Invited Paper:

LONG-TERM COUNTS OF MIGRATING RAPTORS: A ROLE FOR VOLUNTEERS IN WILDLIFE RESEARCH

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Abstract: The science of conservation biology and the practice of wildlife management depend upon long-term databases, but collecting such data can be difficult, expensive, and labor intensive. Conservation biologists and wildlife managers have long used "nonprofessional" volunteers to collect much of the information needed to make informed decisions concerning the resources they are attempting to understand and protect. The advent of the modern field guide in the 1930s, together with the growing availability of prismatic binoculars, heralded the modern age of recreational bird watching. Since then, bird watchers have made significant and substantial contributions to our understanding of bird populations in North America. Hawk Mountain Sanctuary in eastern Pennsylvania has used volunteer hawk watchers, in conjunction with its own paid staff, to help create the longest and most complete record of raptor migration in the world. The Sanctuary's annual counts of migrating raptors have proved a critical resource in assessing long-term trends of raptor populations in northeastern North America. The extensive database played a key role in exposing the threat of organochlorine pesticides to bald eagles (*Haliaeetus leucocephalus*) and other predatory birds earlier this century, as well as in tracking more recent recoveries in many of the same populations. Recent analyses of the database are yielding insights into (1) how cold fronts affect counts of raptors at migration watchsites, (2) the extent to which climate change affects the timing of raptor migration, and (3) changes in the migratory habits of sharp-shinned hawks (*Accipiter striatus*) in eastern North America. I submit that volunteers will play increasingly important roles in wildlife conservation wherever their efforts can be coupled with those of professional practitioners in the field.

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Hawks, eagles, and falcons have attracted the attention of wildlife biologists for centuries. Some of the most ancient of all game laws protected these birds, and their prey, for use in falconry (Leopold 1933). More recently, interest has focused on the role raptors play in limiting game populations (Newton 1993). Indeed, the very first article in the *Journal of Wildlife Management* dealt with this subject in some detail (Errington and Hamerstrom 1937). Most recently, wildlife conservationists have used raptors as "flagship" or "umbrella" species (Newton and Chancellor 1985, Meyburg and Chancellor 1989, Thiollay 1989) to protect entire habitat types and to monitor ecosystem health (Carson 1962, Hickey 1969, Cade et al. 1988).

Raptors are secretive, wide-ranging, area-sensitive predators whose populations can be logistically difficult and financially prohibitive to survey and monitor (Fuller and Mosher 1981, 1987). Hence, wildlife managers often are hard-pressed to assess the conservation status of these potentially significant species. Indeed, lack of information regarding regional and continental populations of many raptors continues to plague management decisions (Kennedy 1997). One potentially cost-effective method for monitoring regional and even continental populations of raptors is sampling their numbers at traditional migratory bottlenecks and concentration points (Bildstein et al. 1995).

Anecdotal accounts of raptor migration date from the Old Testament (Job 39:26–29); Western Hemisphere accounts from within 30 years of European settlement (Oviedo y Valdés [1555] in Baughman 1947). Today, raptor migration "hot spots" in Eilat, Israel, Cape May Point, New Jersey, and Hawk Mountain, Pennsylvania, annually attract tens of thousands of visitors (Bildstein and Zalles 1995). The Hawk Migration Association of North America, an organization with >800 members, is devoted entirely to the study of raptor migration.

Even so, detailed accounts of raptor migra-

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Table 1. Average annual counts and high and low annual counts of raptors seen at Hawk Mountain Sanctuary, Pennsylvania, 1934–95, and average hourly passage rates for 1991–95. Hourly count data were standardized via a species-specific truncation procedure that eliminates 1–2% of the total count at the extremes of each species' overall temporal distributions (Bednarz et al. 1990). Data for vultures are based on counts since 1990.

