Fig. 1. This adult Turkey Vulture is actively molting its primaries and middle secondaries. Wasatch Mountains, Utah; 27 September 2002. © Jerry Liguori.
Good feather condition is an essential component of the lives of birds. All birds undergo the process of molt, replacing worn feathers with new ones, and this process is typically completed annually. Birds normally molt only when sufficient resources are available and when it fits into their life cycles. The process of active flight feather molt is often inserted into the lives of birds when other energetic demands are at a low point, but for large species like raptors, molt takes place over an extended period and often overlaps with breeding. This overlap can be on the order of four months—shorter in smaller species, longer in larger species. This molt typically occurs between April and September, in order to provide ample time to replace flight feathers prior to migration. In contrast, most passerines require less time to molt, undergoing a complete prebasic molt after the breeding season and just before fall migration.

Molt and migration can be physiologically expensive processes for birds, and conventional wisdom suggests that the two processes typically do not occur simultaneously (Payne 1972, Clark 2001, Elphick et al. 2001). However, whether the separation of these two processes is driven by physiological demands or aerodynamic limitations, or by some combination of the two, remains unclear and may depend on the species. Flight feather molt results in gaps in the wing surface, which could compromise successful migration. Exceptions are known for certain taxa, including Herring Gull (Steve N. G. Howell, personal communication), Black Tern (Zenatello et al. 2002), and several swallow species (Howell, personal communication), which undergo slow replacement of flight feathers during migration. Both the Red-eyed Vireo and Rose-breasted Grosbeak are exceptional among temperate breeding long-distance migrant passerines in that they molt flight feathers during fall migration (Tordoff and Mengel 1956, Cannell et al. 1983). Despite previous mention of this phenomenon in the family Accipitridae (Liguori 2000, 2002, 2005, 2009), it is not widely discussed in the molt literature. Pyle (2008) gives raptor molt its most thorough treatment to date, mentioning active wing molt during migration for accipiters and for Broad-winged Hawk.

Here we provide accounts of 11 raptor species that actively molt flight feathers during migration, and we give synopses of the molt patterns for each species. These accounts are based on our review of thousands of images from 15 hawk migration sites across North America where we have studied and photographed raptors.
Our research has revealed the following insights:

- At least six species of Western raptors actively molt flight feathers during fall migration.
- At least six species of Eastern raptors actively molt flight feathers during spring migration.
- Swallow-tailed and Plumbeous Kites actively molt flight feathers while migrating through Panama in the fall.
- Typically, raptors in active molt during fall migration (August–November) are replacing feathers among the outer five primaries.
- Second-year birds actively molt during fall migration less frequently than older adults. Second-year birds actively molting are often females, and are probably breeders from the previous summer.

The results presented here are based on a combination of more than 30 years of raptor field observations as well as the inspection of more than 40,000 raptor images. We encourage others to follow up on our work, and to provide additional quantitative support for our findings.

Species Accounts

All raptors have ten functional primaries, with P1 the innermost and P10 the outermost. But there are fundamental differences in the pattern of flight feather replacement in the hawks (Accipitridae) and vultures (Cathartidae) vs. falcons (Falconidae). Hawks and vultures molt from the innermost primary (P1) sequentially outward to the outermost primary (P10), and falcons start in the middle primaries (P4) and replace feathers in both directions. In many large species, not all feathers are replaced each year, resulting in a stepwise replacement of flight feathers in which several waves of molt occur simultaneously. In larger raptors (for example, eagles), in which the flight feathers are not replaced completely during the prebasic molt, obligate stepwise molt occurs and is present from the second prebasic molt forward (Pyle 2008; Howell in preparation).

Fig. 2. Shown on this page and on p. 37 (lower left) are four of 640 Swallow-tailed Kites migrating past the Canopy Tower between noon and 3 p.m. The bird on p. 37 is molting P4 and P5, and the bird on the center right of this page is molting P6 and P7. Canopy Tower, Panama; 11 August 2008. © Brian Sullivan.

Fig. 3. [Opposite Page, Top Right] This Swallow-tailed Kite is molting P6 and P7. Canopy Tower, Panama; 11 August 2008. © Brian Sullivan.

