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Factors influencing short- and long-term chances in raptor migration at Hawk Mountain Sanctuary, USA, 1934-1995

Faktory ovlivňující krátkodobé a dlouhodobé změny v migraci dravců na lokalitě Hawk Mountain Sanctuary (USA) v letech 1934-1995

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ABSTRACT. Many diurnal raptors aggregate during migration along prominent topographical features, including coastlines and mountain ridges. Migrating raptors are thought to concentrate along such "leitlinie" (leading lines; sensu GEYR von SCHWEPPENBURG 1963) because of better flight conditions there than elsewhere. In eastern North America longterm monitoring at watch-sites along leading lines dates from the early 1930s, when counts were initiated at Hawk Mountain Sanctuary in the central Appalachian Mountains of eastern Pennsylvania, USA, and at Cape May Point, at the southern tip of coastal New Jersey, USA. Hawk Mountain Sanctuary's 60-year monitoring program of migratory raptors is the longest and most complete record of raptor migration in the world. The Sanctuary's annual counts have proved to be a critical resource in assessing longterm trends in North American raptor populations. The extensive database played a key role in exposing organochlorine pesticides as causative agents of declines in Bald Eagles (*Haliaeetus leucocephalus*) and other species of predatory birds earlier this century. Recent analyses of the database are yielding insights into (1) how cold fronts affect counts of raptors at migration watch-sites, (2) the extent to which climate changes is affecting the seasonal timing of raptor migration, and (3) why counts of Sharp-shinned Hawks (*Accipiter striatus*) are declining at many watch-sites along the eastern seaboard of the United States.

Hawk Mountain Sanctuary, the world's first refuge for migrating birds of prey, was established in 1934 by New York conservationist Rosalie Edge. Edge founded the Sanctuary to halt the slaughter of hawks and eagles migrating past the rocky promontory, as well as to foster an understanding of Appalachian Mountain environments (BROUN 1948). Hawk Mountain's 900 hectares straddle Kittatinny Mountain, the eastern-most ridge of Pennsylvania's Valley-and-Ridge Province.

A combination of prevailing northwesterly winds and mountain topography places Hawk Mountain along a major migration corridor for Western Hemisphere birds. Each autumn, tens of thousands of raptors (hawks, eagles, falcons, and ospreys) and New World vultures from northeastern North America migrate along the ridge and over Hawk Mountain (BEDNARZ et al. 1990, ALLEN et al. 1995). Occasionally, spectacular migrations of thousands of birds are recorded on single days (BROUN 1948). Between 1934 and 1995, an annual average of more than 17,000 diurnal raptors and vultures representing 16 of North America's 34 species of raptors and vultures have been counted at the Sanctuary each autumn (Table 1).

Table 1 - Summary of Hawk Mountain's autumn counts, 1934-1995.
Tab. 1 - Počty nasčítaných dravců při podzimní migraci na Hawk Mountain Sanctuary v letech 1934-1995.

Species	Longterm average	Highest count /year/	Lowest count /year/
Cathartes aura (*)	143	190 (1994)	84 (1992)
Coragyps atratus (*)	39	54 (1994)	21 (1992)
Pandion haliaetus	342	872 (1990)	17 (1934)
Haliaeetus leucocephalus	47	136 (1995)	13 (1974)
Circus cyaneus	223	475 (1980)	89 (1934)
Accipiter striatus	4246	10,612 (1977)	1259 (1965)
A. cooperii	283	786 (1989)	61 (1964)
A. gentilis	69	347 (1972)	3 (1953)
Buteo lineatus	245	468 (1958)	87 (1971)
B. platypterus	8527	29,519 (1978)	2886 (1946)
B. jamaicensis	3208	6208 (1939)	1525 (1956)
B. lineatus	9	31 (1961)	0 (6 years)
Aquila chrysaetos	45	100 (1995)	12 (1966)
Falco sparverius	367	839 (1989)	11 (1934)
F. columbarius	33	168 (1995)	7 (1972)
F. peregrinus	23	51 (1989)	6 (1982)
All raptors	17,787	40,696 (1978)	7892 (1934)

* Data for Turkey and Black vultures based on counts since 1990.

