The Raptor Population Index Project: A scientific system to monitor North American raptor populations

A report to the National Fish and Wildlife Foundation
On Project 2004-0153-000

January 1, 2005 to April 30, 2006

A joint project of
Hawk Mountain Sanctuary Association
The Hawk Migration Association of North America
and HawkWatch International, Inc.

The Raptor Population Index Project:
A scientific system to monitor North American raptor populations

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Year One

A joint project of
Hawk Mountain Sanctuary Association
The Hawk Migration Association of North America
and
HawkWatch International

A Final Programmatic Report to
The National Fish and Wildlife Foundation

January 1, 2005 to April 30, 2006

Submitted by:

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"The time to save a species is while it is still common."

--Rosalie Edge, Hawk Mountain founder

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Project Summary

The Raptor Population Index project (RPI) was envisioned as a three-year pilot project to: 1) develop a method for determining population trends of North American migratory raptors counted during spring and fall migrations at sites throughout the United States, Canada, and Mesoamerica; 2) to establish a central system for compiling the raptor count data that allows easy dissemination of data and results; and 3) to use these data and others to determine the conservation status of North American raptor species on a regional, national and continental scale. The project will produce scientifically defensible indices of abundance and trends for each species from count sites and make those results available to the general public, management and conservation agencies and scientific communities.

In Year One of the RPI project we established a working structure among the three partners, hired RPI staff, established and met with scientific advisory committee, and began working on the project goals. In Year One, we developed a statistical approach to the analyses and analyzed data from eight eastern and Great Lakes region fall count sites and five western fall count sites. We expanded the utility of the web-based database and data entry interface and expanded the number of cooperator sites to 178 sites continent-wide. We had the first scientific paper accepted to The Auk, a major ornithological journal, and met with scientists and managers to elicit feedback and input on the RPI project objectives. Model protocols for gathering and entering data were developed and placed on the web to improve data quality and availability. Several popular articles were prepared and released and eastern trend results were placed on the web for broader dissemination to the public.

Introduction

Accurate knowledge of population status and change is fundamental to species conservation. Lack of reliable information on populations of many raptors forms a conspicuous gap in North American monitoring. The premier scheme for monitoring population change in North American birds is the United States Fish and Wildlife Service Breeding Bird Survey (Sauer et al 2003). However, because of low densities of raptors and the timing of the survey, raptors are difficult to monitor with this survey. Special nesting surveys can be logistically challenging and expensive for many species (Dunn and Hussell 1995).

In October 2004 with support from the National Fish and Wildlife Foundation, a pilot project was initiated to establish a permanent, continent-wide monitoring program for North American raptors. This project united the three main hawk migration organizations of the continent, Hawk Mountain Sanctuary Association, the Hawk Migration Association of North America, and HawkWatch International, to work together to provide raptor population trend estimates in a timely and reliable manner. The population trend estimates are to be based primarily, but not exclusively, on migration counts contributed from hawk count sites provided to the Hawk Migration Association of North America database at www.hawkcount.org. Population indices and trends will be integrated with other available information on population trends such as the USFWS Breeding Bird Survey and Audubon's Christmas Bird Counts. At the end of the three-year pilot project, the partners intend to produce a comprehensive report on the status and trends in migratory raptor populations across the continent. We also intend to complete a functional electronic network of citizen science hawk counters providing scientifically-valid data into the RPI database and to have the web-based statistical tools to allow real-time analyses of trends by species and region, where feasible. Biennial reports, press releases, newsletters, presentations and articles will be used to disseminate results to the target communities (scientists, conservationists, wildlife managers and agencies).

In the first year, we proposed to refine the web-based data entry system, recruit over 100 network sites to contribute hourly data to the RPI database, develop a scientifically-defensible statistical approach to analysis of raptor count data, conduct test analyses on sites across the continent and produce preliminary reports or trend results for selected sites and begin networking with continental bird conservation initiatives and wildlife agencies.