Species	Long-term annual counts (1934–95)			Hourly passage rate (1991–95)
	Average	Highest (year)	Lowest (year)	
Turkey vulture (*Carthartes aura*)	143	190 (1994)	84 (1992)	0.23
Black vulture (*Coragyps atratus*)	39	54 (1994)	21 (1992)	0.05
Osprey (*Pandion haliaetus*)	342	872 (1990)	17 (1934)	1.03
Bald eagle (*Haliaeetus leucocephalus*)	47	136 (1995)	13 (1974)	0.09
Northern harrier (*Circus cyaneus*)	223	475 (1980)	89 (1934)	0.31
Sharp-shinned hawk (*Accipiter striatus*)	4,246	10,612 (1977)	1,259 (1965)	10.20
Cooper's hawk (*A. cooperii*)	283	786 (1989)	61 (1964)	0.90
Northern goshawk (*A. gentilis*)	69	347 (1972)	3 (1953)	0.10
Red-shouldered hawk (*Buteo lineatus*)	245	468 (1958)	87 (1971)	0.48
Broad-winged hawk (*B. platypterus*)	8,527	29,519 (1978)	2,886 (1946)	19.70
Red-tailed hawk (*B. jamaicensis*)	3,208	6,208 (1939)	1,525 (1956)	5.73
Rough-legged hawk (*B. lagopus*)	9	31 (1961)	0 (6 years)	0.01
Golden eagle (*Aquila chrysaetos*)	45	100 (1995)	12 (1966)	0.10
American kestrel (*Falco sparverius*)	367	839 (1989)	11 (1934)	1.00
Merlin (*F. columbarius*)	33	168 (1995)	7 (1972)	0.16
Peregrine falcon (*F. peregrinus*)	23	51 (1989)	6 (1982)	0.51
All raptors	17,787	40,698 (1978)	7,892 (1934)	23.30

tion prior to this century are rare (Goldman 1970). Overall, ornithologists and wildlife biologists appear to have been unaware of the large-scale movements of these birds throughout most of the 19th century. As recently as the early 1900s, most information about raptor migration in North America resulted from extensive turn-of-the-century collecting efforts targeting the food habits of various species, many of which were considered vermin at the time (Fisher 1893, May 1935)

The delayed appreciation of large-scale raptor migration in North America and elsewhere is understandable. Raptor migration is brief and episodic, and many raptors migrate inland and away from other birds. Without binoculars or field glasses, much of the migration was too high to be seen. Without modern field guides, many of the birds, even when seen, could not be identified. A good example of the problem is the long-distance migration of the broad-winged hawk, a small, forest-dwelling and completely migratory buteo that breeds throughout much of northeastern North America. (The scientific names of all raptors mentioned in the text are included in Table 1.)

Although there is now a rich and expanding literature regarding the spectacular transequatorial movements of the broad-winged hawk (Olendorff and Olendorff 1969, Goodrich et al. 1996), the species was thought a year-round resident throughout most of its North American breeding range as recently as 100 years ago (Warren 1890, Stone 1894). The earliest published indication of broad-winged hawk migration I have found is that of a springtime flight of 50 individuals seen by an "amateur" birder in coastal Texas in 1877 (Sennett 1878). Almost certainly, the account resulted from the author's use of field glasses, which only then were coming into widespread use. Shortly thereafter, other field-glass assisted observers began reporting "immense clusters" of migrating broad-winged hawks on migration elsewhere in northeastern North America (Trowbridge 1895).

However, it was not until the early 1930s that monitoring the large-scale movements of migrating raptors entered the modern age. By then, a growing number of birders, including many raptor enthusiasts, were using recently affordable prismatic binoculars to spot and identify birds (Kastner 1986). More powerful and accurate than 2 and 4× field glasses, 6 and 7× binoculars allowed hawk watchers to see migrating raptors "closer" and more clearly than ever before. The use of binoculars, particularly in conjunction with the first modern field guide—Roger Tory Peterson's *A Field Guide to the Birds* was published in the spring of 1934 (Peterson 1934)—provided raptor-migration enthusiasts with the tools needed to quickly identify raptors passing overhead.

The establishment of Hawk Mountain Sanctuary in the 1930s, as the world's first refuge for migrating birds of prey, provided an initial outlet for this new "sport." For the first time, conservationists were systematically documenting the regularity and predictability of large-scale movements of birds of prey at particular locations. The intriguing phenomenon of raptor migration became more accessible as people learned where and when to look for it. With these 3 factors in place (field guides, prismatic binoculars, and a count site), recreational hawk watching was ready to make a significant contribution to conservation.

Hawk Mountain Sanctuary

Hawk Mountain Sanctuary was founded in 1934 by conservationist Rosalie Edge. Edge established the Sanctuary to stop the slaughter of hawks and eagles migrating past a rocky promontory in the central Appalachians of eastern Pennsylvania, as well as to foster an appreciation and understanding of raptors and the region's natural environments (Broun 1949). The 900-ha Sanctuary straddles the Kittatinny Ridge, the easternmost range in the Valley-and-Ridge Physiographic Province of eastern Pennsylvania, 175 km west of New York City (Allen et al. 1995).

