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Systematic Review of Age at First Breeding in Diurnal Raptors of the United States and Canada

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ABSTRACT.—Age at first breeding is a key demographic trait with implications for life history strategy, conservation, and population modeling. We conducted a systematic review of published literature, species accounts, and gray literature sources to summarize the minimum and typical ages at first breeding for 31 species of diurnal raptors that regularly breed in the United States and Canada. Structured keyword searches in Google Scholar and PubMed yielded 319 results, supplemented by manual review of Birds of the World (Billerman et al. 2025; https://birdsoftheworld.org) species accounts and Johnsgard (1990; *Hawks, Eagles, and Falcons of North America*, Smithsonian Institution Press). Minimum age at first breeding was reported for 25 species, with smaller species (e.g., small falcons) typically breeding earlier than larger, long-lived species (e.g., eagles and buteos). Females often initiated breeding earlier than males, particularly in the genera *Falco* and *Astur*. Typical age data were reported for 18 species, though most estimates lacked regional or sex-specific detail. Six species lacked reliable age data. These results highlight significant gaps in our understanding of reproductive timing and underscore the need for more comprehensive demographic monitoring to support effective management decisions, especially for threatened or recovering populations. In addition, this work provides a methodological framework that can be applied to reviews of age at first breeding in other bird families.

KEY WORDS: *Age at first breeding*; *demography*; *diurnal raptors*; *life history traits*; *reproductive ecology*; *systematic review*.

REVISIÓN SISTEMÁTICA DE LA EDAD DE LA PRIMERA REPRODUCCIÓN EN RAPACES DIURNAS DE ESTADOS UNIDOS Y CANADÁ

RESUMEN.—La edad de la primera reproducción es un rasgo demográfico clave con implicaciones para la estrategia de la historia de vida, la conservación y la modelización poblacional. Realizamos una revisión sistemática de la literatura publicada, de los registros de las especies y de fuentes de literatura gris para resumir las edades mínimas y típicas de la primera reproducción en 31 especies de rapaces diurnas que se reproducen regularmente en Estados Unidos y Canadá. Las búsquedas estructuradas con palabras clave en Google Académico y PubMed arrojaron 319 resultados, complementados con una revisión manual de los registros de las especies de la publicación Birds of the World (Billerman et al. 2025; https://birdsoftheworld.org) y de Johnsgard (1990; *Hawks, Eagles, and Falcons of North America*, Smithsonian Institution Press). Se reportó la edad mínima de la primera reproducción para 25 especies, con especies más pequeñas (e.g., halcones pequeños) reproduciéndose típicamente antes que las especies más grandes y longevas (e.g., águilas y buteos). Las hembras a menudo iniciaron la reproducción antes que los machos, particularmente en especies de los géneros *Falco* y *Astur*. Los datos de la edad

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típica se reportaron para 18 especies, aunque la mayoría de las estimaciones carecieron de detalle a nivel regional o específico por sexo. Seis especies carecieron de datos confiables sobre la edad. Estos resultados destacan vacíos significativos en nuestra comprensión de la cronología reproductiva y subrayan la necesidad de un monitoreo demográfico más integral para apoyar decisiones de manejo efectivas, especialmente en poblaciones amenazadas o en recuperación. Además, este trabajo proporciona un marco metodológico que puede aplicarse a revisiones de la edad de la primera reproducción en otras familias de aves.

[Traducción del equipo editorial]

INTRODUCTION

Raptors, as apex avian predators, play a crucial role in maintaining ecological balance and biodiversity. Their presence can regulate prey populations and influence trophic cascades, contributing to ecosystem structure and function (Sergio et al. 2006, Estes et al. 2011). Many species also serve as indicators of environmental health due to their sensitivity to contaminants and habitat changes (Newton et al. 1979, Donázar et al. 2016). They inhabit a wide range of ecosystems globally and face numerous threats, including habitat loss and fragmentation, persecution, exposure to environmental contaminants, collisions with and electrocution from power lines, and the effects of climate change (Carrete et al. 2009, O'Bryan et al. 2022). With more than half of raptor species worldwide experiencing population declines as a result of these threats (McClure et al. 2018), understanding key life history traits—such as age at first breeding—is critical for assessing population dynamics and informing conservation strategies.

Age at first breeding influences the intrinsic rate of population growth and is a fundamental component of species resilience (Whitfield et al. 2022). In this review, we define age at first breeding as the youngest age at which a bird initiates a nesting attempt, as defined by Steenhof et al. (2017), regardless of whether that attempt results in successful reproduction. Earlier breeding—including breeding before acquiring definitive appearance—can stabilize or accelerate population growth and amplify reproductive output across generations (Hunt and Law 2023). Cole's (1954) foundational model demonstrated that even modest reductions in age at first reproduction—that is, the age of successful offspring production—can substantially enhance population growth rates.

Beyond these demographic effects, the age structure of breeders can also serve as a sensitive indicator of population health. The increased frequency of subadult Peregrine Falcons (*Falco peregrinus*) occupying territories was an early signal of population expansion during post-DDT recovery in North America (Tordoff and Redig 1997). Monitoring the age of breeders, though often more challenging than measuring occupancy or productivity, can therefore provide valuable insights into population resilience.

However, early breeding is not without cost. Delaying breeding may allow individuals to improve foraging skills, reduce mortality risk, or secure higher-quality territories (Newton 1979, Forslund and Pärt 1995). In contrast, earlier breeding may lead to reduced survival, lower breeding success, and a shorter overall reproductive lifespan—particularly for males (Newton 1979), though such costs may not apply universally, as shown in female Eurasian Sparrowhawks (*Accipiter nisus*; Newton 1985). This has been documented in male Cooper's Hawks (*Astur cooperii*), where early breeders often experienced reduced longevity and lifetime reproductive output (Millsap et al. 2019). Thus, early breeding represents a gamble: although it can yield large demographic returns at the population level, it may come at the cost of reduced individual fitness and longevity.

Age at first breeding in raptors is shaped by multiple ecological and evolutionary factors, including sexual maturity, competitive hierarchies, and habitat saturation (Newton 1979, Hunt 1998). Density-dependence plays a major role, as competition for high-quality territories tends to favor older, more experienced individuals (Steenhof et al. 1983, Ferrer et al. 2004, Pyle et al. 2020). In this context, younger breeders may be relegated to suboptimal nesting areas or face displacement. Reproductive scheduling also reflects sex-specific strategies—females often breed earlier than males, possibly due to differing energetic costs or, as noted above, differing costs to survival (Reynolds 1972, Newton 1979). These pressures interact with physiological readiness and social structure to shape the timing of reproductive onset. Notably, age at first breeding may decrease in declining populations where territory availability increases, or increase when resource limitations constrain recruitment (Pyle 2001, Ferrer et al. 2004).

Yet for many raptor species, detailed data on reproductive initiation are still lacking. Johnsgard

(1990) provided a broad summary of reproductive parameters, but did not consistently include primary sources or region-specific information. Although some recent demographic studies and species accounts provide updated breeding age information (e.g., detailed work on Red Kites [*Milvus milvus*] in central Europe; Dostál et al. 2025), those contributions are taxonomically and geographically scattered. Few synthesize data systematically, and even fewer focus on species that regularly breed in the United States and Canada. Inconsistencies in terminology and reliance on disparate aging criteria further complicate cross-species comparisons. These gaps limit the ability to model population trajectories, assess reproductive output, and evaluate conservation status at regional scales.