Historical perspective

Prior to the Sanctuary's founding, hunters traditionally gathered at Hawk Mountain each autumn to shoot migrating hawks and eagles traveling south. Raptors were considered vermin at the time, and the Pennsylvania Game Commission was paying bounties on several species. Over the years, thousands of birds were killed as they traveled south along the Appalachian Mountains in eastern North America. Because of easy access, Hawk Mountain, especially, became a favored shooting locale. By the early 1930s, gunning at the site was so intense that individuals collected brass from discharged cartridges and sold it for scrap metal (BROUN 1948).

The scene changed dramatically in August of 1934, when Rosalie Edge hired Maurice Broun as head ornithologist of the recently acquired mountaintop bird refuge. Broun spent his first year posting the property and confronting local shooters. Publicity surrounding the Sanctuary's formation was considerable, and the following fall, bird-watchers and naturalists began to flock to the "newly discovered" wildlife refuge in large numbers. As they did, the mountain's use as a shooting gallery faded into history. Today, Hawk Mountain

Sanctuary is a leading example of what grass-roots research, ecological monitoring, and environmental education can accomplish. Throughout its history, the Sanctuary's practical and effective, science-based conservation program has focused on longterm environmental monitoring, applied research, local land-use planning, and public education.

Science at the Sanctuary

Scientific research and monitoring at Hawk Mountain Sanctuary began on 30 September 1934, when Broun first took his post on a rocky outcrop called North Lookout, and began recording the numbers of migrating hawks passing overhead. With the exception of three years in the early 1940s, fall raptor migration at the Sanctuary's North Lookout has been monitored each autumn since (ALLEN et al. 1996).

Research remains one of the primary purposes of the Sanctuary as stated in its mission. Hawk Mountain research focuses on the ecology and conservation biology of raptors, and unique Appalachian Mountain ecosystems. The Sanctuary's effort in science are based on the belief that fundamental ecological research and longterm monitoring provide an essential foundation for understanding and managing our natural resources. To this end, the Sanctuary's resident staff of biologists, together with graduate students, undergraduate interns, and volunteers, is currently involved in dozens of active projects. An additional 15 to 25 visiting scientists conduct research at the site each year.

Because of Hawk Mountain's longstanding commitment to understanding the pattern and process of raptor migration, and because the individual ranges of migratory raptors span extensive geographic regions, Sanctuary science is active on several geographic scales. Currently, research efforts focus on (1) the pattern and process of bird and, especially, raptor migration, (2) analysis of the site's longterm raptor migration database (especially its potential in monitoring longterm population trends of eastern North American birds of prey), (3) development of the first global atlas of internationally important raptor-watch sites, (4) longterm ecological studies of American Kestrels in open habitats surrounding the Sanctuary; (5) the impacts of raptor migration on raptor communities in the farmlands that surround the Sanctuary, and (6) Appalachian landscape ecology, including population dynamics of migrant songbirds nesting in the Sanctuary's forests.

Plans are underway to expand the research program and to develop the site as a place for longterm population and ecosystem studies of the central Appalachian Mountains. With this in mind, resident staff and visiting scientists are currently engaged in a number of inventory, mapping, and monitoring projects involving the Sanctuary's biotic resources.

Longterm population monitoring

Hawk Mountain Sanctuary maintains the longest and most complete record of raptor migration in the world (Table 1). (Excepting the war years of 1943-1946, raptor migration has been recorded at the site each year since 1934.) Initially, data were recorded into field notebooks by Sanctuary curator, Maurice Broun. Data are now collected on standardized daily-record forms.

Data collected before 1966 consist of daily totals of the numbers of each species of raptor migrating over the site's traditional watch-site, the North Lookout, together with information on the number of days before and after the most recent cold fronts, air temperature, wind speed, wind direction, flight direction, duration of observation effort,

and the number of observers. Since 1966, data have been recorded on an hourly basis. Prior to 1966, data were collected between 1 September and 30 November. Since then, data have been collected between 15 August and 15 December. Binoculars and, occasionally, telescopes are used to find and identify migrants. Typically, one or two experienced counters record each day's flight. Daily coverage usually begins at 0800 EST and ends at 1700. (See BEDNARZ et al. 1990 and ALLEN et al. 1996 for additional details.)

