will occur must approve the protocol.

We recommend accessing Internet web sites of Bird Banding Offices and other organizations that provide information about ongoing avian marking programs.

Bird Banding Offices and Marking Permits

North America. In North America, permits are issued through the North American Bird Banding Program, which is administered jointly by the U.S. Geological Survey (USGS) and the Canadian Wildlife Service (CWS). The Bird Banding Laboratory (BBL; USGS Patuxent Wildlife Research Center, Laurel, Maryland [www.pwrc.usgs.gov/bbl/]) manages the USGS banding program in the U.S. and the Bird Banding Office (BBO; National Wildlife Research Centre, Ottawa, Canada) manages the CWS banding program in Canada. Both the BBL and BBO require the principal investigator to possess an active Federal bird banding permit, and all personnel assisting with marking to have current subpermits if they plan to work independently. Subpermits authorize individuals to mark birds as directed by the principal investigator. Occasionally, individuals are authorized to conduct a marking program under the auspices of a "station" permit held by an individual working for an organization on behalf of its employees. BBL and BBO permits only authorize attachment of conventional bands, which are provided by them at no charge. Authorization for the use of any other type of marker must be requested separately; the BBL and BBO do not supply or underwrite the costs of these markers. State and provincial permit requirements vary. Information on permit requirements may be obtained from the appropriate state or provincial wildlife agencies where the marking is planned. Permits and special authorizations should be carried in the field during marking.

Other geographic areas. Government and privately sponsored marking programs exist around the world. Where permits are required, as in the U.S. and Canada, they must be obtained in advance of fieldwork. North American bird bands and approved markers may be used off the continent with written authorization from the BBL or BBO, however as a rule, their use typically is allowed only in Mexico and Central and South American countries where North American birds migrate and winter. Bird banding, which is called ringing in Great Britain and Europe, is organized and coordinated by the British Trust for Ornithology (BTO; www.bto.org) in Britain and Ireland. The European Union for Bird Ringing (EURING; www.euring.org) is particularly helpful in providing information on ringing schemes both in Europe and elsewhere in the world.

Coordination

Biologists using similar marking schemes on the same or similar species should coordinate their work to reduce possible confusion. Coordinating with and alerting others of your activities also increases the likelihood that marked birds will be observed by other biologists. The Bird Banding Office responsible for oversight and permit approval in the region where the work is planned is an excellent place to gather information on similar marking schemes.

Gathering a Sample of Marked Individuals

The most basic and important assumption underlying studies using marking is that the sample of marked birds is representative of the entire population (Brownie et al. 1985, Williams et al. 2002). Ideally, all individuals in the study have the same probability of capture; however, capture probability often is influenced by factors such as capture methods, intraspecific differences (i.e., age, sex, social status), and behavioral response to trapping (Thompson et al. 1998). Because of this, sampling (marking) is seldom random in studies of raptors. In studies involving recapture of marked individuals, captured birds may become trap-happy (the likelihood of recapture is higher postcapture) or trap-shy (less likely to be caught after initial capture) (Thompson et al. 1998), leading to biases in the data. Most raptors are wary by nature and are far more prone to being trap-shy than trap-happy. Alternative trapping methods may be needed to recapture trap-shy individuals.

To ensure a truly representative sample, a random or stratified random sample of birds should be marked over the entire area or period of interest, and a coordinated survey should be conducted to define the population (Thompson et al. 1998, Chapter 5). Although this may not always be possible, steps to increase the likelihood that the marked sample is representative can be taken in any study. For example, when the entire cohort cannot be marked, nests at which young are marked can be selected randomly. Capture effort can be allocated evenly across an entire migration season, and capture sites can be varied. The steps that should be taken will vary depending on the situation and the purpose of marking, but the guiding principle of selecting a representative sample from an accurately defined population remains the same.

It is easier to accurately define a population and mark a representative sample when the population is sedentary (Brownie et al. 1985). During migration it is difficult, if not impossible, to determine the nature and size of the population the marked sample represents. Biologists typically focus their capture efforts during migration at banding stations, which often are linked with watchsites (see Chapter 6); these generally are on migration corridors and take access logistics into account (e.g., proximity to roads). Data collection, including those involving marking efforts, at banding stations may be described as "cluster sampling" of the larger population (Williams et al. 2002).

Collecting Resighting Data on Marked Individuals

A sound sampling design for accumulating sightings is just as important as a representative sample of marked birds. It is best if observation effort is consistent across the entire area in which marked birds may be resighted. This assumption almost always will be violated when the area is large or parts of the area have limited access. It certainly is violated if sightings of marked birds by other biologists, amateur ornithologists, and the general public furnish substantial amounts of data, as resightings will be biased in favor of those areas that are populated or frequented by people who will make and report observations of marked birds.

We recommend that marking be used in conjunction with other sources of data in studies of raptor movements and resource use. Spatial tracking by conventional or satellite telemetry, which allows the marked sample to be observed systematically, is an important additional technique in such studies (see Chapter 14). When marking must be used as the primary technique, we recommend that sample sizes be large, that potential observation areas be searched systematically for marked birds, that the marking program be well publicized in the region where the study takes place, and that inferences on movements and resource use be restricted to general patterns and trends.

Because many observations of marked animals go unreported (Williams et al. 2002), announcements that describe the marking program and procedures for reporting sightings of marked birds are useful. Incomplete distribution of announcements will bias reports in favor of areas in which the marking program was publicized. Announcements should continue through the duration of the project to facilitate a similar resighting probability by the public across time.

Special Considerations in Studies of Population Dynamics

Survival (or apparent survival if mortality and emigration are confounded) can be estimated from marked individuals by analyzing data from recoveries of marked or banded birds that are found dead (band-recovery models), or from recaptures or resightings of marked individuals that are alive (mark-recapture models). These two data sources also can be used in combination. Band-recovery models seldom are used with raptors, mainly because of the large sample sizes required to obtain reliable results. For survival estimates, mark-recapture models (e.g., Gould and Fuller 1995, Morrison 2003, Anthony et al. 2006) and combined dead recovery-live recapture models (Kaufman et al. 2003, Craig et al. 2005) often are employed. Using data on nearly 20,000 Tawny Owls (*Strix aluco*) banded over 19 years, Frances and Saurola (2002) calculated age-specific survival rates using all three approaches, and concluded that for birds banded as nestlings the combined dead recovery-live recapture models are best.

The need for particularly durable, visible markers is paramount for mark-recapture studies. Although different types of markers can be handled in the analysis if marking technologies change over time, such analyses can be more complicated. Marker loss can be a serious problem. If that potential exists, a double- or triple-marking scheme should be used (McCollough 1990).

Within the mark-recapture framework, other parameters of interest can be estimated as well, such as population size (Gould and Fuller 1995), rate of population change (Kaufman et al. 2003, Craig et al. 2005, Anthony et al. 2006), and resighting rate (D. Varland, unpubl. data). Software packages, many of which can be downloaded for free from the Internet, are available for analyzing mark-recapture data (see www.phidot.org/software/). Program MARK (White and Burnham 1999) is a leading software package for mark-recapture analyses. Useful references on the mark-recapture literature include Thompson et al. (1998), Williams et al. (2002), and Dinsmore and Johnson (2005).

Marker Characteristics

Before we discuss marker characteristics, we want to point out that individual raptors may have unique plumage or soft-body-part characteristics, such as carbuncles in condors and vultures, which can be used to identify individuals in the field (natural markers). The female Peregrine Falcon (*Falco peregrinus*) that nested for many years on the Sun Life building in Montreal had an unusual "dimple" in her breast (Hall 1970), making her recognizable; R. Wayne Nelson recognized adult peregrines at nest sites by malar stripes and other physical features (Nelson 1988). Today, the ultimate method of identifying individuals is DNA fingerprinting.

Markers employ colors, often with a combination of numbers and letters (alphanumeric code) or, less frequently, symbols. Below we suggest some general guidelines pertaining to the use of colors and characters that will minimize resighting ambiguity and confusion.