RPI Objectives (year one):

1) Expand and enhance web-based hawk count database to facilitate and expand utility to researchers, hawk count compilers, and the RPI goals.

2) Develop scientifically-defensible statistical approach to trend analyses of raptor migration count data.

3) Recruit new sites for the RPI network of monitoring stations and integrate their data into hawk count database.

4) Conduct test analyses on selected long-term data sets in east and west to examine weather and other factors as variables in the analysis approach.

5) Produce initial trend estimates for eastern and western raptor populations using analyses from multiple sites.

6) Establish a model site protocol for data collection at a migration watch site and share widely.

7) Produce a scientific manuscript on statistical approach to allow further scientific review.

8) Produce popular papers and presentations on the RPI network and goals and population trends derived, and provide preliminary results on the web for use by general public and researchers.

9) Write two draft species conservation assessments based on RPI trend analyses and data sets from other monitoring efforts such as the Breeding Bird Survey and Christmas Bird Count.

Results

1) Expand and enhance web-based hawk count database to facilitate and expand utility to researchers, hawk count compilers, and the RPI goals.

The hawk count database serving the RPI project is the *HawkCount* database established by the Hawk Migration Association of North America, a non-profit organization with nearly 300 contributing hawk count sites providing data since 1974. The database includes a growing subset of those sites contributing data from across the continent (www.hawkcount.org). In the first year of the RPI Project, the HMANA database manager, Jason Sodergren, expanded the network server backup system that houses the hawk count data to allow for three servers operating as back-up to the main server and he increased the main server capacity. New options were added to the web-site to enhance data entry possibilities and network utility by allowing uploading of computer spreadsheets into the database with other user interface upgrades. A link was also introduced for sites and RPI partners to download data from the database into an Excel spreadsheet format or other destinations. This link is useful for hawk count site compilers, regional editors charged with summarizing the migration, and for RPI goals. Providing benefit to the users of the database ensures a continued data stream for the monitoring program.

Other improvements included a new site metadata link online that includes mapping of sites in google maps, and information on the site such as the numbers of years of data, the site contacts, directions to the site, the type of data available (hourly or daily), a site protocol if available, and the data use parameters. This site is important for providing the database user with contextual background for the counts that are available as well. A tabular summary of annual counts by year is also available for each site. The addition of a site database in Year One provides great utility to state or regional wildlife managers who may be interested in using hawk count data for population monitoring or research as it give a direct geographic context to the counts being reported, and sites can be selected by state or province.

Data entry of hourly data was widely encouraged by the RPI manager, Ernesto Ruelas Inzunza, and RPI database manager Jason Sodergren, through public programs, listserve postings, and personal contacts, to improve the scientific depth of the data in the database. A new data use policy was established for HawkCount with categories specifically allowing RPI Project use of the data sets. Ruelas Inzunza and other RPI partners met with representatives of the National Biological Information Infrastructure Initiative (NBII) and the Avian Knowledge Network established by Cornell Lab of Ornithology to establish links of the *HawkCount* database to these systems. These links will greatly facilitate dissemination of RPI results and use of these data by scientists. Meetings were also held with *PartnersInFlight* representatives and state agencies to discern how best to taylor the project database to serve regional and continental conservation and monitoring goals. Additional meetings are planned for Year two.

2) *Develop scientifically-defensible statistical approach to trend analyses of raptor migration count data.*

In Year One of the RPI project, we devoted considerable time to developing a scientifically rigorous approach to trend estimation using raptor count data. Dr. Chris Farmer, HMS North American Monitoring Coordinator, and Dr. David Hussell, project advisor, took the lead on this aspect of the project with consultation with the scientific advisory committee.

Analyses investigated included polynomial regressions considering effort, data, year and some weather factors (see description of method in Appendix B). These investigations focused primarily on the longest available data sets of raptor counts from Hawk Mountain, Pennsylvania, and Cape May, New Jersey. After investigation of several options, it was decided that the best approach would involve use of hourly data sets rather than daily counts as they would allow effort and counts to be standardized to a set hourly coverage. Other investigations involved examining how the model performed when blocks of days were not covered, such as 2-3 days a week, and other scenarios. This investigation allowed the team to determine if sites with partial coverage might be suitable for use in determining long-term trends and how much missing data could be tolerated before the analyses unraveled (see Farmer and Hussell in Appendix 2).