Hawk Mountain's extensive longterm database, portions of which were used by Rachel Carson in her international bestseller, "Silent spring" (CARSON 1962), have played a key role in exposing first-generation organochlorine pesticides, including DDT, as causative agents for precipitous declines in the populations of several species of birds of prey earlier this century, as well as in measuring subsequent rebounds in raptor populations following decreases in the widespread use of these environmental contaminants (Figure 1).

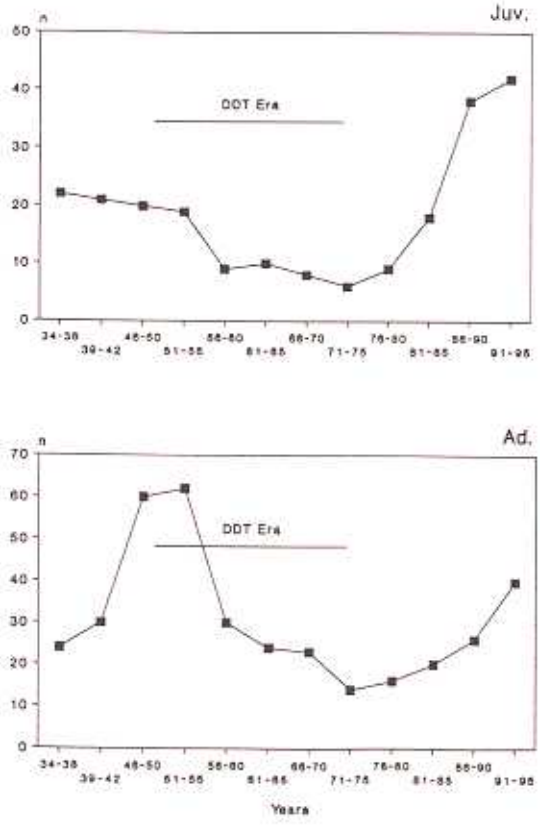

Fig. 1 - Longterm fluctuations in numbers of juvenile and adult *Haliaeetus leucocephalus* counted during autumn migration at Hawk Mountain Sanctuary, 1934-1995. Data are expressed as five-year means. Note the declines in the numbers of both juvenile and adult *Haliaeetus leucocephalus* during the DDT Era of the late 1940s through the early 1970s, followed by the more recent increases in numbers.

Obr. 1 - Dlouhodobé změny v početnosti mladých (Juv.) a dospělých (Ad.) orlů bělohlavých (*Haliaeetus leucephalus*) naščítaných při podzimní migraci na Hawk Mountain Sanctuary v letech 1934-1995. Data jsou uvedena jako pětileté průměry. Patrný je pokles v počtu mladých i dospělých orlů v období používání DDT (od konce 40. let do počátku let 70.) a pozdější nárůst jejich početnosti.

Examples of Sanctuary science

One of the more innovative aspects of the Sanctuary's research program has been the use of the longterm raptor migration database to assess population trends in raptors regularly recorded at the site. We are currently testing the validity of such analyses. For example, researchers have known for some time that a number of weather parameters, including the passage of cold fronts (i.e., large-scale synoptic weather events accompanied by strong northwesterly winds ground winds, decreasing temperatures, clouds, and often, precipitation), influence the numbers of raptors counted at migration-watch sites. In light of this, we have investigated the extent to which the number of cold fronts passing over the Mountain varies from one migration season to the next, and have used this information to determine if such variation affects the numbers of birds seen each year.

Longterm climate change may be especially disruptive to long-distance migrants that depend upon the seasonal timing of climatic conditions in a number of migratory habitats. Therefore, we are exploring our migration database for signs of a biological response to longterm climate change. Specifically, we are investigating the possibility that the timing of raptor migration along the ridge has shifted over the course of data collection, and will examine such shifts in light of longterm climate change.

We also have examined the extent to which recent declines in numbers of Sharp-shinned Hawks (*Accipiter striatus*) migrating past the site are associated with migratory short stopping. Below are summaries of these studies.

Cold fronts and raptor migration. The passage of cold fronts has long been associated with shifts in the numbers of southbound raptors seen at traditional migration watch-sites in eastern North America. Recently, we used the Sanctuary's longterm database together with data from U. S. Department of Commerce daily weather maps to explore the extent to which visible raptor migration at the site was influenced by these large-scale weather events, which pass the Sanctuary, on average once every 4-5 days in autumn.