This review synthesizes current knowledge of age at first breeding for 31 species of diurnal raptors that regularly breed in the United States and Canada. Here, we follow McClure et al. (2019) in defining raptors (or birds of prey) as members of the orders Accipitriformes, Cathartiformes, and Falconiformes, which descended from a raptorial landbird ancestor and have retained that ecological role. Consistent with this framework, our review focuses on diurnal raptors within these groups but excludes owls (Strigiformes), New World vultures (Cathartidae), the California Condor (*Gymnogyps californianus*), and vagrant or nonbreeding species. We focus on this regional subset both to provide continuity with Johnsgard's (1990) synthesis and because raptor management in the United States and Canada occurs under broadly similar legal frameworks (e.g., Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act). Restricting our scope to these 31 species thus ensures consistency, comparability, and direct relevance for conservation and policy.

We aim to (1) compile minimum and typical ages at first breeding from primary sources, species accounts, and gray literature; (2) standardize plumage definitions for comparability across species with differing molt strategies; and (3) identify major gaps to guide future monitoring and research. In doing so, we provide an updated, regionally focused reference that supports demographic modeling and conservation planning across taxa.

To ensure consistency across taxa, we adopted the standardized terminology of pre-definitive and definitive appearance stages to describe age classes at first breeding, as recommended by Clark and Pyle (2015). This approach provides a biologically meaningful and morphologically grounded framework for comparing breeding age across species globally and with differing molt strategies. In doing so, we promote standardized terminology and age classification approaches that enhance comparability across taxa with variable molt timing and plumage development.

Age of first breeding in raptor studies has relied both on marked birds of known age and on inferred age based on plumage appearance. In particular, many studies have focused on observations of birds that breed in pre-definitive plumage (e.g., Henny et al. 1985, Millsap et al. 2019). Many smaller raptors in our study acquire definitive appearance—mature plumage that does not change markedly with further aging—by 2 yr of age. In some cases, yearlings in juvenile or formative plumage (cf. Pyle 2005a) have been observed breeding at 1 yr of age. Larger species may require four or more years to reach definitive appearance.

To best incorporate plumage into studies of breeding age, it is imperative to use accurate aging techniques based on both body feather appearance and flight feather molt patterns. Many species may retain juvenile primaries and/or secondaries despite showing definitive appearance of body plumage. In larger species, Staffelmauser (or stepwise) molt patterns can allow age estimation up to 3 or 4 yr (Pyle 2005b, 2008). Here we define definitive appearance as that in which both body feathering has fully matured and all juvenile flight feathers have been replaced. It is important to note that both the acquisition of definitive appearance and the timing of feather replacement can vary among individuals. For example, the fastest molting and maturing 3-yr-old birds might overlap with, and be indistinguishable from, the slowest molting and maturing 4-yr-old birds (cf. Bloom and Clark 2001). We accommodated this variation by accepting a reasonable range of ages when definitive appearance could not be precisely assigned, based on reported plumage and molt characteristics.

METHODS

We conducted a systematic literature review to compile data on the age at first breeding for 31 diurnal raptor species that regularly breed in the continental United States and Canada. Species names and taxonomic assignments follow the Clements Checklist v2024 (Clements et al. 2024). Species selection was based on regular breeding occurrence according to regional avifaunal checklists (Cornell Lab of Ornithology 2025) and authoritative references such as Birds of the World (Billerman et al. 2025; https://birdsoftheworld.org). Our goal was to consolidate known breeding-age information and identify knowledge gaps across this well-defined subset of raptor species. This review was not registered and no protocol was prepared. We note that some of the youngest breeding ages were documented through intensive monitoring efforts—such as reintroduction projects, telemetry studies, or urban nest monitoring—which may increase the likelihood of detecting early nesting attempts.

On 28 March 2025, we performed structured keyword searches in Google Scholar and PubMed using R (R Core Team 2024) within the RStudio integrated development environment (Posit Software 2024). The searches were executed via the packages *rentrez* (Winter 2017) and *rvest* (Wickham 2022), which allowed for automated scraping and retrieval of search results. We paired reproductive terms (e.g., "age at first breeding," "breeding initiation," "sexual maturity") with both common and scientific names of each focal species. Boolean operators ("AND," "OR") were used to refine and broaden the search queries. See Supplemental Material (Appendix 1) for the full search strategy, including R code used for search automation and the de-duplicated list of retrieved results.

To supplement database results, we manually reviewed the Birds of the World species accounts (Billerman et al. 2025) for all target raptors. These accounts served as foundational compilations of natural history information and often cited key primary studies, and review of them helped ensure coverage of references and personal communications not indexed in academic databases, particularly for older or regionally specific information. When relevant data were available, we consulted and cited the original primary sources referenced in those accounts. Primary studies not included in Birds of the World (Billerman et al. 2025) but identified through database searches or independent review were incorporated as well. We also included gray literature, such as master's theses and doctoral dissertations, if they provided original, age-specific data on wild breeding populations and met basic methodological standards. Information from Johnsgard (1990) was used only when it provided relevant observations not clearly documented elsewhere.

We excluded sources if they lacked data on age at first breeding, involved captive individuals, or focused on populations outside the geographic scope of the United States and Canada. Studies with ambiguous or anecdotal evidence were omitted unless supported by additional citations or clear, methodologically sound observational data. One author (MTS) conducted the initial screening and full-text reviews, and unclear cases were resolved in consultation with coauthors to maintain consistency and objectivity in data inclusion. For each species, we recorded the minimum age at first documented breeding (the youngest observed breeder) and, when available, the typical age at first breeding (the age most individuals first initiate breeding), noting any distinctions by sex or region. In cases of multiple or conflicting reports, we favored the most recent or comprehensive studies and noted any biologically meaningful variation.

To increase transparency and align with best practices in evidence synthesis, this review followed guidelines adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al. 2021), with additional consideration of PRISMA-EcoEvo adaptations for ecology and evolutionary biology (O'Dea et al. 2021). These included the incorporation of gray literature, targeted species-level searches, and flexible inclusion criteria to reflect the observational and ecological nature of raptor life history data. A flow diagram summarizing the literature selection process is provided in Figure 1.

By combining automated database searches with manual reviews of species accounts, we aimed to build a robust and inclusive dataset. This dual strategy allowed us to synthesize both widely known and underreported cases of early breeding across the diurnal raptor species that compose the breeding avifauna of the United States and Canada. The resulting compilation provides a foundation for identifying demographic patterns, informing conservation efforts, and guiding future research on the life histories of raptors and other bird species.

We did not perform statistical testing of sex differences in age at first breeding, as the purpose of this review was to compile and summarize reported values rather than to reanalyze raw data. In many cases, sex-based differences were drawn directly from the literature and reported descriptively or anecdotally, often without formal testing or large sample sizes. When sources noted distinctions by sex, we included them, while recognizing the potential for sampling limitations and methodological variability. Our intention was to summarize the available evidence while acknowledging its limitations, not to evaluate the statistical robustness of each individual study.

RESULTS

Our keyword search returned 319 results, 279 of which were excluded during title and abstract screening. An additional 106 records were included after reviewing species accounts from Birds of the World