Colors. Use as few colors as possible. The more colors used, the greater is the chance of observer error. In studies where markers must be sighted at long distances under adverse conditions, we recommend that, when possible, only three contrasting colors (e.g., red, white, and blue) be used. Use of additional colors may lead to color confusion. Additional colors may be used cautiously if marked birds are observed at close range under favorable conditions by trained personnel. However, additional colors should be used only if essential to accomplishing study objectives, and alternate means of encoding data are not feasible. Certain pairs of colors should not be used in the same marking program under any circumstances. They include red and orange, yellow and white, dark blue and dark green, and purple and blue. Colors should be bright and bold; pale or pastel colors should not be used. Dark colors may be difficult to distinguish under poor light conditions or against dark earth and vegetation tones (Lokemoen and Sharp 1985). We recommend avoiding use of bicolor markers due to the possibility of seeing only one color (Kochert et al. 1983) and the tendency for colors to "merge" at long distances (Anderson 1963). Red markers on nestlings should be avoided, as these may increase pecking by siblings. Colors should contrast with the birds' coloration (e.g., yellow leg bands will not show well against the yellow legs of a Bald Eagle). When possible, colors present in the plumage or soft body parts of raptors should not be used on those species.

Characters. Characters (letters, numbers, or symbols) provide greater opportunity to identify individual birds. However, characters can be relied upon only if observers will be close enough to marked birds to read them consistently. Trials are useful for determining the ranges at which characters can be identified with different optics. As with colors, as few characters as possible should be used; data that are not essential to study objectives should not be encoded. Characters that are easily confused should be used cautiously in the same program (e.g., a 3 and an 8 or a C and an O can easily be confused if part of the character was obscured). Alphanumerics should be avoided if the general public is likely to be important in reporting birds. In such instances numerical sequences alone are preferred.

Characters can be printed in such a manner so as to reduce similarities. Distinct symbols (e.g., circles, triangles) may be more easily discerned than alphanumeric characters (Lokemoen and Sharp 1985). Colors of characters should contrast well with the background color of the marker; either black or white characters are best. Durable, colorfast paints and inks that adhere well to the marker material should be used to print characters. Marking pens and writing inks should not be used; the marks they produce will fade, blur, or deteriorate relatively quickly. Clear finishes, such as acrylic lacquers, can be used to protect characters, however they may increase the marker's reflectivity, causing glare and making identification difficult under certain light conditions.

Decisions regarding colors and characters should be thought through carefully, especially when initiating long-term studies.

PERMANENT MARKERS

Conventional Bands

Three types of bands, or rings, are used in field studies of raptors (Fig. 1). The butt-end band, or split-ring band, is used for smaller species whose bills are not powerful enough to loosen or remove the band. The butt-end band is placed around the tarsus and closed with banding pliers until the ends meet snugly and evenly. To facilitate a proper fit, specially drilled banding pliers are available commercially, but only for smaller-size, butt-end bands. Lock-on bands, also known as locking tab bands, are used with medium-sized to large raptors (except eagles) where overlapped closure is required to keep the band on the bird's leg. The lock-on bands have two flanges of metal, one longer than the other. The longer flange is folded over the shorter and pressed securely against the latter with pliers, locking the band in place. Rivet bands are used with eagles, whose bills are strong enough to remove butt-end (Berger and Mueller 1960) and, sometimes, even lock-on bands (C. Niemeyer and R. Phillips, pers. comm.). The band is closed snugly by hand, the flanges are pressed together with small vice grips or needle-nose pliers, and then they are riveted together using a pop-riveter.

Bands issued by the BBL and BBO are made of aluminum or a hard-metal alloy. They are inscribed on the outer surface with a unique number and with two means by which individuals who recover a band may report their findings, including a toll-free telephone number and a website address (www.reportband.gov) that replaces the mailing address, beginning in 2007. In Europe, EURING has adopted use of a website address (www.ring.ac) on a trial basis for reporting observations, which is inscribed on the ring in addition to a standard mailing address.

Conventional bands have been used almost exclusively on raptors to mark individuals in the event of recapture and to gradually accumulate information on migration, dispersal, longevity, and causes of death. Band recoveries generally occur by happenstance when individuals not connected with the banding research find and report dead or injured birds, resulting in low data yield (e.g., Broley 1947, Kochert et al. 1983). Because of this, we recommend that raptors be banded only as part of a well-planned and coordinated effort in which large numbers of birds are banded. Casual banding should be done only when raptors are captured or handled for other reasons or, in the case of nestlings, when a biologist has entered the nest for other purposes. Except for New World vultures, a bird receiving a marker or a radio transmitter always should be banded with a conventional band. Occasionally, conventional bands may be appropriate for identifying individual raptors at a distance.

Bands should not be used on Cathartid (New World) vultures because these raptors excrete feces on their legs, presumably for thermoregulation (del Hoyo et al. 1994). Consequently, bands may become impacted with fecal material, causing constriction of the leg and loss of circulation (Henckel 1976). This may result in swelling of the leg and foot below the band and, eventually, the loss of the leg (Henckel 1976) and, possibly, death. Houston and Bloom (2005) documented a shift from the use of leg bands to wing markers in Turkey Vulture (*Cathartes aura*) studies to avoid the problem posed by these species wearing conventional bands.

Bands come in a number of sizes and those of the correct size should always be used. Bands that are too loose may impede proper movement of the foot or become entangled with other objects, and bands that are too tight constrict and injure the bird's leg. Due to the

Figure 1. (Top, from left) Three conventional bands: butt-end, lock-on, and rivet. (Bottom, from left) Two color bands: color metal and color nonmetal. *(Photo by D. Varland)*

high degree of sexual size dimorphism in many raptors, males and females often require different size bands. Size differences among individuals within the same sex also may require the use of different size bands. Banders should measure the leg with a leg gauge to determine the correct band size (see the BBL web site [www.pwrc.usgs.gov/bbl/] for suppliers of leg gauges and other banding equipment, including pliers). Bands that are too loose, too tight, or overlapped must be removed. It also may be necessary to remove a band damaged or forced out of round during the banding process. Great care must be taken that the bird's leg is not injured when removing a band. Pressure must never be exerted on the leg during this process. Larger bands may be removed using two pairs of small vice-grip pliers. This technique is described and illustrated in Hull and Bloom (2001). Bands also may be removed by threading two pieces of wire, such as those used to "string" bands together, between the band and the tarsus on either side of the band's butt end. The free ends of each wire are wrapped around an easy-to-grip object, such as banding pliers, so that the opposing wires may be pulled with sufficient force to open the band.

Banders who find that the bands made available to them by the BBL or another banding organization are a poor fit should notify their supplier and provide advice on band-size improvement. The BBL continues to work on updating band sizing to ensure bird safety (M. Gustafson, pers. comm.).

Ideally, nestling raptors should be banded between one-half and two-thirds of the way through the nestling period (Fyfe and Olendorff 1976). At this time the tarsi are sufficiently developed to hold the appropriate size band, yet the birds are not mobile enough to jump from the nest and fledge inappropriately early (Fyfe and Olendorff 1976). If a goal is to assess productivity, the later the productivity estimate is made, the more accurate it will be (see Chapter 11). However, it is paramount that young in the nest not be disturbed so late in the nesting season as to cause premature fledging. Thus, if it appears that young will fledge prematurely when the nest is approached to band nestlings, banding should be avoided.

Color Bands

For studies involving color bands, each bird should receive a conventional band in addition to at least one color band (Fig. 1), and no more than four bands (two per leg) should be applied altogether. Metal bands should not be stacked; they can flare with time and damage the leg. All birds in a study should receive the same number of color bands, and each leg should receive a consistent number of bands; this allows for immediate identification of birds that have lost bands. When only two bands are attached, bands should be placed on both legs so that observers quickly identify banded birds. Conventional aluminum bands, which are silver, may serve as a "color" band. Adjacent bands should not be the same color as this eliminates confusion as to whether one or two bands were seen (Howitz 1981). General information (e.g., age, sex) should be encoded into the color scheme (Howitz 1981), and the scheme should be designed so that this information will not be compromised by band loss. Birds that frequently are seen together (e.g., members of a pair) should have dissimilar color combinations so that they may be distinguished easily (Howitz 1981). Color combinations should be used in a systematic order to facilitate organization of data and reduce the chances of accidentally using the same combination twice.