Our analyses revealed significant increases in the numbers of 12 of 14 species of raptors following the passage of a cold front. Three basic patterns emerged from the analysis. Bald Eagles, Ospreys (*Pandion haliaetus*), and falcons (American Kestrels [*Falco sparverius*], Merlins [*F. columbarius*], and [*F. peregrinus*]), all had their highest rates of passage on the day of frontal passage. Sightings of Merlins, for example, averaged 52% lower during two to four days following frontal passage than on the day of and the first day after the front had passed (Figure 2). By comparison, Golden Eagles (*Aquila chrysaetos*), and accipiters (Sharp-shinned Hawks, Cooper's Hawks [*A. cooperii*], and Northern Goshawks [*A. gentilis*]), all had their highest rates of passage on the day after frontal passage. And Buteos (Red-shouldered Hawks [*Buteo lineatus*], Broad-winged Hawks [*B. platypterus*], and Red-tailed Hawks [*B. jamaicensis*]) all had their highest rates of passage one-to-two or two-to-three days after frontal passage (Figure 2).

The three 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. (See Allen et al. 1996 for details).

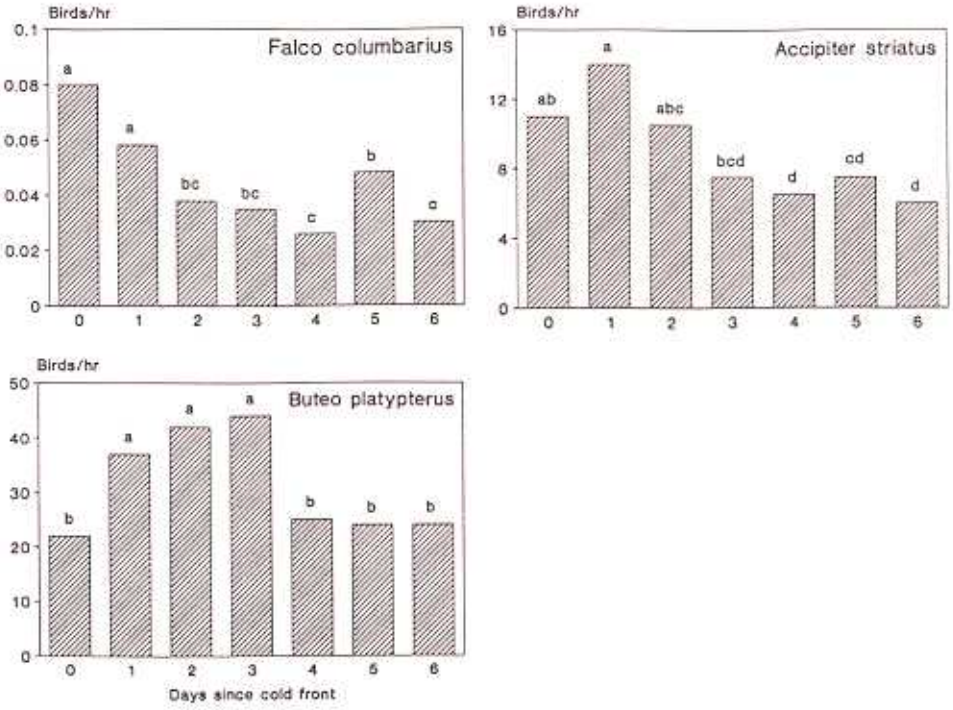

Fig. 2 - Per-hour passage rates of *Falco columbarius*, *Accipiter striatus*, and *Buteo platypterus* at Hawk Mountain Sanctuary, 1934-1991, as a function of days since most recent cold front. Within species, bars with the same letter are not significantly different from one another ($P < 0.05$, one-way ANOVA, Duncan's multiple-range tests). The three species illustrate the typical responses of falcons, Accipiters, and Buteos, respectively, to changing weather conditions following frontal passage. Falcons tend to migrate in high-speed, tail-winds typical of the day of frontal passage. Accipiters appear to prefer the lighter, updraft-producing, northwesterly winds and weak thermals that tend to occur the day after frontal passage. Buteos, tend to migrate during the fair weather conditions that occur two to four days after frontal passage (See ALLEN et al. 1996 for details.)
Obr. 2 - Počty protahujících jedinců (*Falco columbarius, Accipiter striatus, Buteo platypterus*) za hodinu (osa y) v závislosti na dni po přechodu poslední studené fronty (osa x). V rámci jednotlivých druhů jsou sloupce, které se od sebe navzájem neliší, označeny stejným písmenem ($P < 0,05$, "one way" analýza variance, Duncanův test). Tři uvedené druhy reprezentují typickou reakci sokolů (rod Falco), kání (rod Buteo) a jestřábů (rod Accipiter) na měnící se počasí po přechodu studené fronty. Sokoli mají tendenci táhnout v silnějším, zezadu vanoucím větru, který je typický pro přechod studené fronty. Jestřábi preferují podmínky, které se vyskytují den po přechodu fronty - slabší, "updraft-producing", severozápadní vítr a slabší termika. Káně upřednostňují hezké počasí, které se vyskytuje dva až čtyři dny po přechodu fronty (viz ALLEN et al. 1996).