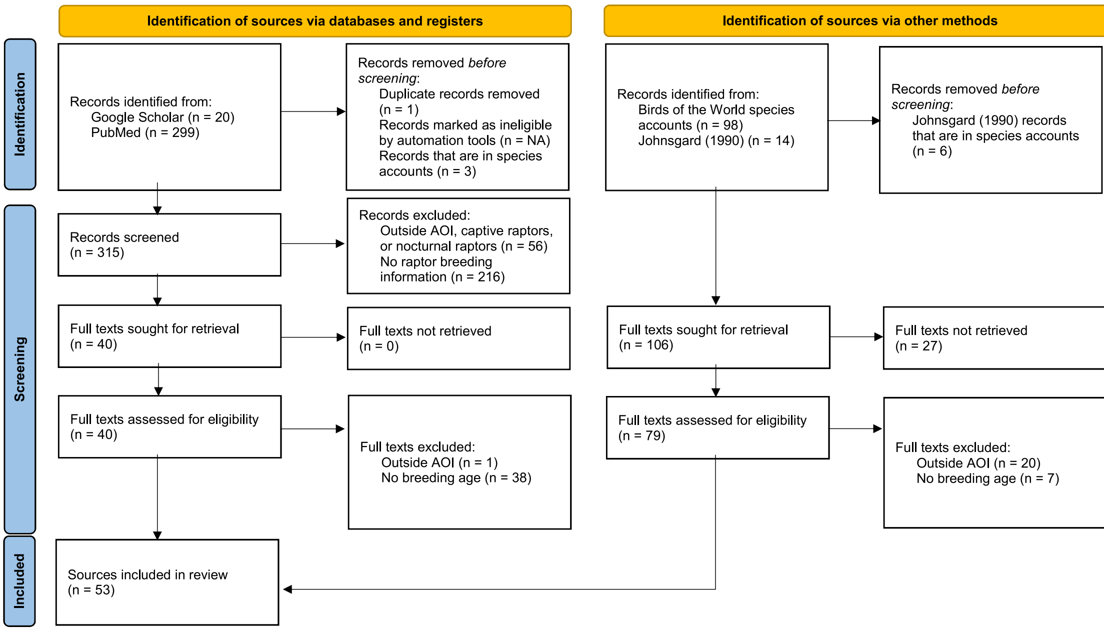

Figure 1. PRISMA 2020 flow diagram showing the literature selection process for sources reporting age at first breeding in North American diurnal raptors. The diagram summarizes all sources assessed, excluded, and the number excluded for specific reasons (e.g., outside the area of interest (AOI) or focused on captive populations). Birds of the World sources refer to species accounts accessed manually. Johnsgard (1990) refers to *Hawks, Eagles, and Falcons of North America*, which provided natural history summaries for the 31 focal species. Figure adapted from Page et al. (2021), licensed under CC BY 4.0.

(Billerman et al. 2025) and other gray literature sources (Fig. 1). In total, we compiled information on age at first breeding for 25 of the 31 species of diurnal raptors that regularly breed in the United States and Canada (Table 1). Minimum age at first breeding was documented for these 25 species, while for the remaining six—White-tailed Kite (*Elanus leucurus*), Hook-billed Kite (*Chondrohierax uncinatus*), Zone-tailed Hawk (*Buteo albonotatus*), Short-tailed Hawk (*Buteo brachyurus*), Common Black Hawk (*Buteogallus anthracinus*), and Gyrfalcon (*Falco rusticolus*)—age at first breeding remains unknown within the United States and Canada due to insufficient data. Typical age at first breeding was reported for 18 species, often with distinctions by sex or region. Species with well-studied populations, such as the Peregrine Falcon and Cooper's Hawk, offered the most detailed estimates.

Falcons (Falconidae) generally exhibited earlier ages at first breeding than eagles or large buteos. For example, species such as the American Kestrel (*Falco sparverius*) and most female Merlins (*Falco columbarius*) commonly breed while still in pre-definitive plumage—typically within their first year. In the kestrel, although the preformative molt of body feathers can make them visually similar to those in definitive plumage, formative plumage can be identified by retained juvenile remiges and rectrices (Pyle 2008). In contrast, most male Merlins delayed breeding until their second cycle (Lieske et al. 1997, Smallwood and Bird 2020).

Large-bodied species like the Bald Eagle (*Haliaeetus leucocephalus*) and Golden Eagle (*Aquila chrysaetos*) typically defer breeding until reaching definitive appearance, often at 4–5 yr of age or later (Steenhof et al. 1983, Gerrard et al. 1992, Pyle 2008). Sex-based differences in age at first breeding were also reported in some species, such as Cooper's Hawks, where 1-yr-old females were more frequently observed breeding in pre-definitive plumage than males (Millsap et al. 2019), and Broad-winged Hawks (*Buteo platypterus*), where young males more frequently bred than females (Crocoll and Parker 1989).

DISCUSSION

Understanding when raptors begin breeding is essential for interpreting reproductive output, forecasting population dynamics, and informing conservation strategies—especially for species facing environmental pressures or ongoing recovery. Our review highlights

Table 1. Minimum and typical age at first breeding for 31 species of diurnal raptors that regularly breed in the United States and Canada. The molt cycle at which definitive appearance is attained, as indicated by body feather appearance or replacement of all juvenile flight feathers, follows species accounts in Pyle (2008) and incorporates an increased understanding of potential variation among individuals in the age at which definitive appearance is reached. Notes include context on sample populations, sex differences, and demographic trends where available.

Species	Minimum Age at First Breeding	Typical Age at First Breeding	Definitive Appearance (Cycle)	Notes	References
Bald Eagle (*Haliaeetus leucocephalus*)	3 yr	5–6 yr	4th–6th	Most breed after attaining definitive appearance; earlier in low-density areas	Hoxie (1910), Swenson et al. (1986), Gerrard et al. (1992), Mulhern et al. (1994), Buehler (2022)[a]
Golden Eagle (*Aquila chrysaetos*)	3 yr	4–5 yr	4th–5th	Early breeding tied to low adult density	Teresa (1980), Steenhof et al. (1983), Steenhof et al. (1984), Katzner et al. (2020)[a]
Snail Kite (*Rostrhamus sociabilis*)	1 yr	≥2 yr	3rd ♀, 3rd–4th ♂	Breeding onset varies with food availability and drought	Beissinger (1986), Snyder et al. (1989), Bennetts (1998), Fletcher et al. (2015), Reichert et al. (2020)[a]
Swallow-tailed Kite (*Elanoides forficatus*)	≥3 yr	Unknown	2nd	—	Coulson (2006), Meyer (2020)[a]
Hook-billed Kite (*Chondrohierax uncinatus*)	Unknown	Unknown	2nd–3rd	—	Greeney and Boesman (2022)[a]
White-tailed Kite (*Elanus leucurus*)	Unknown	Unknown	2nd–3rd	—	Dunk (2020)[a]
Mississippi Kite (*Ictinia mississippiensis*)	1 yr	2 yr	2nd–3rd	Pre-definitive breeding is infrequent, and only when paired with a bird in definitive appearance	Parker and Ports (1982), Glinski and Ohmart (1983), Parker (2020)[a]
Northern Harrier (*Circus hudsonius*)	1 yr	≥2 yr ♀, ≥3 yr ♂	2nd–3rd ♀, 3rd ♂	Pre-definitive breeding can vary by prey abundance	Hamerstrom et al. (1985), Simmons et al. (1986a), Simmons et al. (1986b), Smith et al. (2020)[a]
Sharp-shinned Hawk (*Accipiter striatus*)	1 yr	≥2 yr	2nd–3rd	Pre-definitive females more likely to breed than males	Reynolds and Wight (1978), Henny et al. (1985), Bildstein et al. (2020)[a]
Cooper's Hawk (*Astur cooperii*)	1 yr	1–2 yr ♀, ≥2 yr ♂	2nd–3rd	First year females breed when competition with older females is reduced	Boal (2001), Stout et al. (2007), Rosenfield et al. (2013), Millsap et al. (2019), Millsap et al. (2023), Rosenfield et al. (2024)[a]

Table 1. Continued.