The proposed statistical model and method was evaluated at the one-day Scientific Advisory Committee in January 2005 and alternative approaches reviewed. After further exploration of the model through test analyses, a final model was selected and circulated to the committee for review. Analysis results from the selected model were reviewed in January 2006 at the second Scientific Advisory Committee meeting. Results were accepted by the Scientific Advisory Committee and recommendations for future analyses to improve trend estimation were suggested. The RPI Science Committee recommended that the RPI partners generate trends from as many sites as possible in next two years using the date-adjusted geometric mean method and made recommendations on approach to analysis for rare species and incorporating weather as variables in west and Gulf coast sites. They also suggested exploration of the issue of how to handle days where a count is ended early due to rain or snow as compared to days where counts were just not conducted for other reasons.

A scientific manuscript was prepared that describes the method in detail and submitted in July 2005, after review it was revised and resubmitted in fall 2005. In early 2006, the manuscript and its discussion of the scientific method was officially accepted for publication in *The Auk*, the journal of the American Ornithological Union. The RPI partners consider this an important step in sharing the population trends derived from this model. Because the technique has been accepted under peer-review, we feel we can now apply the model more widely among sites and species, and test its validity in western and gulf coast count sites.

3) Recruit new sites for the RPI network of monitoring stations and integrate their data into hawk count database.

Additional sites were recruited to add their data to the *HawkCount* database including many long-term data sets (see Appendix A) by letters, phone calls, and the email list serve. At the close of Year One, 178 sites were actively entering data from their counts into the web database with 122 of the sites providing hourly count data each field season. This database may now represent the largest database of hawk migration count data anywhere in the world, and the only one receiving current data on a daily or hourly basis in a real time format. The *HawkCount* database has many sites with greater than five years of hourly data available in the online database. In addition, contacts have been made with key western and Midwestern sites to elicit their contributions in Year two and three. As more analysis results are available online, the number of sites wanting to contribute should grow substantially.

In 2004 and early 2005, we finalized the list of sites we selected for the initial RPI trend analyses and began contacting compilers for permissions. Because hourly data became a priority due to the statistical conclusion that hourly data improved the trend estimation, we began identifying sites where we would have to enter the data to use the data sets. Because we did not originally realize an hourly model would be necessary, d ata entry was not initially envisioned to be as large a task as it proved to be for the RPI partners. Most sites store their electronic data in a daily count format, so hourly data in the computer was challenging to find. Data entry began in winter 2005 and has continued to present using Hawk Mountain and HMANA volunteers and Hawk Mountain Interns primarily. Some sites have entered their own historical data, and this approach has been widely encouraged.

The initial sites selected for the eastern flyway analysis were: Hawk Mountain and Waggoner's Gap, Pennsylvania; Montclair HawkWatch and Cape May, New Jersey; Lighthouse Point, Connecticut; Holiday Beach, Ontario; and Hawk Ridge, Minnesota. We also added Tadoussac, Quebec, as an eighth eastern site later in Year one. These sites were selected because of the long-term nature of the data available, the consistency of data collection efforts, and their willingness to provide the data either in spreadsheet format or for data entry by the Hawk Mountain volunteers and interns. During the data entry process the RPI team continued to promote data entry into the on-line database by the sites themselves. Western fall season datasets were provided by HawkWatch International from five count sites. Additional years of data (prior to 1990) were entered by Hawk Mountain and HawkWatch volunteers and staff to extend the daily data available for analysis to a longer span of years. Other non-HawkWatch sponsored sites in western states and provinces were contacted by Jeff Smith, HWI Scientist, for recruitment into the network. In summary, the site recruitment in Year One has gone well. We analyzed trends and derived population indices for eight eastern sites and six western sites. Data entry into the database for future analyses was nearly doubled and the number of sites entering data in hourly format necessary for the RPI analyses exceeds 100 sites continent wide currently. In less than five years, the RPI database should exceed 100 sites with 10 years of hourly data from sites across the continent.