Over the course of the 55-year study period, the number of cold fronts passing the Sanctuary during the period of autumn migration has ranged from 10 to 20, annually. Even so, and despite the within-year associations in numbers of birds seen following the passage of cold fronts, our analyses failed to detect among-year effects of frontal passage rates on annual counts of raptors migrating past the site, suggesting that frontal passage enhances

autumn migration activity of raptors, rather that simply forcing the birds closer to the watch-site and making the birds more visible to observers at such times (Allen et al. 1996).

Timing of raptor migration at Hawk Mountain. Until recently, most analyses of the Sanctuary's longterm migration database set have focused on the numbers of birds passing the site, rather than on the timing of migration. To determine the degree to which species-specific migration schedules at the site are affected by exogenous factors such as short- and longterm changes in climate (i.e., annual fluctuations in numbers of cold fronts during migration, and the effects of global climate change), and annual variation in the magnitude of each species flight, we recently calculated annual dates of passage for 25%, 50%, and 75% of the flights of four representative species, Northern Harriers (*Circus cyaneus*), Sharp-shinned Hawks, Broad-winged Hawks, and Golden Eagles, passing the site between 1946 and 1991. (Our analysis was restricted to counts beginning in 1946 because seasonal coverage of autumn migration has been more consistent at the site since that time.) Arithmetical mean dates of passage for harriers, sharpshins, broadwings, and eagles were 13 Oct., 8 Oct., 16 Sept., and 1 Nov., respectively. Mean numbers of days over which the middle half of each species' flight occurred were 33, 12, 5.7, and 22, respectively. 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 it had been in the 1950s (Figure 3), no species exhibited longterm shifts in its migration schedule. Furthermore, migration schedules did not shift in response to annual fluctuations in the numbers of cold fronts that

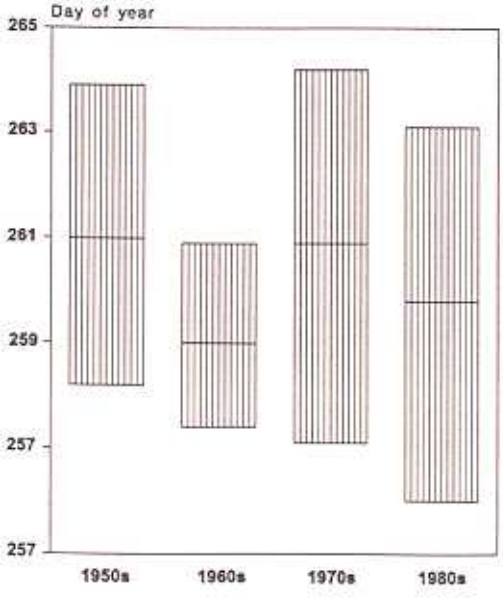

Fig. 3 - Ten-year mean values for the timing of passage of the middle 50% of each season's flight of *Buteo platypterus* at Hawk Mountain Sanctuary, during the 1950s, 60s, 70s, and 80s. Day 260 is 16 September. The base of each vertical bar represents the date at which the first 25% of the flight has occurred, the horizontal bar, the date of 50% of the passage, and the top of the vertical bar the date of 75% of the passage. Statistical analyses (one-way ANOVA with Duncan's multiple-range tests), indicate a significant difference ($P < 0.05$) in date of passage of the first 25% of the flight between the 1950s and 1980s. None of the other differences is significant.