Species	Minimum Age at First Breeding	Typical Age at First Breeding	Definitive Appearance (Cycle)	Notes	References
American Goshawk (*Astur atricapillus*)	1 yr ♀, 2 yr ♂	≥2 yr	2nd–3rd	Pre-definitive birds sometimes breed; more so in expanding or declining populations	Reynolds and Wight (1978), Henny et al. (1985), Speiser and Bosakowski (1991), Younk and Bechard (1994), Squires and Reynolds (2024)[a]
Harris's Hawk (*Parabuteo unicinctus*)	1 yr	≥2 yr	3rd	Few pre-definitive birds breed (contribute genetically to a reproductive effort, not as a nest helper); most breed in definitive appearance	Whaley (1986), Dwyer and Bednarz (2020)[a]
Red-tailed Hawk (*Buteo jamaicensis*)	1 yr	Unknown	3rd	Few pre-definitive birds breed	Luttich et al. (1971), Henny and Wight (1972), Wiley (1975), Steenhof et al. (1984), Preston and Beane (2024)[a]
Red-shouldered Hawk (*Buteo lineatus*)	1 yr	≥2 yr	2nd	Pre-definitive females more likely to breed than males; most breed in definitive appearance	Henny et al. (1973), Wiley (1975), Apanius (1977), Crocoll and Parker (1989), Dykstra et al. (2020)[a]
Zone-tailed Hawk (*Buteo albonotatus*)	Unknown	Unknown	3rd		Johnson et al. (2020)[a]
White-tailed Hawk (*Geranoaetus albicaudatus*)	<3 yr	3 yr	4th	Male in "subadult" plumage observed breeding	Farquhar (2020)[a]
Swainson's Hawk (*Buteo swainsoni*)	2 yr ♀, 3 yr ♂	≥3 yr	3rd		Cameron (1913), Woodbridge et al. (1995), Bechard et al. (2020a),[a] Kane et al. (2020), C. Vennum (unpubl. data)
Broad-winged Hawk (*Buteo platypterus*)	1 yr	Unknown	2nd–3rd	40% of pairs in a NY study involved pre-definitive males	Crocoll and Parker (1989), Goodrich et al. (2020)[a]
Short-tailed Hawk (*Buteo brachyurus*)	Unknown	Unknown	2nd–3rd	A pre-definitive bird built a nest but did not breed	Miller and Meyer (2020)[a]
Common Black Hawk (*Buteogallus anthracinus*)	Unknown	Unknown	3rd	Pre-definitive breeding not confirmed; courtship observed	Johnson and Schnell (2024)[a]

Table 1. Continued.

Species	Minimum Age at First Breeding	Typical Age at First Breeding	Definitive Appearance (Cycle)	Notes	References
Gray Hawk (*Buteo plagiatus*)	1 yr?	≥2 yr	2nd–3rd	Pre-definitive birds of both sexes paired with definitive birds in South TX; breeding unconfirmed	Bibles et al. (2020),[a] M. Stewart (unpubl. data)
Rough-legged Hawk (*Buteo lagopus*)	1 yr?	Unknown	3rd–4th	Based on movement data some females appear to breed at 1 yr, but this has yet to be confirmed	Bechard et al. (2020b),[a] N. Paprocki (unpubl. data)
Ferruginous Hawk (*Buteo regalis*)	2 yr	Unknown	3rd		Ng et al. (2020)[a]
Osprey (*Pandion haliaetus*)	2 yr	3–7 yr	2nd–3rd	Breeding age varies with nest site availability and geographic location	Henny and Wight (1969), Reese (1977), Bierregaard et al. (2020)[a]
Gyrfalcon (*Falco rusticolus*)	Unknown	Unknown	2nd–3rd	No information from the United States or Canada	Booms et al. (2020)[a]
Prairie Falcon (*Falco mexicanus*)	1 yr	2 yr	2nd	Never two pre-definitive birds in a pair	Webster (1944), Enderson (1964), Platt (1977), Steenhof et al. (1984), Runde (1987), Steenhof (2024)[a]
Peregrine Falcon (*Falco peregrinus*)	1 yr	2–4 yr	2nd–3rd	Most begin breeding at 2 yrs; age varies by sex, region, and territory availability	Wendt and Septon (1991), Tordoff and Redig (1997), Johnstone (1998), White et al. (2024)[a]
Merlin (*Falco columbarius*)	1 yr	1 ♀, 2 ♂	2nd	Breeding is more common among pre-definitive females than males	Lieske et al. (1997), Warkentin et al. (2020)[a]
Aplomado Falcon (*Falco femoralis*)	1 yr	Unknown	2nd	Pre-definitive breeding is infrequent	Hunt et al. (2013), Keddy-Hector et al. (2020)[a]
American Kestrel (*Falco sparverius*)	1 yr	1 yr	2nd	Majority of pre-definitive birds initiate breeding	Smallwood and Bird (2020)[a]
Crested Caracara (*Caracara plancus*)	2 yr	Unknown	3rd		Nemeth and Morrison (2002), Dwyer (2010), Morrison and Dwyer (2023)[a]

[a] Species accounts from Birds of the World.

substantial variation in the age at first breeding among diurnal raptors that breed in the United States and Canada, both across species and between sexes. Breeding prior to attainment of definitive appearance was more common in small-bodied species—especially falcons and forest hawks—and particularly among females. In contrast, large-bodied, long-lived species typically initiated breeding later, often several years post-fledging. Sex differences were also common, with females often recruiting earlier than males. Breeding in a pre-definitive stage was also more common in expanding or recovering populations, as seen in Prairie Falcons (*Falco mexicanus*) and Peregrine Falcons during post-DDT recovery (Platt 1977, Wendt and Septon 1991, Tordoff and Redig 1997), and in some urban populations such as Cooper's Hawks, where relaxed territorial competition may facilitate earlier recruitment (Stout and Rosenfield 2010, Millsap 2018).

These patterns reflect the evolutionary trade-offs between reproductive timing, survival, and social constraints discussed previously. While early breeding may boost lifetime reproductive output (Sibly and Calow 1986), it can also come at the cost of reduced survival or lower breeding success—especially for males that must secure and defend territories and provision their mates and broods (Forslund and Pärt 1995, Rosenfield et al. 2013, Millsap et al. 2019). Delayed breeding in larger raptors may also be shaped by social dynamics such as territory saturation, dominance hierarchies, and cooperative behaviors (Newton 1979). In populations where all suitable breeding sites are occupied it is reasonable to expect age at first breeding to average higher—and exceed the age at which definitive plumage is acquired—because some individuals are relegated to floating until suitable breeding sites become available (Hunt 1998). Comparable delays have also been documented in White-tailed Eagles (*Haliaeetus albicilla*), where individuals in a reintroduced Scottish population initiated breeding at about 5 yr of age, despite being physiologically capable of reproducing earlier (Evans et al. 2009). This pattern mirrors that of Bald Eagles, where social and ecological constraints often postpone breeding beyond the age of sexual maturity.

Some species demonstrated flexibility in breeding age under specific demographic or environmental conditions. For instance, Golden Eagles have bred earlier in low-density areas (Steenhof et al. 1983), whereas Snail Kites (*Rostrhamus sociabilis*) showed variation tied to food availability and drought cycles (Beissinger 1986). Younger individuals were more likely to breed in low-density or recovering populations where competition is reduced (Ferrer et al. 2004). Variation in urban environments may also promote earlier breeding by increasing prey availability and reducing predation risk (Boal and Dykstra 2018), though these mechanisms warrant further study across species and regions. Recent observations also suggest that emerging threats, such as disease outbreaks, may influence breeder age structure. Following highly pathogenic avian influenza outbreaks in Scotland, an unusually high proportion of Peregrine Falcon territories were occupied by subadult birds. This pattern is consistent with a possible reduction in adult survival (Smith et al. 2025). Although causation remains difficult to establish, such shifts highlight the potential for breeder age to serve as an indicator of population stress.

Despite several consistent trends, our synthesis reveals notable gaps in current knowledge. Six species in our review lacked reliable data on age at first breeding, and many others were missing sex-specific or regionally nuanced estimates. For three species, no data exist, while for two others only anecdotal observations suggest pre-definitive birds pairing or displaying but not nesting (e.g., Short-tailed Hawk: Miller and Meyer 2020; Common Black Hawk: Boal and Mannan 1996). Gyrfalcons provide a partial exception, with breeding recorded in captivity and in Palearctic populations as early as 2 yr old for females and 3–4 yr old for males (Booms et al. 2020), though such data are lacking for North America. Even in well-studied species, age estimates were sometimes based on captive birds or isolated populations, limiting their broader applicability. Few studies addressed interannual variation or long-term trends, which could provide insight into the effects of habitat change, population instability, or food resource availability on age of first breeding.