A combination of prevailing northwesterly winds and northeast to southwest mountain topography places Hawk Mountain along a major raptor-migration corridor in the Western Hemisphere (Broun 1949, Kerlinger 1989, Brett 1991). Each autumn, tens of thousands of raptors from northeastern North America migrate along the Kittatinny Ridge, a corduroy hill that stretches for 400 km from 90 km north of New York City, through northwestern New Jersey and eastern Pennsylvania, almost to northern Maryland. On more than 120 occasions, spectacular flights of >1,000 raptors have been recorded at the Sanctuary on a single day. During the 62 years from 1934 through 1995, an annual average of >17,000 raptors that represent 16 of North America's 34 species of diurnal birds of prey (including 2 New World vultures) has been counted at the site (Allen et al. 1995, 1996).

Before the Sanctuary was founded, hunters traditionally gathered on the ridgetops of eastern Pennsylvania each autumn to shoot migrating hawks, eagles, and falcons, several species of which had bounties on them (Sutton 1928*a*, Senner 1984). Because of easy roadside access, Hawk Mountain in particular became a favored shooting site in the region. In some years, especially the late 1920s and early 1930s, thousands of birds were killed at the site as they traveled south along the Appalachian Mountains. In spite of considerable local opposition, the Sanctuary's first employee, Maurice Broun, eliminated shooting at the site during the first year of operation.

In 1938, Edge deeded the Sanctuary to the Hawk Mountain Sanctuary Association, a private, member-supported, not-for-profit organization dedicated to fostering "the conservation of birds of prey and other wildlife." By the early 1950s, the Sanctuary was widely recognized as a model program in grassroots conservation, wildlife management, ecological monitoring, and environmental education. In 1984, the President's Council on Environmental Quality cited the Sanctuary as "a striking example of the role of private initiative in achieving major accomplishments in wildlife conservation" (Council on Environmental Quality 1984).

Hawk Mountain Sanctuary's Long-Term Database

Along with marking the property's boundaries and confronting local shooters, Broun spent his first autumn at the Sanctuary identifying and recording the numbers of raptors migrating past the site's North Lookout. Broun had initiated his counts primarily to document the magnitude of the flight to enlist financial support for conservation efforts at the Sanctuary (Broun 1935). However, it quickly became apparent that a series of annual counts would permit the Sanctuary to monitor regional populations of raptors (Broun 1939). By its second year of operation, counts of migrating raptors had become the primary feature of the Sanctuary's fieldwork (Broun 1949).

Today, Hawk Mountain Sanctuary maintains the longest and most complete record of raptor migration in the world (Table 1). Excepting the war years of 1943–45, raptor migration has been recorded at the site each year since 1934 (Bednarz et al. 1990, Allen et al. 1996). Since 1935, counts have occurred almost every day each autumn from early September to late November. Coverage has expanded in recent years, and counts are now conducted on most days from 15 August through 15 December. Daily coverage usually begins at 0800 and ends at 1700. Binoculars and, occasionally, telescopes are used to find and identify migrants.

Initially, count data were recorded into

Broun's field notebooks. Data are now collected on standardized daily-record forms and then transferred to a computerized database. Data collected before 1966 consist of daily totals of the numbers of each species migrating over the Sanctuary's North Lookout count site, together with information on air temperature, barometric pressure, wind speed, wind direction, flight direction, number of days after the most recent cold front, duration of observer effort, number of observers (almost always 1 or 2), and number of visitors. Since 1966, data have been collected on an hourly basis. (See Bednarz et al. [1990] and Allen et al. [1996] for additional details regarding the Sanctuary's database.) Through 1995, the Sanctuary had recorded 1,059,975 raptors representing 16 North American species (Table 1).

Volunteerism at Hawk Mountain Sanctuary

Publicity surrounding the establishment of Hawk Mountain Sanctuary was considerable—predators, including raptors, were considered vermin at the time, even by many wildlife conservationists (Sutton 1928*b*, May 1935)—and news of the unusual Sanctuary's existence quickly spread among the conservation and birding communities. More than 1,000 bird watchers, many eager to see their first migrating bird of prey, flocked to the Sanctuary in the autumn of 1935 (Broun 1949). By the mid-1950s, the Sanctuary was hosting >10,000 visitors a year. By the mid-1990s, >80,000 visitors (67% of which came during the peak of autumn hawk migration from Sep through Nov) were traveling to the site annually, with as many as 3,500 visitors arriving on single weekend days.

As is true of most birding venues, the majority of the Sanctuary's visitors are middle-aged, well educated, and male (59%). Most (69%) are Pennsylvania residents (Kerlinger and Brett 1995). Although 40% are first-time visitors, 25% are Sanctuary members, many of which make annual pilgrimages to the site. Included among the latter is a large number of individuals who contribute significant time and effort as Sanctuary volunteers.