Fig. 4. [Opposite Page, Bottom Right] This adult Plumbeous Kite is actively molting flight feathers during migration. P3 is actively growing, and P4 has been shed. Central Panama; 12 August 2008. © Brian Sullivan.
**Turkey Vulture**
During September and October, Turkey Vultures (and to a lesser extent Black Vultures in the northern parts of their range) can be seen molting during migration. Many Turkey Vultures are short-distance migrants, whereas others migrate long distances. Western birds appear to molt more frequently during migration than Eastern birds (Fig. 1, p. 34).

**Swallow-tailed Kite**
During the period 10–16 August 2008, we observed migrating Swallow-tailed Kites in central Panama. The majority of migrants there were actively molting flight feathers (Figs. 2 and 3). Most were molting primaries among P3–P7, and most often P7. We observed evidence of molt in adults only. We suggest that long-distance migrants such as Swallow-tailed Kites, which leave the U.S. shortly after breeding and show peak numbers on fall migration through Panama by mid-August, may slowly replace primaries during their southbound migration. It is unknown exactly when primary replacement starts, but Pyle (2008) notes that the definitive prebasic molt begins on the breeding grounds in North America and is then suspended for migration, typically with P3–P6 suspended in adults. Perhaps once birds near the wintering grounds, flight feather molt is again initiated, or perhaps after crossing the Gulf of Mexico, they continue molting. Resumed primary molt might also correspond to seasonal food abundance, but more study is needed. Kites have a low wing-load (ratio of body weight to wing surface area), which may allow them to undergo slow replacement of flight feathers during migration, as is seen in Black Tern (Zenatello et al. 2002).

**Plumbeous Kite**
Like the Swallow-tailed Kite, adult Plumbeous Kites were observed actively molting primaries during peak migration through Panama
10–16 August 2008 (Fig. 4). Typical patterns involved actively growing P3–P6. It is unclear from the literature when Plumbeous Kites initiate prebasic molt, but it is reasonable to assume that they may be similar to the congeneric Mississippi Kite in this regard, except that they molt during migration, which is not yet documented in Mississippi Kite. According to Pyle (2008), Mississippi Kites initiate prebasic molt on the breeding grounds and suspend it for migration. Much like Swallow-tailed Kites, Plumbeous Kites likely reinitiate flight feather molt at some point on their southbound migration, perhaps in anticipation of arrival on the winter grounds, or when flight conditions are optimal—even if they have to do so with compromised wing shape and aerodynamics. Or perhaps they don’t suspend molt at all (like swallows), as they don’t cross any significant water barriers.

**Osprey**

We found at least three examples of Ospreys molting during migration, all from the Atlantic Coast (Figs. 5 and 6). Ospreys exhibited stepwise molt, in which active flight feather molting is happening in multiple places simultaneously, with two waves of active molt occurring in the primaries, one starting at P6 or P7 and the other at P1. Ospreys initiate the definitive prebasic molt (annual complete molt after breeding) on the breeding grounds, typically suspend for migration, and then resume on the winter grounds (Pyle 2008). It is unclear whether the birds we observed were in the process of suspending prebasic molt for migration or perhaps were nearby breeders finishing their molt at the beginning of fall migration. More study is needed.

**Sharp-shinned Hawk**

In contrast to the larger Cooper’s Hawks, Sharp-shinned Hawks exhibit active molt during migration only infrequently, since they typically com-
plete molt prior to migration. It is possible that long-distance migrant accipiter species don’t typically molt while migrating. Perhaps due to the Sharp-shinned Hawk’s more northerly breeding distribution and longer migration, active molt was only noted in individuals migrating through the Intermountain West (Fig. 7). Perhaps individuals breeding farther south than the majority of the population have shorter migrations and can thus afford to molt and migrate simultaneously. More study is certainly needed.

**Cooper’s Hawk**

Based on our observations, we found that Cooper’s Hawks are the most frequently noted raptor actively molting during migration in the West (Figs. 8 and 9). Although other species seem to molt less frequently during migration, molt during migration appears to be a regular part of the Cooper’s Hawk’s life cycle, at least for Western montane breeders. Cooper’s Hawks are often seen completing their prebasic molt during September and October, typically molting the outer primaries and secondaries, along with a few rectrices. Some adults, however, are observed earlier in their prebasic molt cycle, growing middle primaries and initiating tail molt (Fig. 9).

**Fig. 5.** [Top Left] This adult **Osprey** is molting P5 and P9. Cape May Point, New Jersey; 29 September 2003. © Jerry Liguori.