Finally, the propensity for early breeding based on the proportion of birds observed in pre-definitive plumage at nesting sites may not be representative of the actual frequency of early breeding. For example, Millsap (2018) estimated that 96% of 1-yr-old female Cooper's Hawks in an urban study population acquired a breeding territory and attempted to breed, yet only 11% of breeding females on the study area were first-year birds (many of the early breeders emigrated and bred elsewhere). Although our review compiles available evidence of sex-based variation in age at first breeding, the underlying data were often limited or descriptive and should be interpreted cautiously. Few studies conducted formal statistical comparisons, particularly for large-bodied raptors where sample sizes are typically small. This underscores a clear need for more rigorous, sex-specific demographic studies to clarify when and how males and females begin breeding across species.

Although our review focused solely on age at first breeding, it highlighted several broader research needs. Long-term demographic monitoring, including individual banding and resighting, remains essential for tracking reproductive onset across life stages. Telemetry and emerging tools such as remote cameras could be particularly valuable for detecting breeding behavior of younger individuals, especially in remote or low-density populations where such events may be underreported. Future studies should aim to include sex-specific and regionally stratified data, as gaps remain for many species—particularly kites and Neotropical migrants. Finally, a more mechanistic understanding of reproductive timing could be gained by assessing how ecological factors such as prey availability, density dependence, or habitat quality influence the age of first breeding.

An especially promising tool for future research is the Cornell Lab of Ornithology's Macaulay Library (https://media.ebird.org/catalog), which currently hosts more than 70 million images of birds worldwide. This resource has been used to study molt patterns and age in birds (cf. Pyle 2022). Researchers can filter images by species, age class, nest, and other breeding parameters to search for breeding individuals in pre-definitive plumages. Many of these birds can then be aged precisely by molt-related information (Pyle 2005b, 2008). Pre-definitive birds showing "suspension limits" indicating molt was suspended due to breeding during the previous season can also be investigated (Pyle 2005b).

To support future syntheses, we strongly recommend that researchers use consistent and searchable terminology—such as "age at first breeding," "breeding age," or "reproductive maturity"—in titles, abstracts, and keywords. Standardized terminology and age classification frameworks are especially important for ensuring comparability across studies and taxa, particularly in species with differing molt strategies and plumage development timelines. Clear, consistent definitions help unify disparate data sources and allow findings to be meaningfully compared across populations, regions, and species. In addition, we emphasize the importance of editorial willingness to publish rigorous natural history studies—including foundational demographic traits like age at first breeding—that are essential for long-term conservation planning. Despite their importance, such studies are often underrepresented in the literature, and greater editorial support could help ensure that basic but vital biological data are more widely accessible.

Our automated searches queried both titles/abstracts and, in the case of Google Scholar, much of the full text. Thus, mentions of age at first breeding in discussions could have been retrieved if consistent terminology had been used. However, in practice, many papers reported these data only incidentally—for example, in the discussion of broader breeding ecology studies—without using standardized terms in searchable fields. This pattern limited the effectiveness of automated searches. Our review process revealed that a substantial portion of relevant data (more than 100 sources) was therefore absent from automated search results and only uncovered through manual review of species accounts and gray literature. Similarly, inconsistent or incorrect use of terminology—such as referring to, alternatively, formative or second basic plumage as the "first prebasic plumage," despite proposed revisions to the Humphrey-Parkes system—hinders accurate age determination (Howell et al. 2003, Pyle 2005a, Clark and Pyle 2015). This underscores how use of differing terminology can obscure homologies, complicate age-class identification, and limit integration of existing knowledge into broader syntheses. An understanding of variation in the acquisition of definitive plumage appearance among species is poorly known, especially for larger species that take >2 yr to reach this definitive appearance and where pre-definitive appearance can overlap in different cohorts. This can be investigated by comparing plumage appearances among marked known-age birds or with those in which age can be more accurately determined by remigial molt patterns (Pyle 2005b, 2008).

Although our synthesis focuses on diurnal raptors that breed in the United States and Canada, we recognize that age at first breeding has also been studied in populations elsewhere. For widely distributed species such as Peregrine Falcons, Golden Eagles, and Bald Eagles, international comparisons may reveal differences in breeding age associated with climate, density, or management context. Although we restricted our review to a well-defined regional subset to ensure consistency and feasibility, future syntheses could build on this foundation by incorporating global data to assess the generality of these patterns across the broader ranges of shared or closely related species. Available evidence from outside North America suggests that such patterns are broadly consistent, indicating they are unlikely to reflect geographic peculiarity.

Understanding when individuals enter the breeding population is critical for estimating reproductive rates, forecasting population growth, and identifying demographic bottlenecks. In threatened or recovering species, early breeding may buffer populations during periods of high adult mortality or habitat loss (Cole 1954). By clarifying the timing and variability of the onset of breeding, this synthesis provides a foundation for improved population modeling and conservation planning across a diverse guild of avian predators, and we provide a methodological roadmap for the review of age at first breeding in other bird families.

SUPPLEMENTAL MATERIAL (available online): Appendix 1: Literature search protocol and code: Systematic literature search for age at first breeding in diurnal raptors.

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LITERATURE CITED

Apanius, V. (1977). Red-shouldered Hawks in juvenile plumage nest successfully. The Auk 94:585. doi:10.1093/auk/94.3.585.

Bechard, M. J., C. S. Houston, J. H. Sarasola, and A. S. England (2020a). Swainson's Hawk (*Buteo swainsoni*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.swahaw.01.

Bechard, M. J., T. R. Swem, J. Orta, P. F. D. Boesman, E. F. J. Garcia, and J. S. Marks (2020b). Rough-legged Hawk (*Buteo lagopus*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.rolhaw.01.

Beissinger, S. R. (1986). Demography, environmental uncertainty, and the evolution of mate desertion in the Snail Kite. Ecology 67:1445–1459. doi:10.2307/1939076.

Bennetts, R. E. (1998). The demography and movements of Snail Kites in Florida. Ph.D. dissertation, University of Florida, Gainesville, FL, USA.

Bibles, B. D., R. L. Glinski, and R. R. Johnson (2020). Gray Hawk (*Buteo plagiatus*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.gryhaw2.01.

Bierregaard, R. O., A. F. Poole, M. S. Martell, P. Pyle, and M. A. Patten (2020). Osprey (*Pandion haliaetus*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.osprey.01.

Bildstein, K. L., K. D. Meyer, C. M. White, J. S. Marks, and G. M. Kirwan (2020). Sharp-shinned Hawk (*Accipiter striatus*), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.shshaw.01.

Billerman, S. M., B. K. Keeney, G. M. Kirwan, F. Medrano, N. D. Sly, and M. G. Smith (Editors) (2025). Birds of the World. Cornell Laboratory of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.

Bloom, P. H., and W. S. Clark (2001) Molt and sequence of plumages of Golden Eagles and a technique for in-hand ageing. North American Bird Bander 26:97–116.

Boal, C. W. (2001). Nonrandom mating and productivity of adult and subadult Cooper's Hawks. The Condor 103:381–385. doi:10.1093/condor/103.2.381.

Boal, C. W., and C. R. Dykstra (Editors) (2018). Urban Raptors: Ecology and Conservation of Birds of Prey in Cities. Island Press, Washington, DC, USA.

Boal, C. W., and R. W. Mannan (1996). Conservation assessment for the Common Black Hawk (*Buteogallus anthracinus*). US Department of Agriculture, Forest Service, Tonto National Forest, Phoenix, AZ, USA.

Booms, T. L., T. J. Cade, and N. J. Clum (2020). Gyrfalcon (*Falco rusticolus*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.gyrfal.01.