As of late 1997, the refuge's volunteer workforce included an active roster of >200 individuals. Most volunteers live within 100 km of the site, and most participate in Sanctuary activities on a weekly or monthly basis. Volunteers assist the Sanctuary's staff in visitor reception, gate admissions, parking, bookstore sales, on- and off-site education programs, care of captive raptors, data entry, field research, ecological monitoring, maintaining the buildings and grounds, clerical work, and Sanctuary mailings. Volunteers currently contribute >12,000 hr of service per year; the equivalent of >6 full-time employees.

Although volunteers have been involved in most aspects of Sanctuary operations for some time, among their earliest area of activity was helping to conduct the daily hawk count. Between 1934 and 1948, Broun conducted the count on his own. In 1949, however, he decided to supplement his efforts with those of volunteers. In the early 1950s (1950–55), 72 volunteers conducted 24% of the daily counts. Between 1990 and 1995, 25 volunteers conducted 37% of the counts. In addition to counting hawks, volunteers are responsible for initial duplicative entry of count data into a spreadsheet database for validation by the Sanctuary's staff, before archival storage.

In most years, 6–12 volunteers assist 3–4 Sanctuary staff and count raptors over the course of autumn migration. Most volunteer counters are assigned a specific day of the week. Volunteers have at least 1–2 years of experience counting raptors, either at the Sanctuary or elsewhere along the Kittatinny Ridge. Most continue to count at the Sanctuary for at least 2–3 years, and several have counted at the site for more than a decade.

Examples of Uses of the Sanctuary's Volunteer-Assisted Database

Volunteers are among the most important "tools" in the Sanctuary's conservation "tool kit." At Hawk Mountain Sanctuary, volunteers are not *a way* of doing conservation, they are *the way*. Without their assistance, the Sanctuary's long-term database might not exist. During the past 60 years, Sanctuary staff and volunteers have published 33 peer-reviewed articles and 2 books based on the volunteer-assisted database. Below are specific examples of how the Sanctuary has used this database to help understand and protect migrating birds of prey for more than half a century.

The DDT Era

We now know that the widespread use of DDT and other organochlorine pesticides in North America in mid-20th century deleteriously affected populations of many birds, in-

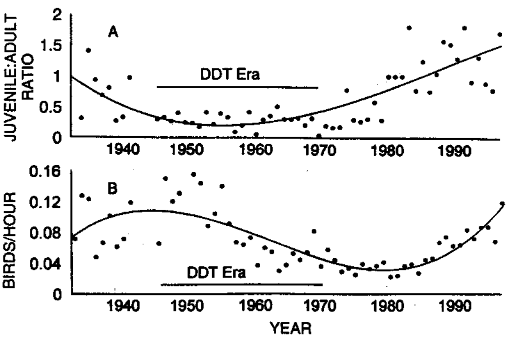

Fig. 1. Long-term fluctuations in the ratio of juvenile:adult bald eagles seen at Hawk Mountain Sanctuary, Pennsylvania, 1934–95, (A) together with annual rates of passage (birds/hr) for bald eagles at the site during the same period (B).

cluding several species of raptors (Risebrough 1986, Cade et al. 1988). Although conservationists had suggested the potential for such an effect as early as the late 1940s (Gabrielson et al. 1950), documenting effects of DDT proved far more difficult, partly because long-term databases were lacking (Hickey 1969).

Among the earliest conservation uses of the Sanctuary's long-term database was an analysis of annual ratios of juvenile and adult bald eagles sighted at the Sanctuary before and after the widespread use of DDT (Fig. 1). A distinctive bimodal pattern in the timing of autumn migration of bald eagles at the Sanctuary—a major movement in late August–early September, followed by a much smaller movement in mid-November (Atkinson et al. 1996)—suggested that although both "southern" and "northern" bald eagles migrated past Hawk Mountain, most of the site's birds were southern bald eagles, most of which nested in Florida (Broley 1947).

As early as 1952, a concerned Broun was commenting on the substantial decline in the ratio of juvenile:adult bald eagles at the site, which had begun in the late 1940s and coincided with decreases in the reproductive success of bald eagles nesting in Florida (Broley 1950; M. Broun. 1952. Curator's report. Hawk Mountain Sanctuary Newsletter to Members 21:3–4, unpublished). A decade later, Rachel Carson used this same database in her conservation classic *Silent Spring* to support arguments for the effect of organochlorine pesticides on populations of bald eagles and other species of predatory birds (Carson 1962).