**Fig. 6.** [Bottom Left] This adult **Osprey** is molting P5–P6 and P1–P2 in two waves of a “stepwise” molt pattern. Kiptopeke State Park, Virginia; 15 September 2005. © Brian Sullivan.

**Fig. 7.** [Right] This adult **Sharp-shinned Hawk** is actively molting its tail and flight feathers. The central tail feathers as well as a middle secondary and the middle primaries are in molt. Wasatch Mountains, Utah; 29 April 2002. © Jerry Liguori.
Northern Goshawk
Northern Goshawks are rarely seen actively molting during migration (Fig. 10). Being a larger species with a more protracted molt and heavier wing loading, the Northern Goshawk perhaps has little to gain by undergoing molt during its relatively short migration. The species may follow a strategy of molting on the breeding grounds throughout the long nesting cycle, and then suspending if needed, leading to stepwise replacement of flight feathers after the second year (Pyle 2008).

Broad-winged Hawk
Adult Broad-winged Hawks are rarely observed molting during fall migration; in fact, we found only one photograph of an adult in molt, at Veracruz, Mexico. Only a few such birds have been seen there in early October—fewer than one in a thousand (Howell, personal communication). Pyle (2008) notes that definitive prebasic molt can be completed either during southbound migration or on the winter grounds in after-second-year birds. Northbound second-year birds in spring often start their flight feather molt (beginning with the inner primaries and central tail feathers) in late April to early May, when they are seen in large numbers along or crossing the Great Lakes (Fig. 11).

Swainson’s Hawk
Like Broad-winged Hawks, adult Swainson’s Hawks are rarely seen molting during fall migration. Broad-winged and Swainson’s Hawks are the long-distance migration champions of the genus Buteo, and perhaps due to their extended migration, neither actively molts with regularity during fall. Like other migrant buteos, however, second-year Swainson’s Hawks in spring migration can be seen molting inner primaries at the onset of their second prebasic molt in March to early May (Fig. 12).

Red-tailed Hawk
In the West, adult Red-tailed Hawks are often seen molting during fall migration (Fig. 13), especially among populations using mountain ridges. Most adults are at the end of the definitive prebasic molt at this time, typically replacing outer primaries, secondaries, and

Fig. 8. [Left] This adult (after-second-year) Cooper’s Hawk is molting P9, S1, S5, and R2–R5. Wasatch Mountains, Utah; 21 September 2008. © Jerry Liguori.

Fig. 9. [Top Right] This adult (after-second-year) Cooper’s Hawk is molting P6, S1, and R1–R6. Goshute Mountains, Nevada; 3 October 1998. © Jerry Liguori.

Fig. 10. [Bottom Right] This adult (after-second-year) Northern Goshawk is molting S1 and R3–R4. Goshute Mountains, Nevada; 7 October 1999. © Jerry Liguori.
tail feathers during southbound migration. Second-year birds may be seen initiating their second prebasic molt during spring migration across North America.

**Ferruginous Hawk**

Ferruginous Hawks are short-distance migrants, and they rarely molt during migration. In spring, however, migrant second-year birds can be seen beginning primary and tail molt, and adults can sometimes be seen molting P8–P10 (Fig. 14).

**Golden Eagle**

Second-through-fourth-year Golden Eagles are frequently seen actively molting flight feathers during fall migration in the montane West (Fig. 15). Second-year birds are often initiating their second prebasic molt at this time, with S1 and S2 erupting, whereas third-year and fourth-year Golden Eagles are typically nearing the end of their prebasic molt, often replacing outer primaries, secondaries, and tail feathers. Adult Golden Eagles are rarely seen molting during fall migration. In spring, second-year birds can be seen beginning their flight feather molt as early as mid-April.
Peregrine Falcon

Adult Peregrine Falcons often possess two ages of flight feathers at a time, but it is uncommon to see them in active molt during fall migration. Adult Peregrine Falcons that do molt flight feathers during fall migration (Fig. 16) may be individuals that have experienced a difficult or energy-expensive breeding season. Peregrines are excellent fliers, equally adept at both powered and soaring flight. As such, small gaps in the wings may be tolerable during migration. In spring, second-year birds can be seen molting flight feathers on migration as early as April. Juvenile Peregrines begin to replace body feathers as early as February, unlike most juvenile raptors, which start body molt in April.