Buehler, D. A. (2022). Bald Eagle (*Haliaeetus leucocephalus*), version 2.0. In Birds of the World (P. G. Rodewald and S. G. Mlodinow, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.baleag.02.

Cameron, E. S. (1913). Notes on Swainson's Hawk (*Buteo swainsoni*) in Montana. The Auk 30:167–176.

Carrete, M., J. L. Tella, G. Blanco, and M. Bertellotti (2009). Effects of habitat degradation on the abundance, richness and diversity of raptors across Neotropical biomes. Biological Conservation 142:2002–2011. doi:10.1016/j.biocon.2009.02.012.

Clark, W. S., and P. Pyle (2015). Commentary: A recommendation for standardized age-class plumage terminology. Journal of Raptor Research 49:513–517. doi:10.3356/rapt-49-04-513-517.1.

Clements, J. F., P. C. Rasmussen, T. S. Schulenberg, M. J. Iliff, T. A. Fredericks, J. A. Gerbracht, D. Lepage, A. Spencer, S. M. Billerman, B. L. Sullivan, M. Smith, and C. L. Wood (2024). The eBird/Clements checklist of Birds of the World: v2024. https://www.birds.cornell.edu/clementschecklist/download.

Cole, L. C. (1954). The population consequences of life history phenomena. Quarterly Review of Biology 29:103–137. doi:10.1086/400074.

Cornell Lab of Ornithology (2025). eBird Explore: Discover species, hotspots, and recent checklists. Cornell Lab of Ornithology, Ithaca, NY, USA. https://ebird.org/explore.

Coulson, J. A. (2006). Intraguild predation, low reproductive potential, and social behaviors that may be slowing the recovery of a northern Swallow-tailed Kite population. Ph.D. dissertation, Tulane University, New Orleans, LA, USA.

Crocoll, S. T., and J. W. Parker (1989). The breeding biology of Broad-winged and Red-shouldered Hawks in western New York. Journal of Raptor Research 23:125–139.

Donázar, J. A., A. Cortés-Avizanda, J. A. Fargallo, A. Margalida, M. Moleón, Z. Morales-Reyes, R. Moreno-Opo, J. M. Pérez-García, J. A. Sánchez-Zapata, I. Zuberogoitia, and D. Serrano (2016). Roles of raptors in a changing world: From flagships to providers of key ecosystem services. Ardeola 63:181–234. doi:10.13157/arla.63.1.2016.rp8.

Dostál, M., J. Škrábal, R. Raab, P. Spakovszky, H. Matušík, J. Svetlík, B. Maderič, K. Makonõ, and I. Literák (2025). Breeding behaviour of central European Red Kites: Parental sex-dependent differences. Journal of Ornithology 166:417–433. doi:10.1007/s10336-024-02235-3.

Dunk, J. R. (2020). White-tailed Kite (*Elanus leucurus*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.whtkit.01.

Dwyer, J. F. (2010). Ecology of non-breeding and breeding Crested Caracaras (*Caracara cheriway*) in Florida. Ph.D. dissertation, Virginia Polytechnic Institute and State University (Virginia Tech), Blacksburg, VA, USA.

Dwyer, J. F., and J. C. Bednarz (2020). Harris's Hawk (*Parabuteo unicinctus*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.hrshaw.01.

Dykstra, C. R., J. L. Hays, and S. T. Crocoll (2020). Red–shouldered Hawk (*Buteo lineatus*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.reshaw.01.

Enderson, J. H. (1964). A study of the Prairie Falcon in the central Rocky Mountain region. The Auk 81:332–352. doi:10.2307/4082689.

Estes, J. A., J. Terborgh, J. S. Brashares, M. E. Power, J. Berger, W. J. Bond, S. R. Carpenter, T. E. Essington, R. D. Holt, J. B. C. Jackson, R. J. Marquis, et al. (2011). Trophic downgrading of planet Earth. Science 333: 301–306. doi:10.1126/science.1205106.

Evans, R. J., J. D. Wilson, A. Amar, A. Douse, A. MacLennan, N. Ratcliffe, and D. P. Whitfield (2009). Growth and demography of a re-introduced population of White-tailed Eagles *Haliaeetus albicilla*. Ibis 151: 244–254. doi:10.1111/j.1474-919X.2009.00908.x.

Farquhar, C. C. (2020). White-tailed Hawk (*Geranoaetus albicaudatus*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.whthaw.01.

Ferrer, M., F. Otalora, and J. M. García-Ruiz (2004). Density-dependent age of first reproduction as a buffer affecting persistence of small populations. Ecological Applications 14:616–624. doi:10.1890/02-5361.

Fletcher, R. J., Jr., E. P. Robertson, R. C. Wilcox, B. E. Reichert, J. D. Austin, and W. M. Kitchens (2015). Affinity for natal environments by dispersers impacts reproduction and explains geographical structure of a highly mobile bird. Proceedings of the Royal Society B 282:20151545. doi:10.1098/rspb.2015.1545.

Forslund, P., and T. Pärt (1995). Age and reproduction in birds—Hypotheses and tests. Trends in Ecology & Evolution 10:374–378. doi:10.1016/S0169-5347(00)89141-7.

Gerrard, J. M., P. N. Gerrard, G. R. Bortolotti, and E. H. Dzus (1992). A 24-year study of Bald Eagles on Besnard Lake, Saskatchewan. Journal of Raptor Research 26:159–166.

Glinski, R. L., and R. D. Ohmart (1983). Breeding ecology of the Mississippi Kite in Arizona. Condor 85:200–207.

Goodrich, L. J., S. T. Crocoll, and S. E. Senner (2020). Broad-winged Hawk (*Buteo platypterus*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.brwhaw.01.

Greeney, H. F., and P. F. D. Boesman (2022). Hook-billed Kite (*Chondrohierax uncinatus*), version 3.0. In Birds of the World (B. K. Keeney, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.hobkit.03.

Hamerstrom, F., F. N. Hamerstrom, and C. J. Burke (1985). Effect of voles on mating systems in a central Wisconsin population of harriers. Wilson Bulletin 97:332–346.

Henny, C. J., R. A. Olson, and T. L. Fleming (1985). Breeding chronology, molt, and measurements of accipiter hawks in northeastern Oregon. Journal of Field Ornithology 56:97–112.

Henny, C. J., F. C. Schmid, E. M. Martin, and L. L. Hood (1973). Territorial behavior, pesticides, and population ecology of Red-shouldered Hawks in central Maryland, 1943–1971. Ecology 54:545–554. doi:10.2307/1935339.

Henny, C. J., and H. M. Wight (1969). An endangered Osprey population: Estimates of mortality and production. The Auk 86:188–198. doi:10.2307/4083495.

Henny, C. J., and H. M. Wight (1972). Population ecology and environmental pollution: Red-tailed and Cooper's Hawks. In Population Ecology of Migratory Birds: A Symposium (R. L. Smith and J. R. Palmer, Editors). US Department of the Interior, Wildlife Research Reports 2. Washington, DC, USA. pp. 229–250.

Howell, S. N. G., C. Corben, P. Pyle, and D. I. Rogers (2003). The first basic problem: A review of molt and plumage homologies. The Condor 105:635–653. doi: 10.1093/condor/105.4.635.

Hoxie, W. J. (1910). Notes on the Bald Eagle in Georgia. The Auk 27:454. doi:10.2307/4070908.

Hunt, W. G. (1998). Raptor floaters at Moffat's equilibrium. Oikos 82:191–197. doi:10.2307/3546929.

Hunt, W. G., J. L. Brown, T. J. Cade, J. Coffman, M. Curti, E. Gott, B. Heinrich, J. P. Jenny, P. Juergens, A. Macías-Duarte, A. B. Montoya, et al. (2013). Restoring Aplomado Falcons to the United States. Journal of Raptor Research 47:335–351. doi:10.3356/JRR-12-52.1.