Here we identify four types of color bands: metal bands, nonmetal bands, painted bands, and bands wrapped with colored tape. A list of suppliers and manufacturers of metal and nonmetal color bands is maintained on the BBL web site (www.pwrc.usgs.gov/bbl/).

Metal bands. Colored pigments are affixed to metal bands by anodizing, an electrolyzing process in which the band functions as the anode. Anodizing was improved in the early 1990s, making anodized bands less prone to fading (D. Cowen, pers. comm.). As such, anodized bands are now a better choice for raptor studies than were those available when Young and Kochert (1987) reported on marking techniques.

Color metal bands, plain or engraved with alphanumerics or symbols (Fig. 1), are commercially available in North America through ACRAFT Sign and Nameplate Co. Ltd. of Edmonton, Canada. ACRAFT carefully monitors band codes issued to avoid duplication. According to reports to the BBL by field researchers, these bands are mostly durable and colorfast (M. Gustafson, pers. comm.). The only known exception to this among raptors wearing these bands occurred with Galapagos Hawks (*Buteo galapagoensis*) on Santiago Island. In this situation, the bands were so abraded by lava rocks the alphanumerics were unreadable within 4 to 5 years (K. Levenstein, pers. comm.). Color metal bands also can become difficult to read if dirt builds up on them (D. Varland, pers. obs). When this occurs, it may be necessary to recapture individuals and clean their bands.

Metal color bands can be made by anodizing conventional aluminum bands from the BBL or BBO. However, approval first must be granted by the BBL or BBO. These bands will fade somewhat over time. The extent to which fading occurs is not predictable and depends upon factors such as exposure to sunlight, abrasive rocks, and salt water. D. Varland detected little to no fading of blue or red anodized conventional bands worn by Peregrine Falcons in coastal Washington. On the other hand, fading did occur on anodized conventional bands worn by peregrines in the Midwest within four years; purple bands appeared pink and gold bands appeared silver (H. Tordoff, pers. comm.).

Non-metal bands. The plastics, celluloid and Reoplex, and the nonplastic polyvinylchloride Darvic, are common materials used in the manufacture of non-metal color leg bands (Fig. 1). When wrap-around, or overlap bands are used, special adhesives are employed to ensure bonding between the sides of the band. Non-metal band suppliers usually offer the adhesive needed with their product or will offer advice on purchase.

Laminated bands consist of two layers of plastic: a colored surface layer bonded to a contrasting white or black base layer. Alphanumerics or symbols may be inscribed on laminated bands by routing the surface layer to expose the contrasting base color. Whereas laminated bands demonstrated durability and retention in use on Spotted Owls (*S. occidentalis*) (Forsman et al. 1996), McCollough (1990) reported poor retention on the stronger-billed Bald Eagle; all 118 attached were lost within four years. In California, some Red-tailed Hawks (*B. jamaicensis*) lost their laminated bands within six years of application (P. Bloom, pers. comm.). These observations suggest that laminated plastic bands should not be used in long-term studies of large raptors capable of exerting substantial force on their bands, or in studies where band loss will bias the data.

Painted bands. Painted bands can be made with chip-free nail polish, which adheres well to bands (M. Gustafson, pers. comm.). Paint, however, wears off with time and is impractical for banding large numbers of birds. Pliers used for attaching painted bands should be wrapped in masking tape to avoid chipping painted surfaces.

Bands wrapped in tape. Wrapping bands with colored cloth tape offers a short-term means of identification, as most raptors quickly tear the tape. Bands such as these sometimes are used to identify raptors released after rehabilitation from injury or sickness.

Summary. Maximum distance for reading alphanumeric codes on bands varies with band size, lighting conditions, behavior of subject birds, and habitat. Alphanumeric codes on bands have been read with a spotting scope at distances of up to 150 m in observations of Galapagos Hawks (K. Levenstein, pers comm.) and Peregrine Falcons (D. Varland, pers. obs.), and up to 190 m with Bald Eagles (McCollough 1990). That said, because of their small size and relative inconspicuousness, color bands should be used as a primary marking technique only in studies where birds can be observed routinely with a spotting scope or with binoculars from relatively short distances.

Additionally, for reasons mentioned above, colored bands should not be used with Cathartid vultures. Color bands also are unsuitable for species whose tarsal feathering is likely to obscure the band, and they should not be used with species that spend large amounts of time standing in tall vegetation, or perching in locations where their tarsi are out of view.

Leg Markers

Leg markers are suitable for the same applications as color bands. In studies employing leg markers, birds also should receive a conventional band. There are two types of leg markers: leg flags, which are fastened around the leg itself, and leg band tags, which are attached to the conventional band (Fig. 2). Durability is necessary with leg markers because they are situated where good leverage can be brought to bear on them by the bird with both the bill and the feet.

Leg flags. Materials used to make leg flags (Fig. 2) include virgin vinyl (i.e., vinyl with no recycled material) (Bednarz 1987, Varland and Loughin 1992), Herculite® (Platt 1980, Warkentin et al. 1990) and Darvic (Fig. 2). Leg flags extending beyond the leg have the potential to interfere with behavior associated with hunting and incubation. Trained falcons wearing long jesses often are pursued by other raptors that mistake the jesses for a prey item and attempt prey robbery (Platt 1980). Herculite® leg flags that extended about 10 cm from the leg had no discernable impact on the hunting success of Merlins (*F. columbarius*) (Warkentin et al. 1990, I. Warkentin, pers. comm.). Far shorter leg flags have been used on Merlins (Fig. 2), Prairie Falcons (*F. mexicanus*) (ca. 1 cm) (Platt 1980); American Kestrels (*F. sparverius*) (3.5 cm) (Varland and Loughin 1992) and Harris's Hawks (*Parabuteo unicinctus*) (2.5 cm) (Bednarz 1987).

Leg flags should be restricted to short-term studies

Figure 2. Leg band tag (above) attached to a conventional band on a Bald Eagle (*Haliaeetus leucocephalus*) (worn for 384 days) and leg flag (left) on a Merlin (*Falco columbarius*). *(Photos courtesy of J. Watson [above] and by D. Varland [left])*

because long-term retention of these markers by raptors often is poor (Picozzi and Weir 1976, Platt 1980, I. Warkentin, pers. comm.). Leg flags should be of the correct diameter. Leg flags that are too loose may slip off the foot or become entangled in the toes or on branches, wire, and other objects. Loose markers also are easier for a bird to tear. Markers that are too tight may cause abrasion or restrict circulation.

Leg-band tags. McCollough (1990) attached leg-band tags (Fig. 2) to Bald Eagles in Maine; the markers were retained better than laminated bands (0.6% annual loss rate for leg band tags vs. 35% for laminated bands). Alphanumerics on these tags were readable as far away as 220 m. Leg-band tags made of the vinyl Herculite® were retained well on Bald Eagles marked in Washington, where no marker loss was known in 59 deployments through seven years of monitoring (J. Watson, pers. comm.).

Wing Markers

Wing markers consist of two basic types: wrap-around and piercing, depending upon how the marker is secured to the wing. Markers made of various materials have been attached to or around the patagium. Wrap-around markers are wrapped around the wing and the ends are fastened between a natural break in the feathers, most often between the tertials and scapulars (Kochert et al. 1983; Fig. 3). Piercing markers usually consist of a tag or streamer attached to the wing by a pin or clip that pierces the patagium. Piercing markers are of three general types: a single tag attached to the dorsal surface of the wing (Smallwood and Natale 1998; Fig. 4), two separate tags attached to the dorsal and ventral surfaces of the wing, and a single tag that folds over the leading edge of the wing and is secured both above and below the patagium (Wallace et al. 1980; Fig. 3). In some instances, no pin or clip is employed, and the marker itself pierces the patagium (Sweeney et al. 1985). Sizes and shapes of wing markers vary.