Obr. 3 - Průtah Buteo platypterus na Hawk Mountain Sanctuary - desetileté průměry načasování průtahu středních 50% protahujících jedinců v každé sezóně (50., 60., 70. a 80. léta). Den s číslem 260 je 16. září. Spodní linka v každém sloupci představuje datum, kdy protáhlo prvních 25% všech jedinců, prostřední vodorovná čára představuje datum, kdy protáhlo 50% jedinců a horní linka 75% jedinců. Statistická analýza dat ("one-way" analýza variance, Duncanův test) ukázala signifikantní rozdíl v datu průtahu prvních 25% jedinců mezi 50. a 80. léty. Ostatní rozdíly nejsou statisticky významné.

passed Hawk Mountain during each species migration period, nor did they shift in response to fluctuations in the numbers of birds observed each year.

Overall, our analyses indicate considerable constancy in seasonal timing of autumn raptor migration at the site, suggesting that this aspect of migration is less responsive to exogenous factors than are many other aspects of raptor migration. We intend to continue to monitor this aspect of raptor migration ecology at the site in an effort to assess the possible effect of global climate change on raptor biology.

Recent declines in numbers of migrating Sharp-shinned Hawks. During the 1980s and into the early 1990s, the numbers of Sharp-shinned Hawks sighted at many traditional raptor-migration watch-sites in the northeastern United States declined substantially (Figure 4). Declines have been especially precipitous at counts sites that usually record high proportions of juvenile birds. Initial reports of the decline suggested that the decrease might be due to natural population cycling, changes in migration routes, or to increased overwintering north of many of the watch-sites. More recent suggestions include the effects of habitat loss, pesticide contamination, and acid precipitation (VIVERETTE et al. 1996).

We used migration count data from Hawk Mountain Sanctuary, together with count data from Cape May Point, New Jersey, and National Audubon Society Christmas Bird Count data from the easternmost United States, to test the possibility that the decline resulted, at least in part, from migratory short-stopping in the species. The results of our analysis, which demonstrated increased overwintering in the species north of many migration watch-sites, support the shift in migration behavior ("short-stopping") hypothesis (Figure 5). Although the reason for this change in migration behavior is not clear, data from Cornell University's (Ithaca, New York, USA) Project FeederWatch Program indicate that Sharp-shinned Hawks are the most frequent predator of small birds at bird feeders

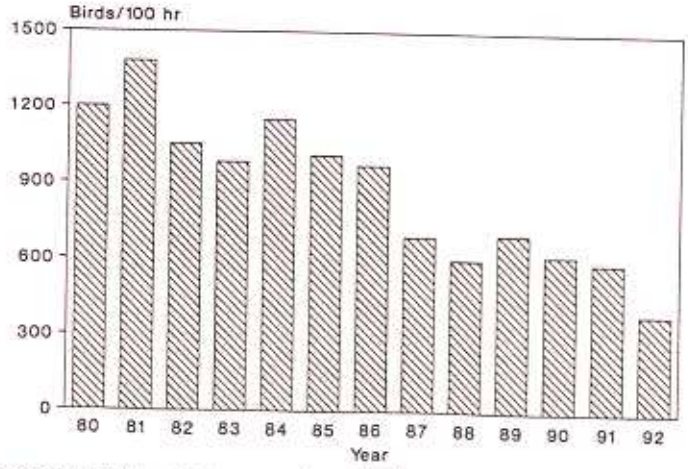

Fig. 4 - Numbers of *Accipiter striatus* counted per 100 hr at migration watch-sites in eastern North America, 1980-1989 (after KELLOGG 1993). The number of sites reporting counts ranged from 27 to 60 during the period. Spearman rank correlation analysis indicates a significant decline ($P < 0.01$).
Obr. 4 - Počty protahujících krahujců amerických (*Accipiter striatus*) zaznamenané za 100 sčítacích hodin na sčítacích bodech v Severní Americe v letech 1980-1989 (podle KELLOGGA 1993). Počet sčítacích lokalit se pohybuje od 27 do 60. Statistická analýza ukazuje na signifikantní pokles ($P < 0,01$, Spearmanův korelační test).