What is particularly notable is that the same database, which now extends through the mid-1990s (Fig. 1A), not only tracks the decline in the ratio of juvenile:adult bald eagles through the early 1970s, but also the recovery of bald eagle populations subsequent to bans on use of DDT in Canada and the United States in 1972. Even more noteworthy is evidence of the delayed decline and recovery in the Sanctuary's total counts of bald eagles during the same period (Fig. 1B), exactly as expected if declines in the ratio of juvenile:adult bald eagles reflected decreased reproductive success. Sanctuary counts of peregrine falcons, together with those of 2 largely avivorous accipiters (sharp-shinned hawk, Cooper's hawk), also declined and similarly recovered during the same period (Bednarz et al. 1990), bolstering Carson's interpretation of the bald eagle age-ratio data (Fig. 2).

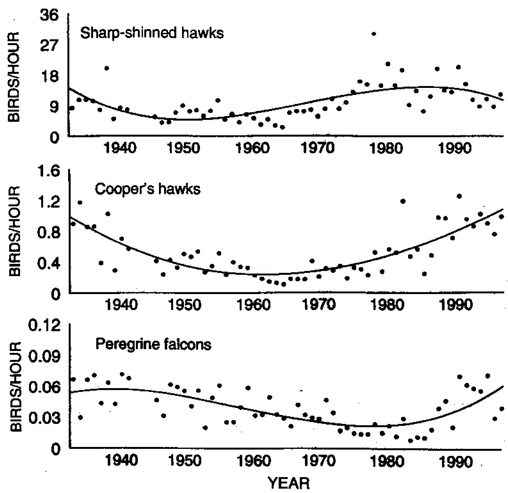

Fig. 2. Long-term fluctuations in annual passage rates (birds/hr) for sharp-shinned hawks, Cooper's hawks, and peregrine falcons seen at Hawk Mountain Sanctuary, 1934–95. Note the declines in the counts during the DDT era of the 1950s and 1960s, followed by recoveries in the 1970 and 1980s.

Weather Effects on Raptor Migration

In spite of results such as those presented above, the validity of population trend analyses based on migration counts continues to be challenged by some who cite confounding factors including a lack of standardization, observer variability and fatigue, inherent variability in the migratory habits of raptors, and weather. Inter- and intra-annual variation in weather were particularly cited as problematic (Kerlinger 1989 and references therein; but see Hussell 1985).

With regard to weather, a longstanding consensus in the literature posits, at least in eastern North America, that raptor migration counts increase 1–2 days after the passage of a cold front, especially when such fronts are accompanied by strong northwesterly winds (Allen et al. 1996). As early as 1935, for example, Broun was suggesting that cold fronts significantly enhanced the Sanctuary's counts (Broun 1935).

Explanations for the phenomenon fall largely into 2 categories. Some investigators suggest that passage of a cold front actually enhances the likelihood of autumn movements of raptors. Others contend that migrants simply are more visible at such times, either because the high winds that accompany such events push birds longitudinally from broad frontal migrations into movements along leading lines such as Hawk Mountain, or because winds divert the birds from high-altitude thermal soaring to low-altitude slope soaring. Whether either or both of these hypotheses is true has important implications for the use of migration counts to determine long-term population trends.

If, for example, frontal passage enhances raptor migration, then numbers of cold fronts per year should have little, if any, effect on the annual counts of raptors at a site. Conversely, if frontal passage simply brings raptors into better view at places like the Sanctuary, then annual variation in number of fronts should affect annual counts, and in turn, the usefulness of those counts in detecting long-term trends.

On average, cold fronts pass the Sanctuary once every 4–5 days in autumn (Allen et al. 1996). In 1992, Sanctuary scientists used paired 55-year (1934–91) weather and raptor-migration databases to determine the extent of within- and among-year associations in frontal passage rates and the magnitude of autumn raptor migration at the Sanctuary (Allen et al. 1996). Two questions were asked of the data: (1) did the passage of individual cold fronts affect the numbers of raptors seen at the site; and (2) if so, did annual variation in frontal passage rates affect annual counts of raptors at the site.

The analyses revealed significant and consistent within-year effects of individual fronts on the magnitude of raptor migration. Twelve of the Sanctuary's 14 species of raptors (New World vultures were not included in the analysis) exhibited significant increases in passage rates during ≥1 of the 3 days after a cold front moved through the area. Responses fit 1 of 3 basic patterns, each of which appeared closely tied to the flight behavior of the species involved (Allen et al. 1996).