Wing markers have been one of the most commonly used color markers in studies of raptors. They are relatively large and conspicuous, facilitating identification at long distances. Many species have been marked successfully with wing markers, including California Condors (*Gymnogyps californianus*) (Meretsky and Snyder 1992), Black Kites (*Milvus migrans*), Red Kites (*M. milvus*) (Viñuela and Bustamante 1992), Northern Harriers (*Circus cyaneus*) (Picozzi 1984), Common Buzzards (*B. buteo*) (Picozzi and Weir 1976), and Spanish Imperial Eagles (*A. adalberti*) (Gonzalez et al. 1989).

Success of wing markers for falcons has been variable. Wrap-around markers caused substantial feather wear and skin abrasion on Peregrine Falcons and Prairie Falcons to the extent of producing open sores (Sherrod et al. 1981, Kochert et al. 1983). American Kestrels wearing wrap-around markers showed no sign of injury, and they hovered, captured prey, and bred normally (Mills 1975). Pierced wing markers had no observed adverse effects on Common Kestrels (*F. tinnunculus*) (Village 1982) and American Kestrels (Smallwood and Natale 1998). Marker design and attachment methods are particularly important with falcons due to their long, narrow wings and rapid wing beats.

Wing markers are best suited for applications in which the observation area is known and marked birds are likely to be viewed from long distances at which smaller, less conspicuous markers would not be discernible. Examples include studies of nest-site fidelity (Picozzi 1984), dispersal (Miller and Smallwood 1997),

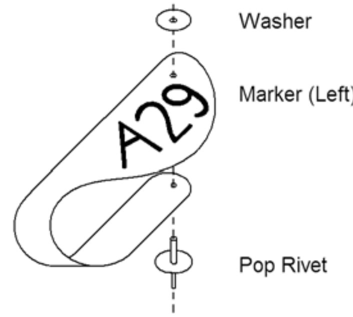

Figure 3. Adult Bald Eagle (*Haliaeetus leucocephalus*) wearing wrap-around wing markers (left) (photo courtesy of H. Allen). The marker is wrapped around the leading edge of the wing and the ends are fastened to the patagium between the tertials and scapulars (right) (Kochert et al. 1983; drawing courtesy of N. Smallwood).

winter-site fidelity (Harmata and Stahlecker 1993), and social relationships (Mossman 1976). Wing markers are highly effective in identifying individuals in behavioral studies (Mendelsohn 1982) and can provide much supplemental information on movements in studies in which conventional radio telemetry also is used (Meretsky and Snyder 1992).

Most wing markers are made from one of three types of materials: vinyl-coated nylon fabrics, upholstery plastics, and semi-rigid plastics. Vinyl-coated nylon fabrics consist of a vinyl coating over a meshlike nylon matrix. This material has been used extensively and is available in a variety of colors and weights. As a group, vinyl-coated nylons are durable and colorfast; wing markers of this material have been worn by Bald Eagles for as long as 22 years (McClelland et al. 2006). Vinyl-coated nylons vary in these characteristics (Nesbitt 1979, Kochert et al. 1983) however, even to the extent that colors of the same material from the same manufacturer may perform quite differently. Materials used with generally good results include Herculite®, Stamoid PE, Suncote, TXN, and Weym-O-Seal (Furrer 1979, Nesbitt 1979, Kochert et al. 1983). On the other hand, Coverlite, Dantex, and Facilon have been known to fade or deteriorate relatively quickly (Guarino 1968, Nesbitt 1979, Kochert et al. 1983). Variable results have been reported for Saflag, the most commonly used vinyl-coated nylon. Saflag has been observed to fade rapidly and dramatically, and to deteriorate relatively quickly (Nesbitt 1979; J. Smallwood, pers. observ.). In contrast, Saflag markers performed well for up to two years in studies of American Woodcock (*Scolopax minor*) (Morgenweck and Marshall 1977) and Band-tailed Pigeons (*Columba fasciata*) (Curtis et al. 1983).

Upholstery plastics such as Masland Duran and Naugahyde are much less durable than vinyl-coated nylon fabrics. Markers cut from these materials have a tendency to curl (Labisky and Mann 1962). For this reason we do not recommend using upholstery plastic for this purpose.

A few studies (e.g., Picozzi 1971, Mudge and Ferns 1978) used markers made of semi-rigid laminated plastics. These materials are very durable and have excellent color retention but sometimes crack if stressed. Common Buzzards occasionally lost markers because the plastic broke between the hole through which the retaining pin passed and the edge of the marker (Picozzi 1971). Laminated plastic markers may not be suitable for use on falcons because of possible severe wing abrasion.

Wing markers should be sized and fitted properly. Markers that are too small are difficult to observe, and markers that are too large may hamper flight. Wallace et al. (1980) equipped nestling Black Vultures (*Coragyps atratus*) and Turkey Vultures with two sizes of marker of the same design. Nestlings with the larger marker (1.5 times as long and 1.9 times the surface area of the smaller marker) fledged on average two weeks later than unmarked vultures. The larger markers caused asynchrony in wing beat, affected soaring ability, and fluttered during flight. Fledging dates of nestlings with the smaller marker were similar to those of unmarked nestlings, and their flight appeared to be unimpaired. If the fit is too loose, markers can cause irritation, and become caught on sticks or other objects, or lost. If the fit is too tight, markers may cause excessive feather wear and abrade the wing.

Mudge and Ferns (1978) developed an equation, $T = 5.6L - 411$, to estimate suitable marker size (for a single tag on the upper surface of the wing) where T = tag area in mm^2, L = wing length in mm, and width to length ratio of the marker = 3:7. Vinyl-coated nylon fabric should be cut shiny side facing out, and such that the completed marker follows the natural contour of the wing. Markers cut with the shiny side facing in are more likely to curl up when attached to the bird, making them a poor fit and difficult to read. Laminated plastic markers may be curved to the contour of the wing by heating the marker and bending it to the desired shape (Picozzi 1971).

Holes for pins, rivets, and other fasteners should be punched in vinyl-coated nylon markers using a leather punch, awl, or dissecting needle appropriate for the desired size of the hole. Holes in laminated plastic markers should be drilled with a fine bit. The area around the hole may be reinforced with a washer or other material to counteract wear and prevent tearing or breaking that can lead to marker loss.

Unless the number of birds marked is small, colors alone cannot identify individuals. Furthermore, use of colors may be governed by regional, national, or international protocols that restrict the available colors. Thus, colors usually should be used to denote general information and, if necessary, characters should be used to identify individuals. Wings without a marker should not be part of a marking scheme; this prevents birds that have lost a marker from being misidentified. Marking schemes requiring observation of two wing markers to obtain a single type of data should be avoided so that at least some data still can be gathered if one wing marker is lost or unseen. If marker color is used to denote only one type of information, then left and right markers should be the same. If marker color is used to encode two types of data, then each wing should provide a separate type of information. Characters identifying individuals always should be the same on both markers.

Characters should be as large as possible, extending over the entire exposed portion of the marker. Wrap-around markers typically are preened such that a portion of the marker is obscured, and characters should not be printed there. Characters made from permanent marking pens tend to fade quickly; paint (from paint sticks available at arts and crafts stores) is longer lasting (J. Smallwood, pers. obs.). Buckley (1998) reported that the numbers on cattle ear tags used as wing markers sometimes fade. Printing the band number and address of the researcher on the reverse side of each marker enables identification and reporting if the marker alone is retrieved.

Wing markers have been attached in a number of ways. Wrap-around markers have been fastened with metal eyelets (Southern 1971), staples (Curtis et al. 1983), grommets (Servheen and English 1979), and pop rivets (Kochert et al. 1983). Pop rivets should be stainless steel rather than aluminum or copper. Various fas-

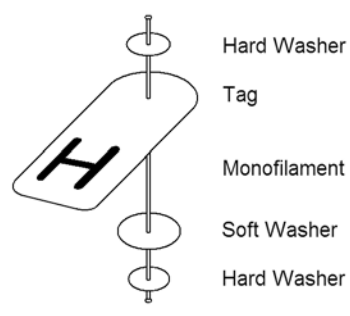

Figure 4. American Kestrel (*Falco sparverius*) wearing piercing marker (left) (photo courtesy of C. Meyer). The single marker is attached to the upper surface of the wing by a monofilament pin that pierces the patagium. The monofilament pin is depicted longer than is needed for clarity; actual distance between hard plastic washers is 4 mm (right) (Smallwood and Natale 1998; drawing courtesy of N. Smallwood).

teners have been used to secure piercing markers to the patagium, including metal pins and washers (Mudge and Ferns 1978), nylon pins and washers (Village 1982), plastic cattle-ear tags (Wallace et al. 1980), and pop rivets (Stiehl 1983). Materials used as fasteners should be smooth and round in cross-section, such as the 80-lb test monofilament fishing line used by Smallwood and Natale (1989; Fig. 4), so that any rotation does not injure the tissue surrounding the hole in the patagium.