Hunt, W. G., and P. R. Law (2023). Commentary: Subadult nest occupancy rates and floater-to-breeder ratios in raptor population assessment. Journal of Raptor Research 57:493–497. doi:10.3356/JRR-22-87.

Johnsgard, P. A. (1990). Hawks, Eagles, and Falcons of North America: Biology and Natural History. Smithsonian Institution Press, Washington, DC, USA.

Johnson, L. S., and J. H. Schnell (2024). Common Black Hawk (*Buteogallus anthracinus*), version 2.1. In Birds of the World (G. M. Kirwan, B. K. Keeney, and S. M.

Billerman, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.comblh1.02.1.

Johnson, R. R., R. L. Glinski, and S. W. Matteson (2020). Zone-tailed Hawk (*Buteo albonotatus*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.zothaw.01.

Johnstone, R. M. (1998). Aspects of the population biology of tundra Peregrine Falcons (*Falco peregrinus tundrius*). Ph.D. dissertation, University of Saskatchewan, Saskatoon, Canada.

Kane, S. A., C. R. Vennum, B. Woodbridge, M. W. Collopy, P. H. Bloom, and C. W. Briggs (2020). Age distribution and longevity in a breeding population of Swainson's Hawks, *Buteo swainsoni*. Journal of Ornithology 161: 885–891. doi:10.1007/s10336-020-01776-7.

Katzner, T. E., M. N. Kochert, K. Steenhof, C. L. McIntyre, E. H. Craig, and T. A. Miller (2020). Golden Eagle (*Aquila chrysaetos*), version 2.0. In Birds of the World (P. G. Rodewald and B. K. Keeney, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.goleag.02.

Keddy-Hector, D. P., P. Pyle, and M. A. Patten (2020). Aplomado Falcon (*Falco femoralis*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.aplfal.01.

Lieske, D. J., L. W. Oliphant, P. C. James, I. G. Warkentin, and R. H. M. Espie (1997). Age of first breeding in Merlins (*Falco columbarius*). The Auk 114:288–290. doi:10.2307/4089170.

Luttich, S. N., L. B. Keith, and J. D. Stephenson (1971). Population dynamics of the Red-tailed Hawk (*Buteo jamaicensis*) at Rochester, Alberta. The Auk 88:75–87. doi:10.2307/4083962.

McClure, C. J., S. E. Schulwitz, D. L. Anderson, B. W. Robinson, E. K. Mojica, J.-F. Therrien, M. D. Oleyar, and J. Johnson (2019). Commentary: Defining raptors and birds of prey. Journal of Raptor Research 53:419. doi:10.3356/0892-1016-53.4.419.

McClure, C. J. W., J. R. S. Westrip, J. A. Johnson, S. E. Schulwitz, M. Z. Virani, R. Davies, A. Symes, H. Wheatley, R. Thorstrom, A. Amar, R. Buij, et al. (2018). State of the world's raptors: Distributions, threats, and conservation recommendations. Biological Conservation 227:390–402. doi:10.1016/j.biocon.2018.08.012.

Meyer, K. D. (2020). Swallow-tailed Kite (*Elanoides forficatus*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.swtkit.01.

Miller, K. E., and K. D. Meyer (2020). Short-tailed Hawk (*Buteo brachyurus*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.shthaw.01.

Millsap, B. A. (2018). Demography and metapopulation dynamics of an urban Cooper's Hawk subpopulation. The Condor 120:63–80. doi:10.1650/CONDOR-17-124.1.

Millsap, B. A., J. V. Gedir, F. Abadi, M. J. Gould, and K. Madden (2023). A two-sex integrated population model reveals intersexual differences in life history strategies in Cooper's Hawks. Ecosphere 14:e4368. doi:10.1002/ecs2.4368.

Millsap, B. A., K. Madden, R. K. Murphy, M. Brennan, J. E. Pagel, D. Campbell, and G. W. Roemer (2019). Demographic consequences of sexual differences in age at first breeding in Cooper's Hawks (*Accipiter cooperii*). The Auk 136:1–20. doi:10.1093/auk/ukz032.

Morrison, J. L., and J. F. Dwyer (2023). Crested Caracara (*Caracara plancus*), version 1.1. In Birds of the World (N. D. Sly, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.y00678.01.1.

Mulhern, D. W., M. A. Watkins, M. A. Jenkins, and S. K. Sherrod (1994). Successful nesting by a pair of Bald Eagles at ages three and four. Journal of Raptor Research 28:113–114.

Nemeth, N. M., and J. L. Morrison (2002). Natal dispersal of the Crested Caracara (*Caracara cheriway*) in Florida. Journal of Raptor Research 36:203–206.

Newton, I. (1979). Population Ecology of Raptors. Buteo Books, Vermillion, SD, USA.

Newton, I. (1985). Lifetime reproductive output of female sparrowhawks. Journal of Animal Ecology 54:241–253. doi:10.2307/4634.

Newton, I., M. Marquiss, and D. Moss (1979). Habitat, female age, organo-chlorine compounds and breeding of European Sparrowhawks. Journal of Applied Ecology 16:777–793. doi:10.2307/2402853.

Ng, J., M. D. Giovanni, M. J. Bechard, J. K. Schmutz, and P. Pyle (2020). Ferruginous Hawk (*Buteo regalis*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.ferhaw.01.

O'Bryan, C. J., J. R. Allan, A. F. Suarez-Castro, D. M. Delsen, R. Buij, C. J. W. McClure, J. A. Rehbein, M. Z. Virani, J. D. McCabe, P. Tyrrell, P. J. Negret, et al. (2022). Human impacts on the world's raptors. Frontiers in Ecology and Evolution 10. doi:10.3389/fevo.2022.624896.

O'Dea, R. E., M. Lagisz, M. D. Jennions, J. Koricheva, D. W. A. Noble, T. H. Parker, J. Gurevitch, M. J. Page, G. Stewart, D. Moher, and S. Nakagawa (2021). Preferred reporting items for systematic reviews and meta-analyses in ecology and evolutionary biology: A PRISMA extension. Biological Reviews 96:1695–1722. doi:10.1111/brv.12721.

Page, M. J., J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, J. M. Tetzlaff, E. A. Akl, S. E. Brennan, R. Chou, et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. The BMJ 372:n71. doi:10.1136/bmj.n71.

Parker, J. W. (2020). Mississippi Kite (*Ictinia mississippiensis*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.miskit.01.

Parker, J. W., and M. Ports (1982). Helping at the nest by yearling Mississippi Kites. Raptor Research 16:14–17.

Platt, S. W. (1977). Successful breeding of juvenile Prairie Falcons in northeast Colorado. Raptor Research 11:81–82.

Posit Software (2024). RStudio (Build 375). Posit Software, PBC, Boston, MA, USA. https://www.posit.co.

Preston, C. R., and R. D. Beane (2024). Red-tailed Hawk (*Buteo jamaicensis*), version 1.1. In Birds of the World (A. F. Poole and M. G. Smith, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.rethaw.01.1.

Pyle, P. (2001). Age at first breeding and natal dispersal in a declining population of Cassin's Auklet. The Auk 118:996–1007. doi:10.2307/4089848.

Pyle, P. (2005a). First-cycle molts in North American Falconiformes. Journal of Raptor Research 39:378–385.

Pyle, P. (2005b). Remigial molt patterns in North American Falconiformes as related to age, sex, breeding status, and life-history strategies. The Condor 107:823–834. doi:10.1093/condor/107.4.823.

Pyle, P. (2008). Identification Guide to North American Birds. Part II. Slate Creek Press, Point Reyes Station, CA, USA.

Pyle, P. (2022). Examination of digital images from Macaulay Library to determine avian molt strategies: A case study on molts and plumages in eight species of North American hummingbirds. Wilson Journal of Ornithology 134:52–65. doi:10.1101/2021.02.03.429637.