Falcons, particularly merlins and peregrine falcons, had their highest rates of passage on the day of frontal passage. Counts of merlins, for example, averaged 52% higher the day of and the day after frontal passage than during the next 2 days (Fig. 3). By comparison, accipiters, particularly Cooper's hawks and northern goshawks, had highest rates of passage on the day after frontal passage. Buteos, including red-shouldered hawks, broad-winged hawks, and red-tailed hawks, had highest rates of passage 1–2 or 1–3 days after frontal passage (Fig. 3).

The 3 distinctive patterns appear to result from a combination of changing weather conditions following frontal passage, together with differences in the aerodynamic capabilities of the species involved. For example, although falcons sometimes soar on migration, they usually spend most of their time in rapid, relatively low-altitude, direct flapping flight, a flight tactic ideally suited to the high-speed, near-surface winds that typically occur during and within a day of frontal passage. Conversely, migrating accipiters fly higher, flap less, and soar more than migrating falcons. As such, accipiters are far better suited to the lighter, updraft-producing northwesterly winds and weak thermals that begin to form within a day of frontal passage. Finally, buteos soar more and fly higher on migration than do most other raptors, making them ideally suited to the fair weather conditions that occur 2–3 days after frontal passage.

During the 55-year study period, 10–20 cold fronts passed Hawk Mountain each year between 1 September and 23 November (the peak migration period). Even so, and despite consistent within-year associations in numbers of birds seen following the movements of cold fronts through the area, there was no among-year effect of frontal passage rate on annual counts of raptors (Allen et al. 1996). This finding is of more than passing interest, given that frontal passage rates declined during the DDT era of the late 1940s–early 1970s (Bednarz et al. 1990), at the same time that counts of many raptors declined. If annual counts of raptors and numbers of cold fronts were associated, use of the Sanctuary's long-term database would be suspect with regard to links between DDT use and declines in raptor populations (Hickey 1969, Bednarz et al. 1990).

Seasonality of Migration

Until recently, most analyses of raptor-migration databases have focused on numbers of

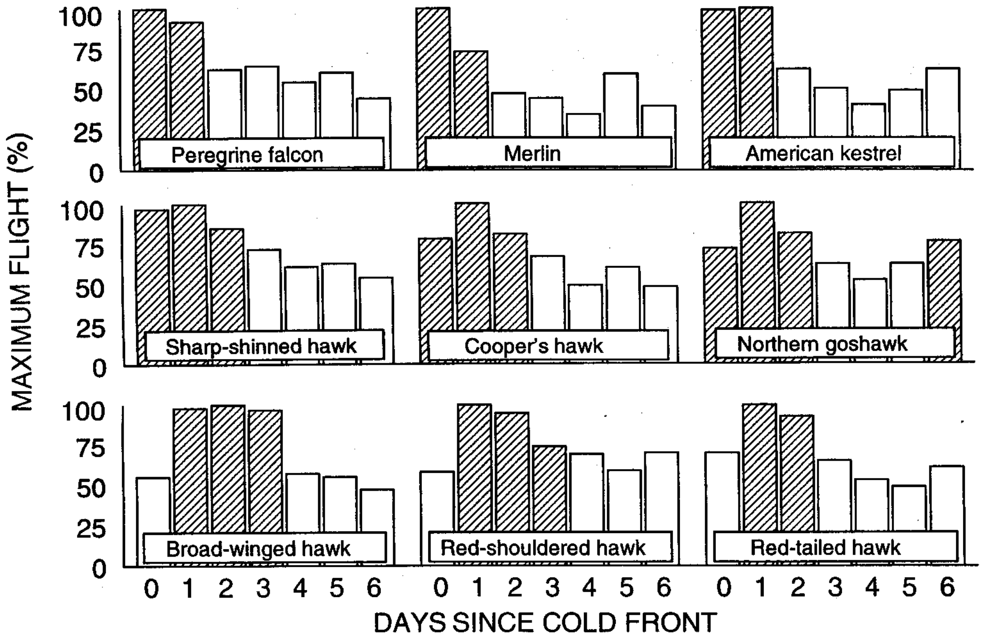

Fig. 3. Passage rates for 9 species of raptors at Hawk Mountain Sanctuary, Pennsylvania, 1934–91, as a function of days since the most recent cold front passed through the region. The height of each bar is expressed as a percentage of the highest passage rate for each species. Passage rates on days with bars with diagonal stripes are significantly different than those on days with open bars (Tukey's test in association with 1-way analysis of variance: $P < 0.05$). A figure depicting actual passage rates for all 14 species of raptors appeared in Viverette et al. 1996.

birds passing a site, and not on seasonal timing of migration. To determine the extent to which species migration schedules at a site are affected by exogenous factors such as climate change, Sanctuary count data recently were used to calculate annual dates of passage for 25%, 50%, and 75% of the flights of 4 species (northern harriers, sharp-shinned hawks, broad-winged hawks, golden eagles). The analysis was restricted to counts conducted since 1946 because seasonal coverage of autumn migration has been more consistent at the site since that time.