(DUNN & TESSAGLIA 1994), leading us to suggest that recent increases in bird feeders in northeastern North America may be affecting the migration and winter ecology of this raptor (VIVERETTE et al. 1996).

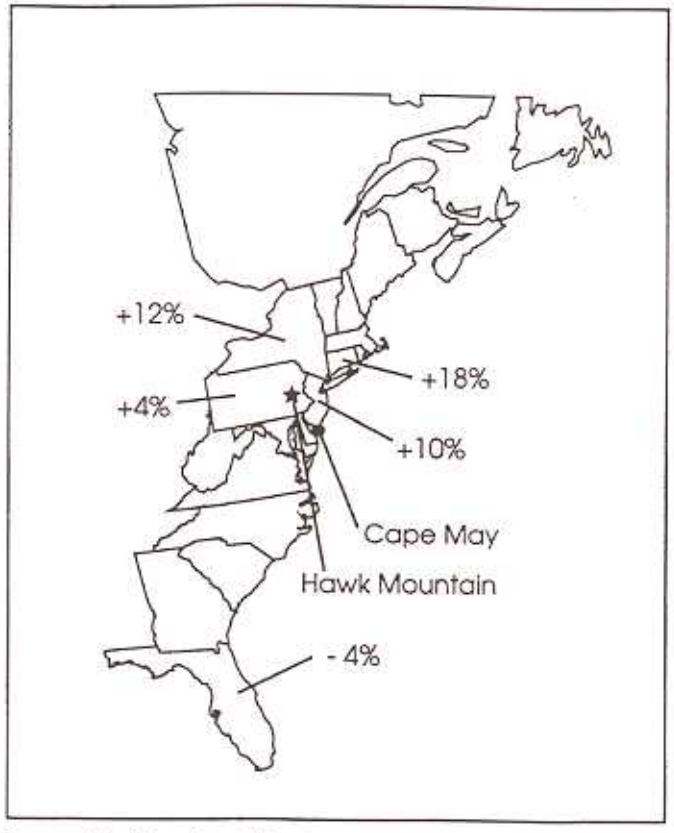

Fig. 5 - Map of eastern North America indicating the locations of Cape May Point, New Jersey, and Hawk Mountain Sanctuary, Pennsylvania, the two longest-running raptor-migration watch-sites in the region, together with annual % changes in the numbers of *Accipiter striatus* seen on National Audubon Society Christmas Bird Counts in states with significant shifts in numbers seen. The numbers of hawks counted on 147 count sites north of the migration watch-sites increased significantly (P 0.05) at a rate of 8% annually, while those on 128 count sites south of the two watch-sites did not change significantly. (See VIVERETTE et al. 1996 for additional details.)
Obr. 5 - Mapa východní části Severní Ameriky s vyznačenými lokalitami Cape May Point (New Jersey) a Hawk Mountain Sanctuary (Pensylvánie), které představují dvě lokality s nejdelšími záznamy o počtech protahujících dravců v oblasti. Současně jsou znázorněny procentuální změny v počtech krahujce amerického zjištěných během zimního sčítání "National Audubon Society Christmas Bird Counts" (státy se signifikantními změnami v početnosti). Počty registrovaných krahujců na 147 lokalitách severně od obou migračních lokalit statisticky významně vzrostly (P 0.05) s ročním přírůstkem 8%, zatímco na 128 lokalitách jižně od obou zmíněných migračních lokalit se počty krahujců signifikantně nezměnily (podrobnosti viz VIVERETTE et al. 1996).

Conclusions

The examples cited above suggest considerable potential for the use of traditional raptor migration watch-sites as centers of monitoring activity and scientific research. Since 1935, Hawk Mountain research personnel and collaborators have contributed more than 150 technical publications, reviews, theses, and dissertations to the scientific literature. These efforts, together with Sanctuary efforts in the field of raptor protection and conservation are summarized in several Sanctuary publications (BROUN 1948, BRETT 1991, BILDSTEIN & ZALLES 1995).

Through its international internship program and other training opportunities, Hawk Mountain Sanctuary has long played a role in mentoring scientists and conservationists at newly established migration watch-sites. The Sanctuary's recently established global conservation initiative, Hawks Aloft Worldwide, which uses the plight of migrating raptors to capture support for local conservation efforts along international migratory corridors (Bildstein et al. 1995), formalizes this important role. Those interested in learning more about the Sanctuary's research and conservation efforts, including Hawks Aloft Worldwide, should contact the author at the Sanctuary.