Discussion

Are These Molting Birds True Migrants?

One complication is that some of the birds observed at hawk watches are residents. How do we know that hawks observed in their prebasic molt are true migrants, as opposed to local residents? Although it is true that resident birds are observed at many migration sites in North America, skilled observers can separate them from actual migrants based on plumage and behavior. Usually, it is straightforward to distinguish high-flying migrants in sustained passage from local residents moving around. Local raptors at migration sites typically consist of one or two pairs; the sheer volume of birds seen at migration sites indicates that nearly all are migrants. However, there are coastal sites, such as the Marin Headlands just north of San Francisco, Curry Hammock along the Florida Keys, and Cape May, where local birds are known to wander back and forth repeatedly past the official count site.

We know that several species do not winter at certain migration sites (particularly in the montane West) due to
the climate, habitat type, or elevation. The Goshutes hawk watch in eastern Nevada is one of those sites. Resident species include single pairs of Northern Goshawks, Red-tailed Hawks, Golden Eagles, and Peregrine Falcons. These residents are seen regularly from mid-August to late September but depart thereafter. The high number of raptors observed and captured at the Goshutes indicates that almost all observed are indeed migrants. Resident adults are wise to plastic owl decoys and trapping operations, and they are nearly impossible to catch. The same can be said for Swallow-tailed and Plumbeous Kites migrating south through Panama in August. While some resident kites may be involved, kettles of 100+ moving quickly past at high elevation are indicative of migrants. Migrant Ospreys, especially along the Atlantic Coast, can be more difficult to discern since they overlap with breeders that congregate along the coast for days at a time in September before moving south.

**More Questions than Answers**
The relationships between active flight feather molt and other avian biological processes require further study, and here we can only put forth theories. Many long-distance migrant raptors do not appear to molt and migrate simultaneously with regularity, but patterns of migration distance and molt are still unclear. Pyle (2008) delineates molt timing for North American raptors. Many species apparently start their definitive prebasic molt on the breeding grounds, suspend molt for migration, and then complete wing molt on the wintering grounds. A few scenarios might explain the high proportion of Western migrants actively molting during migration. Perhaps they are late breeders, in the process of suspending ac-
tive molt during the first days of migration. Alternatively, they could be short-distance migrants nearing the winter grounds and resuming their prebasic molt. We hypothesize that late-breeding, high-elevation, montane populations of Western migrant raptors may lack the time to complete molt prior to fall migration; thus, they molt and migrate simultaneously. The effects of poor aerodynamics may be ameliorated partly on raptors that primarily use ridges for lift, as opposed to those primarily using thermal updrafts. More study is needed to find the answers. Other interesting questions worthy of further exploration include the following:

• Is extended molt timing related to a presumably later montane breeding season?
• Is migration distance a factor in determining whether a species or population molts during migration?
• Do migratory patterns differ among molting and non-molting birds? For example, do long-distance migrant populations of Sharp-shinned and Cooper’s Hawks suspend molt during migration, whereas short-distance migrant populations do not?
• And if so, where do these populations breed and winter, and what are the biological reasons for these differences?
• Are food availability and molt during migration related?

**Conclusions**

Many raptors actively molt during migration, especially in western North America. As we learn more about molt and its true physiological costs, we may better understand why certain species molt and migrate simultaneously while others do not. With the help of birders and ornithologists who observe, document, and study molt, we may indeed find the answers to these questions in the future, and we
will undoubtedly work out many new puzzles in the process.

Acknowledgments
We thank Steve N. G. Howell for inspiring the development of this manuscript, and for shedding light on the process of molt in general. Allen Fish and Buzz Hull of Golden Gate Raptor Research provided valuable input from West Coast banding sites at Marin Headlands, California.

Literature Cited

Fig. 14. [Left] This adult light-morph Ferruginous Hawk is molting its primaries. *Wasatch Mountains, Utah; 4 May 2002*. © Jerry Liguori.

Fig. 15. [Top Right] This third-year Golden Eagle is molting P2 and P8. *Wasatch Mountains, Utah; 30 September 2005*. © Jerry Liguori.

Fig. 16. [Bottom Right] This adult Peregrine Falcon is molting P1, P2, P3, and P7. *Wasatch Mountains, Utah; 24 September 2006*. © Jerry Liguori.