Except for broad-winged hawks, for which the mean date of passage for the first 25% of the flight was 2.2 days earlier in the 1980s than in the 1950s, none of the species exhibited long-term shifts in migration schedules. Further, migration schedules did not shift in response to annual fluctuations in the numbers of cold fronts that passed the Sanctuary during each species' migration period, nor did schedules shift in response to fluctuations in numbers of birds observed each year.

Overall, this preliminary analysis indicates considerable stability in the seasonal timing of autumn raptor migration at the Sanctuary and suggests this aspect of migration is less responsive to exogenous factors than are other aspects of migration. Thus, seasonal timing of migration may provide a useful benchmark for studies of large-scale, climate-change effects.

Shifts in Migration Behavior of Sharp-Shinned Hawks

As powerful as long-term raptor migration data may appear, in some instances their use in isolation can lead to misinterpretation. An example is the recent decline in the numbers of sharp-shinned hawks counted at many traditional count sites in the northeastern United States (Kellogg 1993). The Sanctuary's long-term database indicated populations of sharp-shinned hawks began to decline in 1949, presumably in response to widespread use of organochlorine pesticides, and that this species began to recover from this environmental insult in the mid- to late 1960s. By the late 1970s, counts of sharp-shinned hawks at the Sanctuary suggested a complete recovery from the pesticide-era lows of mid-century (Bednarz et al. 1990). In general, Sanctuary counts for sharp-shinned hawks

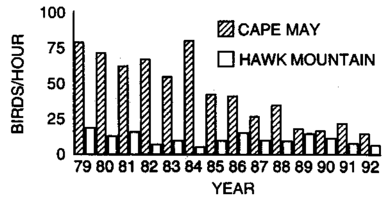

Fig. 4. Passage rates (bird/hr) of sharp-shinned hawks counted at a coastal (Cape May Point, New Jersey) and an inland watchsite (Hawk Mountain Sanctuary, Pennsylvania) in the northeastern United States, 1979–92. The overwhelming majority of sharp-shinned hawks migrating along the coastal migration corridor were juvenile birds.

paralleled those at other northeastern migration watchsites during this period.

In the 1980s and early 1990s, numbers of sharp-shinned hawks sighted at many traditional migration watchsites again began to decline substantially (Kellogg 1993). The declines were especially noticeable at coastal watchsites, where the flight consisted almost entirely of juvenile birds (Fig. 4). At first, reports of the decline were accompanied by suggestions of natural population cycling, changes in migration behavior, and increased wintering north of the watchsites in question. As declines continued into the early 1990s, however, "explanations" for the decrease became decidedly more ominous, including suggestions of widespread habitat loss, pesticide contamination, the effect of acid precipitation, and declines in Neotropical migratory songbirds that the species preys upon (Viverette et al. 1996).

Given this uncertainty, in 1993, sharp-shinned hawk count data from the Sanctuary and Cape May Point, New Jersey, were compared with data from National Audubon Society Christmas Bird Counts (CBCs) to test the hypothesis that at least part of the decline resulted from northward shifts in overwintering populations of the species, versus changes in overall abundance.

Eleven years of CBC data (1979–89) were computerized and available for analysis. During this period, numbers of sharp-shinned hawks at 147 CBCs north of the 2 migration watchsites increased at an annual rate of 7.7%, with significant statewide changes recorded for Connecticut, New York, Pennsylvania, and New Jersey. An independent analysis of New England CBCs during the same period revealed similar increased numbers of early-winter sharp-shinned hawks (Duncan 1996). At the same time, numbers of hawks seen on the 128 CBCs south of the 2 count sites did not change significantly overall, although counts in Florida, the state with the highest number of banding returns for the region's migratory population, did decline significantly (Viverette et al. 1996).