When applying a piercing wing marker great care must be taken to avoid bones, muscles, tendons, and blood vessels. Isopropyl alcohol can be used to wet feathers to afford better visibility during fastening (Sweeney et al. 1985), as well as to cleanse the skin that is pierced. If a minor blood vessel is ruptured, bleeding usually is limited to one or two drops. A pinch of powdered alum or other coagulant usually stops the bleeding immediately. The fastener should pierce an area slightly distal to the elbow joint at a point about 1/3rd the distance from the biceps to the leading edge of the spread patagium (i.e., a little closer to the biceps) (Smallwood and Natale 1989; Fig. 5). If the fastener is not sufficiently sharp to puncture the patagium easily, a tool such as a dissecting needle may be used to make the smallest hole through which the fastener can pass. Fasteners must hold the marker snugly and securely in place, but not so tightly as to restrict circulation or damage tissue. Pop rivets should be crimped by hand; a rivet tool should not be used because it crimps pop rivets much too tightly, and will crush the patagium (Seel et al. 1982). Persons should consider how the marker contacts the wing when folded. If folding the wing results in the sharp edge of a washer or other fastener rubbing against the biceps, a piece of wing marker fabric (a soft washer) (Fig. 4) may be used to reduce the likelihood of injury (Smallwood and Natale 1989).

During the first few days or weeks following attachment, birds may preen and tug at the markers, presumably in attempts to remove them (Mills 1975, Sweeney et al. 1985). An adult Prairie Falcon removed a marker within 10 minutes of application, and an adult Swainson's Hawk (*B. swainsoni*) removed its wing marker within one week of marking (Fitzner 1980, Kochert et al. 1983). After this initial period, however, most marked birds accept wing markers and do not preen them excessively (Sweeney et al. 1985, Watson 1985).

Although wrap-around and piercing markers both work well with raptors, the latter have certain advantages. Piercing markers can be attached to nestlings at a younger age, whereas wrap-around markers require considerable feather development to hold the marker in place. Piercing markers, other than the fold-over type, do not involve the leading edge of the wing. This is an area where tissue irritation commonly is noted with wrap-around markers and is a critical part of the wing with respect to aerodynamics. The piercing fastener also prevents the marker from rotating around the wing, which has been observed with wrap-around markers (Watson 1985; R. McClelland, pers. comm.).

Minor feather wear and callusing of the patagium have been the most commonly reported effects of wing markers on raptors (Kochert et al. 1983). These effects are caused by chafing of the marker against the wing and in most cases are probably of little consequence. Many workers have observed no feather wear or tissue irritation (e.g., Hewitt and Austin-Smith 1966, Wallace et al. 1980). Indeed, consistent severe abrasion has been noted only with falcons wearing wrap-around markers (Sherrod et al. 1981, Kochert et al. 1983). That said, abrasion occasionally can be severe with some individuals of other species (Harmata 1984). Design, materials, fit, and attachment all influence feather wear and tissue irrita-

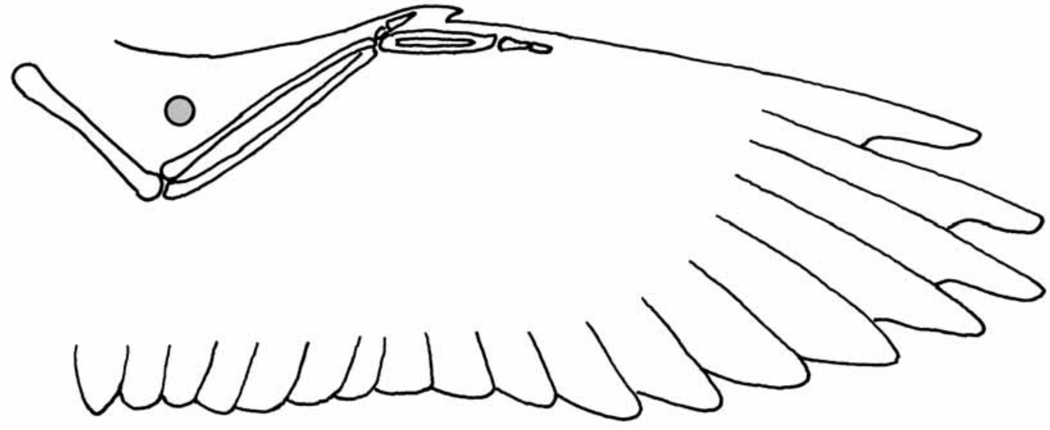

Figure 5. Location on the patagium for piercing fastener (shaded). See text for position relative to biceps and leading edge of patagium. Great care must be taken to avoid muscles, tendons, and blood vessels (redrawn by J. Smallwood from Smallwood and Natale 1998).

tion. A properly fitted and attached marker of a suitable material minimizes the chance of severe abrasion.

Many biologists have found that properly fitted wing markers did not affect flight (Hewitt and Austin-Smith 1966, Mills 1975, Wallace et al. 1980, Kochert et al. 1983). On the other hand, Howe (1980) suggested that wrap-around wing markers worn by Willets (*Catoptrophorus semipalmatus*) increased aerodynamic drag and caused abnormal feather replacement during molts. Marked Willets frequently shook their bodies during flight, suggesting some discomfort.

Wing markers did not affect survival of marked birds in several studies (e.g., Hewitt and Austin-Smith 1966, Kochert et al. 1983). In contrast, marked Willets apparently were more susceptible to predation and nutritional stress during migration, and wing markers may have reduced survival of Ring-billed Gulls (*Larus delawarensis*) and Band-tailed Pigeons (Howe 1980, Curtis et al. 1983, Southern and Southern 1985). Only one of 17 (6%) American Kestrels fitted with wing markers returned to a wintering area the year after capture, whereas 21–27% of banded kestrels returned (Bolen and Derden 1980). In each of the above studies, birds wore wrap-around markers on wings that were relatively long or had rapid wing beats, or both.

Occasionally, an accident involving a wing marker results in the death of a marked bird. A fledgling Bald Eagle that apparently had jumped from its nest and caught one of its markers on a branch died as a result (Gerrard et al. 1978). Non-lethal harm also is possible. Sherrod et al. (1981) suggested that wing markers might make foraging Peregrine Falcons more conspicuous to their potential prey, resulting in lower foraging success and presumably higher mortality. On the other hand, wing-marked Prairie Falcons examined by Kochert et al. (1983) appeared in good nutritional condition.

Studies examining effects of wing markers on breeding behavior and reproduction of raptors suggest that the effects usually are negligible. Marking did not affect nest-site fidelity of Black Vultures, and five of six adult Swainson's Hawks captured and wing-marked on their territories returned to their nests the following spring (Fitzner 1980, Wallace et al. 1980). Breeding success of Red-tailed Hawks, Golden Eagles, American Kestrels, Prairie Falcons, and Common Ravens (*Corvus corax*) for which at least one member of the pair was marked did not differ significantly from that of unmarked pairs (Kochert et al. 1983, Phillips et al. 1991, Smallwood and Natale 1998). Wallace et al. (1980) observed that all young were fledged from all eight Turkey Vulture and two of three Black Vulture nests where at least one adult was marked.

Harmata (1984:177) suggested that wing markers disrupted relationships between members of Bald Eagle pairs captured at their wintering area. In contrast, wing-marked Golden Eagles appeared to be accepted by other eagles and participated in all the normal breeding behaviors (Phillips et al. 1991).