ACKNOWLEDGMENTS. Analyses of Hawk Mountain's database would not be possible except for the longterm count efforts of Maurice Broun, Alex Nagy, Jim Brett, Laurie Goodrich, and numerous other Sanctuary personnel and volunteers. I thank Eric Atkinson, Nancy Keeler, Wendy Schelsky, Petr Voříšek, and two anonymous referees for comments on earlier versions of the ms. This is Hawk Mountain Sanctuary contribution number 51.

SOUHRN

Mnoho dravců se během migrace koncentruje podél význačných terénních prvků v krajině, jako jsou např. mořská pobřeží nebo horské hřebeny. Předpokládá se, že táhnoucí dravci se shromažďují podél takovýchto krajinných struktur ("leitlinie" - GEYR von SCHWEPPENBURG 1963), protože zde nacházejí lepší podmínky pro svůj let než jinde. Dlouhodobý monitoring migrujících dravců ve východní části Severní Ameriky se datuje od 30. let tohoto století, kdy byla zahájena pravidelná sčítání na lokalitě Hawk Mountain Sanctuary ve střední části Apalačského pohoří (východní Pensylvánie, USA) a na mysu Cape May Point na jižním výběžku pobřeží státu New Jersey (USA). Šedesátiletý monitoring v Hawk Mountain Sanctuary představuje nejdelší a nejkomplexnější soubor dat o migraci dravců na světě. Data z každoročních sčítání v Hawk Mountain Sanctuary představují rozsáhlý zdroj informací pro zhodnocení dlouhodobých trendů ve změnách početnosti severoamerických dravců. S pomocí tohoto rozsáhlého souboru dat se podařilo ukázat na příčinnou souvislost mezi poklesem početnosti orla bělohlavého (*Haliaeetus leucocephalus*) a některých dalších druhů a používáním chlorovaných pesticidů (obr. 1).

Nashromážděná data také umožňují analýzu vlivu přechodu studené fronty na počty nasčítaných táhnoucích dravců na sčítacích stanovištích a analýzu vlivu klimatických změn na sezónní načasování migrace. Počet táhnoucích jedinců se po přechodu studené fronty signifikantně zvyšuje u 12 ze 14 druhů. Analýza ukázala, že existují tři základní typy průtahu v závislosti na průběhu studené fronty: orel bělohlavý, orlovec říční (*Pandion haliaetus*) a sokoli (*Falco sparverius, F. columbarius, F. peregrinus*) protahují nejvíce v den přechodu fronty, orel skalní (*Aquila chrysaetos*) a jestřábi (*Accipiter cooperi, A. gentilis*) byli nejčastěji zaznamenáváni jeden den po přechodu fronty a káně (*Buteo lineatus, B. platypterus,*

B. jamaicensis) protahují nejvíce jeden až tři dny po přechodu fronty (obr. 2). Tyto tři typy reakce na přechod studené fronty jsou důsledkem kombinace měnících se povětrnostních podmínek provázejících přechod fronty a rozdílných aerodynamických vlastností jednotlivých druhů. Nebyl zjištěn vliv počtu front v jednotlivých letech na roční počty protahujících dravců, což ukazuje na to, že studená fronta pouze stimuluje migrační aktivitu dravců.

Sezónní načasování tahu se mezi roky výrazně nemění, což svědčí o tom, že tento aspekt migrace podléhá méně vlivu exogenních faktorů.

Data nashromážděná v Hawk Mountain Sanctuary umožňují též rozbor příčin poklesu nasčítaných krahujců amerických (*Accipiter striatus*) na řadě migračních lokalit podél východního pobřeží Spojených států. V průběhu 80. a na počátku 90. let se počet protahujících jedinců tohoto druhu výrazně snížil na řadě lokalit ve východní části USA (obr. 4). Za nejpravděpodobnější příčinu tohoto poklesu lze považovat změnu jeho migračního chování. Protože krahujec americký je nejčastějším ptačím predátorem malých ptáků na zimních krmítkách, zdá se, že změna v jeho migračním chování byla způsobena zvýšeným zimním přikrmováním ptáků v posledních letech (viz též obr. 5).

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