The results strongly support the shift-in-migration-behavior hypothesis (i.e., migration short-stopping). That the number of sharp-shinned hawks declined more abruptly at Cape May Point than at the Sanctuary probably reflects the fact that the sharp-shinned hawk flight at Cape May Point overwhelmingly consists of juvenile birds, whereas the flight at the Sanctuary contains many adults. Work with several other migratory species indicates that juveniles are more likely to modify their migration in response to changing environmental conditions than are adults (Berthold 1993).

Although the reason for the change in migratory behavior is not certain, the study period does coincide with a series of especially warm winters (Intergovernmental Panel on Climate Change 1992). This weather change, together with the fact that sharp-shinned hawks rank above domestic cats as the number 1 predator on small birds at bird feeders (Dunn and Tessaglia 1994), suggests that climate change and growing numbers of bird feeders in the northeastern United States may be responsible for the change in behavior (Viverette et al. 1996).

CONCLUSIONS

Twentieth-century wildlife management and conservation biology abounds with examples of significant contributions by volunteers (Gill 1994). Earlier this century, most of those contributions were singular efforts on the part of especially dedicated individuals. Particularly notable examples include Margaret Morse Nice's studies of population dynamics of song sparrows (*Melospiza melodia*; Nice 1937), and Harold Mayfield's long-term efforts with the endangered Kirtland's warbler (*Dendroica kirtlandii*; Mayfield 1960). More recently, many local, regional, and national conservation organizations have come to depend upon significant volunteer work forces.

In 1995, a corps of >200 volunteers bolstered the Sanctuary's paid workforce by almost 50%. The Sanctuary is not alone in this regard. Other, well-established raptor-migration watchsite organizations, including HawkWatch International in Salt Lake City, Utah (S. W. Hoffman, Hawkwatch International, personal communication) and the Golden Gate Bird Observatory in San Francisco, California (A. M. Fish, Golden Gate Bird Observatory, personal communication) maintain similarly effective volunteer programs. The Hawk Migration Association of North America (HMANA), the largest and most successful raptor-migration organization in the world, consists almost entirely of individuals who voluntarily monitor raptor migration without financial remuneration (Bildstein and Zalles 1995). As of late 1997, HMANA's accumulating migration-count database, which is archived at the Sanctuary, included data from 1,066 count sites, 54 of which have been active for a decade or more.

Raptor migration science and conservation are not the only areas of wildlife management for which volunteers provide a potentially rich source of field assistance. With an estimated 63 million participants, bird watching currently ranks among the fastest growing recreational activities in the United States (Stangel and Fenwick 1997). Many bird watchers provide conservationists with useful sources of information. Each year, >40,000 bird watchers from across the United States and Canada actively participate in >1,600 National Audubon Society Christmas Bird Counts (F. B. Gill, National Audubon Society, personal communication); >6,000 participate in the Cornell Laboratory of Ornithology's Project FeederWatch (R. E. Bonney, Jr., Cornell Laboratory of Ornithology, personal communication). Earthwatch, an affiliate of The Center for Field Research, in Watertown, Massachusetts, has sent 50,000 volunteers to work with wildlife biologists and conservationists on hundreds of field projects around the world (Kricher 1997). In the public sector, federal and state wildlife managers have long depended upon data collected by recreational hunters and fishermen to monitor the extent to which these activities affect wildlife populations, as well as to provide movement and demographic data for game species (Giles 1969).

I have used the results of volunteer efforts at Hawk Mountain Sanctuary to argue that data collected by amateur bird watchers, wildlife enthusiasts, and hunters and fishermen provide a potentially significant resource for conservation biologists and wildlife managers. However, there are caveats.

First, data collected by multiple sources are not without problems (Giles 1969, Ralph and Scott 1981). Nevertheless, these data, especially when used in conjunction with additional spatially explicit datasets, including other volunteer-supported databases such as CBCs, Breeding Bird Surveys, Breeding Bird Censuses, bird-banding returns, and Project Feederwatch observations frequently provide useful information on the distribution and abundance of raptors and other birds (Root 1988, Viverette et al. 1996).

Second, attention needs to be given to the human side of the volunteer workforce. Groups of conservation volunteers are every bit as sociologically diverse as any large assemblage of people. Personality conflicts, different work ethics, worker dependability, scheduling concerns, and other issues occur in volunteer workforces just as they do in professional staff. Alternatively, volunteer work forces often serve to invest large segments of local communities in conservation work, thereby increasing the likelihood of local community acceptance and support of these efforts.

In sum, volunteers offer wildlife managers a practical solution to the conundrum of conducting effective conservation in an era of declining budgets and expanding mandates. The potential value of volunteers to wildlife managers is reason enough to explore this promising human resource.

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