Wing coloration is important to social relationships in some birds including, for example, Red-winged Blackbirds (*Agelaius phoeniceus*) (Smith 1972). In raptors without natural, colored signal patches on the wings, wing coloration probably is not as important in determining social relationships. However, some raptors, including some harriers and kestrels, exhibit marked sexual dichromatism, so body color likely plays an important role in social behavior in general and breeding behavior in particular. Such species could be especially vulnerable to negative effects of colored wing markers. Although marked American Kestrels appear to behave normally (Mills 1975, Smallwood and Natale 1989), quantitative data are lacking. Until potential behavioral effects are evaluated more fully, wing markers should be used cautiously, with full awareness of unintended consequences. Studies in which wing markers are used should be designed so that quantitative analyses of marker effects are possible. Particular attention should be directed toward discriminating the effects of capture and handling from those of marking *per se*, and evaluating the influences of age, sex, and social status of the marked bird and time of marker application.

TEMPORARY MARKERS

Dyes, Paints and Inks

Dyes and paints have been used to mark a variety of raptors including Bald Eagles (Southern 1963), Golden Eagles (Ellis and Ellis 1975), Verreaux's Eagles (*A. verreauxii*) (Gargett 1973), and Snowy Owls (*Bubo scandiaca*) (Keith 1964). A principal advantage is that no materials are attached to the bird; the color of the plumage is simply altered. This makes the technique suitable for use with almost any species. A chief disadvantage is that even the most permanent dyes, paints, or inks will color the bird only until the next molt. This restricts the technique to short-term studies or applications where birds can periodically be re-marked. Suitable applications include studies of individual development of nestlings from hatching (too young to band) to fledging, studies of nestling behavior, and studies of birds at seasonal concentrations if observations during other times of the year or subsequent years are not of interest. Knowledge of the molt sequence of the subject species is important in predicting marker life; temporary markers have been employed to study molt sequence in Northern Saw-whet Owls (*Aegolius acadicus*) (Evans and Rosenfield 1987, E. Jacobs, pers. comm.)

To effectively mark a bird's plumage, a dye must penetrate feathers well (i.e., be readily absorbed), produce a bright color, and resist fading or washing for several months. Three dyes, Malachite Green, Rhodamine B Extra (bright pink), and picric acid (yellow), consistently display good penetration and brilliance of color, and have the best color retention of dyes tried (Wadkins 1948, Bendell and Fowle 1950, Kozlik et al. 1959). Picric acid, however, sometimes explodes if allowed to crystallize during long-term storage. Therefore, it must be used with great care. Other dyes have been used with variable or poor success. Jones (1950) noted identification problems caused by differential fading of component dyes; the least permanent dye faded first, changing the color of the mark to that of the more permanent dye. Because of this, dyes should not be mixed to produce a third color. Dyes are most effective when applied in a 33% alcohol/66% water solution (Wadkins 1948). Dyes can be applied by spraying, brushing, or dipping the appropriate feathers. Complete saturation is necessary for best results. Dyed feathers should be completely dry before the bird is released. Dyes are most effective with species with light plumage (Kozlik et al. 1959). The BBL recommends that dyes not be used on primary feathers because of the potential for feathers to wear more rapidly (M. Gustafson, pers. comm.).

Both brush-on and spray paints have been used to color plumage, with model airplane paints and bright fluorescent spray paints being used most frequently. Swank (1952) recommended that only flight feathers be painted. Paint should not be applied so heavily that feathers are matted together. Petersen (1979) used a cardboard template to produce marks of a certain shape and to prevent spray paint from drifting onto other body parts. Paint always should be allowed to dry before a bird is released.

Non-toxic blue ink from markers has been applied to more than 8,500 Northern Saw-whet Owls in Wisconsin to study molt sequence (E. Jacobs, pers. comm.). The ink was visible on recaptured birds for up to two years.

Feather Imping

Imping is a technique commonly used in falconry in which a broken flight feather is repaired by replacing the missing distal end of the feather with a corresponding piece from a previously molted feather (Fig. 6). The shaft of the replacement piece is held in place against the shaft of the broken feather with a pin or fine dowel that fits snugly inside both shafts, and may be further secured with glue. Birds may be marked by clipping a natural feather, typically a tail feather, and imping a dyed or brightly colored feather of another species (Wright 1939, Hamerstrom 1942). To increase conspicuousness, the marker feather may be longer than the other natural feathers (Fig. 6). Individual marks are produced by a combination of marker color, alphanumeric or symbol applied to the replacement feather and position in tail (left, center, right).

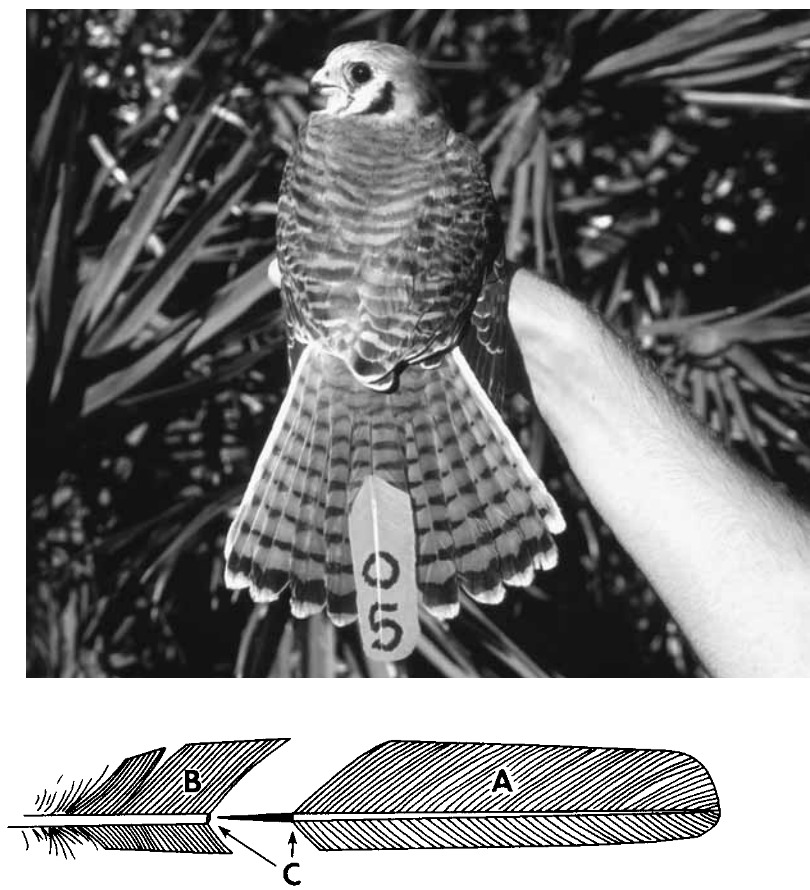

Figure 6. Imping. American Kestrel *(Falco sparverius)* with imped tail feather (top) (photo courtesy of J. Smallwood). The needle protruding from the marker feather (A) is pushed into the natural feather (B) until the cut shafts (C) meet (drawing from Wright 1939, in Young and Kochert 1987).

Feather Clipping

Feather clipping was used to mark large African raptors in the 1970s (Snelling 1970, Gargett 1973, Kemp 1977) but has not been used since, due to its limitations (D. Oschadleus, pers. comm.). The technique involves cutting "windows" in the wings or tail by clipping the vanes from part of the shafts of several adjacent feathers. Individuals are identified by varying the shape and position of the mark(s). Clipping should be done judiciously so that flight is not hampered. The principal advantage of the technique is its simplicity; no materials are used, and plumage is not colored. Clipping is unlikely to affect behavior (Harmata 1984). The chief disadvantage is that marks are inconspicuous when a bird is perched (Snelling 1970, Gargett 1973); this renders the technique of limited use in species that do not fly regularly. Also, the number of shape and position combinations that can be used effectively is limited (Gargett 1973) and the pattern is lost with molting, making this a short-term marking technique. The technique has received little attention in North America.

ACKNOWLEDGMENTS

We thank Mary Gustafson, Tracy Fleming, and Paul Doherty for comments and suggestions on earlier drafts of this manuscript, and Nathan Smallwood for enhancing photographs in Figures 3 and 4.

LITERATURE CITED

ANDERSON, A. 1963. Patagial tags for waterfowl. *J. Wildl. Manage.* 27:284–288.