Pyle, P., K. R. Foster, C. M. Godwin, D. R. Kaschube, and J. F. Saracco (2020). Yearling proportion correlates with habitat structure in a boreal forest landbird community. PeerJ 8:e8898 doi:10.7717/peerj.8898.

R Core Team (2024). R: A language and environment for statistical computing (Version 4.4.1). R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org.

Reese, J. G. (1977). Reproductive success of Ospreys in central Chesapeake Bay. The Auk 94:202–221.

Reichert, B. E., C. E. Cattau, R. J. Fletcher, Jr., P. W. Sykes Jr., J. A. Rodgers, Jr., and R. E. Bennetts (2020). Snail Kite (*Rostrhamus sociabilis*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.snakit.01.

Reynolds, R. T. (1972). Sexual dimorphism in accipiter hawks: A new hypothesis. The Condor 74:191–197. doi:10.2307/1366283.

Reynolds, R. T., and H. M. Wight (1978). Distribution, density, and productivity of accipiter hawks breeding in Oregon. Wilson Bulletin 90:182–196.

Rosenfield, R. N., J. Bielefeldt, T. L. Booms, J. A. Cava, and M. A. Bozek (2013). Life-history trade-offs of breeding in one-year-old male Cooper's Hawks. The Condor 115:306–315. doi:10.1525/cond.2013.120001.

Rosenfield, R. N., K. K. Madden, J. Bielefeldt, and O. E. Curtis (2024). Cooper's Hawk (*Astur cooperii*), version 1.1. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.coohaw.01.1.

Runde, D. E. (1987). Population dynamics, habitat use and movement patterns of the Prairie Falcon (*Falco mexicanus*). Ph.D. dissertation, University of Wyoming, Laramie, WY, USA.

Sergio, F., I. Newton, L. Marchesi, and P. Pedrini (2006). Ecologically justified charisma: Preservation of top predators delivers biodiversity conservation. Journal of Applied Ecology 43:1049–1055. doi:10.1111/j.1365-2664.2006.01218.x.

Sibly, R., and P. Calow (1986). Why breeding earlier is always worthwhile. Journal of Theoretical Biology 123: 311–319. doi:10.1016/S0022-5193(86)80246-6.

Simmons, R., P. Barnard, B. MacWhirter, and G. L. Hansen (1986b). The influence of microtines on polygyny, productivity, age, and provisioning of breeding Northern Harriers: A 5-year study. Canadian Journal of Zoology 64:2447–2456. doi:10.1139/z86-365.

Simmons, R. E., P. C. Smith, and R. B. MacWhirter (1986a). Hierarchies among Northern Harrier (*Circus cyaneus*) harems and the costs of polygyny. Journal of Animal Ecology 55:755–771. doi:10.2307/4414.

Smallwood, J. A., and D. M. Bird (2020). American Kestrel (*Falco sparverius*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.amekes.01.

Smith, G. D., M. J. McGrady, B. C. Beckmann, and M. K. Oli (2025). Potential effects of HPAI on occupancy rates, breeding success, age and turnover of breeding Peregrine Falcons *Falco peregrinus* in southern Scotland. Bird Study 72:69–73. doi:10.1080/00063657.2024.2396564.

Smith, K. G., S. R. Wittenberg, R. B. Macwhirter, and K. L. Bildstein (2020). Northern Harrier (*Circus hudsonius*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi: 10.2173/bow.norhar2.01.

Snyder, N. F. R., S. R. Beissinger, and R. Chandler (1989). Reproduction and demography of the Florida Everglade (Snail) Kite. The Condor 91:300–316. doi:10.2307/1368308.

Speiser, R., and T. Bosakowski (1991). Nesting phenology, site fidelity, and defense behavior of Northern Goshawks in New York and New Jersey. Journal of Raptor Research 25:132–135.

Squires, J. R., and R. T. Reynolds (2024). American Goshawk (*Astur atricapillus*), version 1.2. In Birds of the World (N. D. Sly, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.norgos.01.2.

Steenhof, K. (2024). Prairie Falcon (*Falco mexicanus*), version 2.0. In Birds of the World (B. K. Keeney, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.prafal.02.

Steenhof, K., M. N. Kochert, and J. H. Doremus (1983). Nesting of subadult Golden Eagles in southwestern Idaho. The Auk 100:743–747. doi:10.1093/auk/100.3.743.

Steenhof, K., M. N. Kochert, C. L. McIntyre, and J. L. Brown (2017). Coming to terms about describing Golden Eagle reproduction. Journal of Raptor Research 51:378–390. doi:10.3356/JRR-16-46.1.

Steenhof, K., M. N. Kochert, and M. Q. Moritsch (1984). Dispersal and migration of southwestern Idaho raptors. Journal of Field Ornithology 55:357–368.

Stout, W. E., and R. N. Rosenfield (2010). Colonization, growth, and density of a pioneer Cooper's Hawk population in a large metropolitan environment. Journal of Raptor Research 44:255–267. doi:10.3356/JRR-09-26.1.

Stout, W. E., R. N. Rosenfield, W. G. Holton and J. Bielefeldt (2007). Nesting biology of urban Cooper's

Hawks in Milwaukee, Wisconsin. Journal of Wildlife Management 71:366–375. doi:10.2193/2005-664.

Swenson, J. E., K. L. Alt, and R. L. Eng (1986). Ecology of Bald Eagles in the greater Yellowstone ecosystem. Wildlife Monographs 95.

Teresa, S. (1980). Golden Eagles successfully breeding in subadult plumage. Journal of Raptor Research 14:86–87.

Tordoff, H. B., and P. T. Redig (1997). Midwest Peregrine Falcon demography, 1982–1995. Journal of Raptor Research 31:339–346.

Warkentin, I. G., N. S. Sodhi, R. H. M. Espie, A. F. Poole, L. W. Oliphant, and P. C. James (2020). Merlin (*Falco columbarius*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.merlin.01.

Webster, H., Jr. (1944). Survey of the Prairie Falcon in Colorado. The Auk 61:609–616. doi:10.2307/4080182.

Wendt, A. M., and G. A. Septon (1991). Notes on a successful nesting by a pair of yearling Peregrine Falcons *Falco peregrinus*. Journal of Raptor Research 25:21–22.

Whaley, W. H. (1986). Population ecology of the Harris's Hawk in Arizona. Raptor Research 20:1–15.

White, C. M., N. J. Clum, T. J. Cade, and W. G. Hunt (2024). Peregrine Falcon (*Falco peregrinus*), version 1.1. In Birds of the World (S. M. Billerman and M. G. Smith, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.perfal.01.1.

Whitfield, D. P., A. H. Fielding, D. Anderson, S. Benn, R. Dennis, J. Grant, and E. D. Weston (2022). Age of first territory settlement of Golden Eagles *Aquila chrysaetos* in a variable competitive landscape. Frontiers in Ecology and Evolution 10:743598. doi:10.3389/fevo.2022.743598.

Wickham, H. (2022). *rvest*: Easily harvest (scrape) web pages. R package version 1.0.3. https://CRAN.R-project.org/package=rvest.

Wiley, J. W. (1975). The nesting and reproductive success of Red-tailed Hawks and Red-shouldered Hawks in Orange County, California, 1973. The Condor 77:133–139. doi:10.2307/1365782.

Winter, D. J. (2017). *rentrez*: An R package for the NCBI eUtils API. The R Journal 9:520–526. doi:10.32614/RJ-2017-058.

Woodbridge, B., K. K. Finley, and P. H. Bloom (1995). Reproductive performance, age structure, and natal dispersal of Swainson's Hawks in the Butte Valley, California. Journal of Raptor Research 29:187–192.

Younk, J. V., and M. J. Bechard (1994). Breeding ecology of the Northern Goshawk in high-elevation aspen forest of northern Nevada. Studies in Avian Biology 16:119–121.

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