ANTHONY, R.G., E.D. FORSMAN, A.B. FRANKLIN, D.R. ANDERSON, K.P. BURNHAM, G.C. WHITE, C.J. SCHWARZ, J. NICHOLS, J.E. HINES, G.S. OLSON, S.H. ACKERS, S. ANDREWS, B.L. BISWELL, P.C. CARLSON, L.V. DILLER, K.M. DUGGER, K.E. FEHRING, T.L. FLEMING, R. P. GERHARDT, S.A. GREMEL, R.J. GUTIERREZ, P.J. HAPPE, D.R. HERTER, J.M. HIGLEY, R.B. HORN, L.R. IRWIN, P. . LOSCHL, J.A. REID AND S.G. SOVERN. 2006. Status and trends in demography of Northern Spotted Owls, 1985–2003. *Wildl. Monogr.* 163:1–48.

BARCLAY, R.M.R. AND G.P. BELL. 1988. Marking and observational techniques. Pages 59–79 *in* T.H. Kunz [ED.], Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, DC U.S.A.

BEDNARZ, J.C. 1987. Successive nesting and autumnal breeding in Harris' Hawks. *Auk* 104:85–96.

BENDELL, I.F.S. AND C.D. FOWLE. 1950. Some methods for trapping and marking Ruffed Grouse. *J. Wildl. Manage.* 14:480–482.

BERGER, D.D. AND H.C. MUELLER. 1960. Band retention. *Bird-Banding* 31:90–91.

BOLEN, E.G. AND D.S. DERDEN. 1980. Winter returns of American Kestrels. *J. Field Ornithol.* 51:174–175.

BROLEY, C.L. 1947. Migration and nesting of Florida Bald Eagles. *Wilson Bull.* 59:3–20.

BROWNIE, C., D.R. ANDERSON, K.P. BURNHAM AND D.S. ROBSON. 1985. Statistical inference from band recovery data - a handbook. USDI Fish and Wild1ife Service Resource Publication No. 156, 2nd Ed. Washington, DC U.S.A.

BUCKLEY, N.J. 1998. Fading of numbers from patagial tags: a potential problem for long-term studies of vultures. *J. Field Ornithol.* 69:536–539.

CRAIG, G.R., G.C. WHITE AND J.H. ENDERSON. 2005. Survival, recruitment, and rate of population change of the Peregrine Falcon population in Colorado. *J. Wildl. Manage.* 68:1032–1038.

CURTIS, P.D., C.E. BRAUN AND R.A. RYDER. 1983. Wing markers: visibility, wear, and effects on survival of Band-tailed Pigeons. *J. Field Ornithol.* 54:381–386.

DEL HOYO, J., A. ELLIOTT AND J. SARGATAL [EDS.]. 1994. Handbook of the birds of the world, Vol. 2. New World Vultures to Guineafowl. Lynx Edicions, Barcelona, Spain.

DINSMORE, S.J. AND D.H. JOHNSON. 2005. Population analysis in wildlife biology. Pages 154–184 *in* C. E. Braun [ED.], Research and management techniques for wildlife and habitats, 6th Ed. The Wildlife Society, Bethesda, MD U.S.A.

ELLIS, D.H. AND C.H. ELLIS. 1975. Color marking Golden Eagles with human hair dyes. *J. Wildl. Manage.* 39:445–447.

EVANS, D.L. AND R.N. ROSENFIELD. 1987. Remegial molt in fall migrant Long-eared and Northern Saw-whet owls. Pages 209–214 *in* R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre [EDS.], Biology and conservation of northern forest owls. USDA Forest Service General Technical Report RM-142, Rocky Mountain Research Station, Ft. Collins, CO U.S.A.

FERNER, J.W. 1979. A review of marking techniques for amphibians and reptiles. *Soc. Study Amphib. Reptiles Herpetol. Circ.* 9.

FITZNER, R.E. 1980. Behavioral ecology of the Swainson's Hawk (*Buteo swainsoni*) in Washington. Pacific Northwest Laboratory, Richland, WA U.S.A.

FORSMAN, E.D., A.B. FRANKLIN, F.M. OLIVER AND J.P. WARD. 1996. A color band for Spotted Owls. *J. Field Ornithol.* 67:507–510.

FRANCES, C.M. AND P. SAUROLA. 2002. Estimating age-specific survival rates of Tawny Owls-recaptures versus recoveries. *J. Appl. Stat.* 29:637–647.

FYFE, R.W. AND R.R. OLENDORFF. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. *Can. Wildl. Serv. Occas. Pap.* 23.

FURRER, R.K. 1979. Experiences with a new back-tag for open-nesting passerines. *J. Wildl. Manage.* 43:245–249.

GARGETT, V. 1973. Marking Black Eagles in the Matopos. *Honeyguide* 76:26–31.

GERRARD, I.M., D.W.A. WHITFIELD, P. GERRARD, P.N. GERRARD AND W.I. MAHER. 1978. Migratory movements and plumage of subadult Saskatchewan Bald Eagles. *Can. Field-Nat.* 92:375–382.

GONZALEZ, L.M., B. HEREDIA, J.L. GONZALEZ AND J.C. ALONSO. 1989. Juvenile dispersal of Spanish Imperial Eagles. *J. Field Ornithol.* 60:369–379.

GOULD, W.R. AND M.R. FULLER. 1995. Survival and population size estimation in raptor studies: a comparison of two methods. *J. Raptor Res.* 29:256–264.

GUARINO, I.L. 1968. Evaluation of a colored leg tag for starlings and blackbirds. *Bird-Banding* 39:6–13.

HALL, G.H. 1970. Great moments in action: the story of the Sun Life falcons. *Can. Field-Nat.* 84: 209–230.

HAMERSTROM, F. 1942. Dominance in winter flocks of chickadees. *Wilson Bull.* 54:32–42.

HARMATA, A.R. 1984. Bald Eagles of the San Luis Valley, Colorado: their winter ecology and spring migration. Ph.D. dissertation, Montana State University, Bozeman, MT U.S.A.

——— AND D.W. STAHLECKER. 1993. Fidelity of migrant Bald Eagles to wintering grounds in southern Colorado and northern New Mexico. *J. Field Ornithol.* 64:129–134.

HENCKEL, R.E. 1976. Turkey Vulture banding problem. *N. Am. Bird Bander* 1:126.

HEWITT, O.H. AND P.J. AUSTIN-SMITH. 1966. A simple wing tag for field-marking birds. *J. Wildl. Manage.* 30:625–627.

HOUSTON, C.S. AND P. BLOOM. 2005. Turkey Vulture history: the switch from leg bands to patagial tags. *N. Am. Bird Bander* 30: 59–64.

HOWE, M.A. 1980. Problems with wing tags: evidence of harm to Willets. *J. Field Ornithol.* 51:72–73.

HOWITZ, J.L. 1981. Determination of total color band combination. *J. Field Ornithol.* 52:317–324.

HULL, B. AND P. BLOOM. 2001. The North American bander's manual for raptor banding techniques. The North American Banding Council, Point Reyes, CA U.S.A.

JONES, G.F. 1950. Observations of color-dyed pheasants. *J. Wildl. Manage.* 14:81–83.

KAUFFMAN, M.J., W.F. FRICK AND J. LINTHICUM. 2003. Estimation of habitat-specific demography and population growth for Peregrine Falcons in California. *Ecol. Applic.* 13:1802–1816.

KEITH, L.B. 1964. Territoriality among wintering Snowy Owls. *Can. Field-Nat.* 78:17–24.

KEMP, A.C. 1977. Some marking methods used on a variety of southern African raptors. *Safring News* 6:38–43.

KOCHERT, M.N., K. STEENHOF AND M.Q. MORITSCH. 1983. Evaluation of patagial markers for raptors and ravens. *Wildl. Soc. Bull.* 11:271–281.

KOZLIK, F.M., A.W. MILLER AND W.C. RIENECKER. 1959. Color-marking white geese for determining migration routes. *Calif. Fish Game* 45:69–82.

LABISKY, R.F. AND S.H. MANN. 1962. Backtag markers for pheasants. *J. Wildl. Manage.* 26:393–399.

LOKEMOEN , J.T. AND D.E. SHARP. 1985. Assessment of nasal marker materials and designs used on dabbling ducks. *Wildl. Soc. Bull.* 13:53–56.

MARION, W.R. AND J.D. SHAMIS. 1977. An annotated bibliography of bird marking techniques. *Bird-Banding* 48:42–61.

MCCLELLAND, B.R., P.T. MCCLELLAND AND M.E. MCFADZEN. 2006. Longevity of Bald Eagles from autumn concentrations in Glacier National Park, Montana, and assessment of wing-marker durability. *J. Raptor Res.* 40: *in press*.

MCCOLLOUGH, M.A. 1990. Evaluation of leg markers for Bald Eagles. *Wildl. Soc. Bull.* 18:298–303.

MENDELSOHN, J. 1982. The feeding ecology of the Black-shouldered Kite *Elanus caeruleus* (Aves: Accipitridae). *Durban Mus. Novit.* 13:75–116.

MERETSKY, V.J. AND N.F.R. SNYDER. 1992. Range use and movements of California Condors. *Condor* 94:313–335.

MILLER, K.E. AND J.A. SMALLWOOD. 1997. Natal dispersal and philopatry of Southeastern American Kestrels in Florida. *Wilson Bull.* 109:226–232.

MILLS, G.S. 1975. Winter population study of the American Kestrel in central Ohio. *Wilson Bull.* 87:241–247.

MORGENWECK, R.O. AND W.H. MARSHALL. 1977. Wing marker for American Woodcock. *Bird-Banding* 48:224–227.

MORRISON, J.L. 2003. Age-specific survival of Florida's Crested Caracaras. *J. Field Ornithol.* 74:321–330.

MOSSMAN, M. 1976. Turkey Vultures in the Baraboo Hills, Sauk County, Wisconsin. *Passenger Pigeon* 38:93–99.

MUDGE, G.P. AND P.N. FERNS. 1978. Durability of patagial tags on Herring Gulls. *Ringing & Migr.* 2:42–45.

MURRAY, D.L. AND M.R. FULLER. 2000. A critical review of effects of marking on the biology of vertebrates. Pages 15–64 *in* L. Boitani and T.F. Fuller [EDS.], Research techniques in animal ecology. Columbia University Press, New York, NY U.S.A.

NELSON, R.W. 1988. Do natural large broods increase mortality of parent Peregrine Falcons? Pages 719-728 in T.J. Cade, J.H. Enderson, C.G. Thelander, and C. White [EDS.], Peregrine Falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID U.S.A.

NESBITT, S.A. 1979. An evaluation of four wildlife marking materials. *Bird-Banding* 50:159.

NIETFELD, M.T., M.W. BARRETT, AND N. SILVY. 1996. Wildlife marking techniques. Pages 140–168 *in* T. A. Bookhout [ED.], Research and management techniques for wildlife and habitats, 5th Ed. The Wildlife Society, Bethesda, MD U.S.A.

PETERSEN, L. 1979. Ecology of Great Horned Owls and Red-tailed Hawks in southeastern Wisconsin. *Wis. Dep. Nat. Resour. Tech. Bull.* 111.

PHILLIPS, R.L., J.L. CUMMINGS AND J.D. BERRY. 1991. Effects of patagial markers on the nesting success of Golden Eagles. *Wildl. Soc. Bull.* 19:434–436.

PICOZZI, N. 1971. Wing tags for raptors. *The Ring* 68–69:169–170.

———. 1984. Breeding biology of polygynous Hen Harriers *Circus c. cyaneus* in Orkney. *Ornis Scand.* 15:1–10.

——— AND D. WEIR. 1976. Dispersal and cause of death of buzzards. *British Birds* 69:193–201.

PLATT, S.W. 1980. Longevity of Herculite leg jess color markers on the Prairie Falcon (*Falco mexicanus*). *J. Field Ornithol.* 51:281–282.

SEEL, D.C., A.G. THOMSON AND G.H. OWEN. 1982. A wing-tagging system for marking larger passerine birds. *Bangor Res. Station Occas. Pap.* 14.

SERVHEEN, C. AND W. ENGLISH. 1979. Movements of rehabilitated Bald Eagles and proposed seasonal movement patterns of Bald Eagles in the Pacific Northwest. *Raptor Res.* 13:79–88.

SHERROD, S.K., W.R. HEINRICH, W.A. BURNHAM, J.H. BARCLAY AND T.J. CADE. 1981. Hacking: a method for releasing Peregrine Falcons and other birds of prey. The Peregrine Fund, Inc., Ft. Collins, CO U.S.A.

SILVY, N.J., R.R. LOPEZ AND M.J. PETERSON. 2005. Wildlife marking techniques. Pages 339–376 *in* C.E. Braun [ED.], Research and management techniques for wildlife and habitats, 6th Ed. The Wildlife Society, Inc., Bethesda, MD U.S.A.

SMALLWOOD, J.A. AND C. NATALE. 1998. The effect of patagial tags on breeding success in American Kestrels. *N. Am. Bird-Bander* 23:73–78.

SMITH, D.G. 1972. The role of epaulets in the Red-winged Blackbird (*Agelaius phoeniceus*) social system. *Behaviour* 41:251–268.

SNELLING, J.C. 1970. Some information obtained from marking large raptors in the Kruger National Park, Republic of South Africa. *Ostrich* 8:415–427.

SOUTHERN, W.E. 1963. Winter populations, behavior, and seasonal dispersal of Bald Eagles in northwestern Illinois. *Wilson Bull.* 75:42–55.

———. 1971. Evaluation of a plastic wing marker for gull studies. *Bird-Banding* 42:88–91.

SOUTHERN, L.K. AND W.E. SOUTHERN. 1985. Some effects of wing tags on breeding Ring-billed Gulls. *Auk* 102:38–42.

STIEHL, R.B. 1983. A new attachment for patagial tags. *J. Field Ornithol.* 54:326–328.

SWANK, W.G. 1952. Trapping and marking of adult nesting doves. *J. Wildl. Manage.* 16:87–90.

SWEENEY, T.M., J.D. FRASER AND J.S. COLEMAN. 1985. Further evaluation of marking methods for Black and Turkey vultures. *J. Field Ornithol.* 56:251–257.

THOMPSON, W.L., G.C. WHITE AND C. GOWAN. 1998. Monitoring vertebrate populations. Academic Press, San Diego, CA U.S.A.

VARLAND, D.E. AND T.M. LOUGHIN. 1992. Social hunting in broods of two and five American Kestrels after fledging. *J. Raptor Res.* 26:74–80.

VILLAGE, A. 1982. The home range and density of kestrels in relation to vole abundance. *J. Anim. Ecol.* 51:413–428.

VIÑUELA, J. AND J. BUSTAMANTE. 1992. Effect of growth and hatching asynchrony on the fledging age of Black and Red Kites. *Auk* 109:748–757.

WADKINS, L.A. 1948. Dyeing birds for identification. *J. Wildl. Manage.* 12:388–391.

WALLACE, M.P., P.G. PARKER AND S.A. TEMPLE. 1980. An evaluation of patagial markers for cathartid vultures. *J. Field Ornithol.* 51:309–314.

WARKENTIN, I.G., P.C. JAMES AND L.W. OLIPHANT. 1990. Body morphometrics, age structure, and partial migration of urban Merlins. *Auk* 107:25–34.

WATSON, J.W. 1985. Trapping, marking, and radio-monitoring Rough-legged Hawks. *N. Am. Bird Bander* 10:9–10.

WHITE, G.C. AND K.P. BURNHAM. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46 Supplement:120–139.

WILLIAMS, B.K., J.D. NICHOLS AND M.J. CONROY. 2002. Analysis and management of vertebrate populations. Academic Press, San Diego, CA U.S.A.

WRIGHT, E.G. 1939. Marking birds by imping feathers. *J. Wildl. Manage.* 3:238–239.

YOUNG, L.S. AND M.N. KOCHERT. 1987. Marking techniques. Pages 125–156 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. National Wildlife Federation, Washington, DC U.S.A.