4) Conduct test analyses on selected long-term data sets in east and west to examine weather and other factors as variables effecting trend estimation.

During the evaluation of the analysis approach examining data from Hawk Mountain and Cape May, Dr. Farmer and Dr. Hussell used long-term hourly data from the National Weather Service stations near the count stations to examine how effects of some weather variables impact the trend estimations. Wind direction and speed were incorporated as covariates in the model. The investigation suggested that weather variables do not improve the model ability to estimate trends and were deemed unnecessary for initial trend models. Other evaluations of western data sets and other weather variables may be instituted in year two and three, including evaluation of spring sites.

In other analyses the precision of trend estimates were examined by species for Cape May and Hawk Mountain and compared to that of the Breeding Bird Survey. For most species, the hawk migration counts provided greater precision of trend estimates (see Appendix B) indicating that migration counts may provide a better data source for long-term monitoring of raptor populations.

Test analyses suggest that the hawk migration counts can produce valid trend estimates despite the variability due to weather or other factors.

5) Produce initial trend estimates for eastern and western raptor populations using analyses from multiple sites.

Initial trend estimates were completed for eight eastern and five or more western sites using hourly data and the new statistical model during Year One (see Appendix B for graphs and tables). For each species and site a graph was created to show the population change over time and the percent change per year (Figures 1-6). In order to reach a wider audience, Dr. Farmer created a map of trends for each species showing the direction of the trajectory of population change, if any, and the level of significance, associated with each site. These maps (Figures 8-22) provide the viewer with an easy to understand geographic sense of how trends vary across the region. For some species, the trends are quite consistent among sites (e.g. Osprey or Cooper's Hawk are both uniformly increasing), while for others the trends are complex with some sites showing increasing and others showing decreasing trends (e.g. Sharp-shinned Hawk). For such species additional sites or examining additional sources of data such as the Christmas Bird Counts may be instructive. These maps are being refined with western data sets for use in the State of the Raptors report planned as a culmination of the three-year pilot project (Year three).

In the statistical analyses, different year spans were examined for each species A (see Tables in Appendix B). The 10-year blocks of 1980 to 1990, 1990-2000, and the 1974 to 2004 span as a long-term trend for the eastern sites. In the west, the year spans analysed included 1998-2005, 1986 to 1997 and 1983 to 2005. For all eastern and western sites the mean annual count and coefficient of variation (measure of year to year variability) is shown as well. Of the species examined in the east, the ones showing significant declines at a majority of the sites examined from 1990 to 2000 included: American Kestrel, Broad-winged Hawk, Rough-legged Hawk, and Northern Harrier. Significant increasesat a majority of sites were seen for Bald Eagle, Cooper's Hawk, Golden Eagle, Merlin and Peregrine Falcon. For western sites from 1998 to 2005, species showing declines included: Northern Harrier, American Kestrel. No species showed significant increases at a majority of western sites (Appendix B, Tables).

6) Establish model site protocol for data collection at a migration watch site.

Dr. Ruelas Inzunza, RPI project manager collected sample site protocols from five or more long-term migration count stations. These documents were scanned to place on the website as sample protocols and also placed in the site metadata on www.hawkcount.org. From these he drafted a model site protocol including recommendations for what types of information should be included by a site and what considerations should be taken in establishing site protocols. For example, sites should avoid moving their station based on weather patterns and monitor from fixed locations. The model site protocol was reviewed by RPI partners and revised. Sites have been encouraged to write a protocol for their site that documents how they collect their data and site conditions for posting on the website in the site database. The model protocol and individual site protocols are available for downloading at the rpi-project.org website and the HawkCount website. A copy of model protocol is provided in Appendix A.

7) Produce a scientific manuscript on statistical approach to allow further scientific review.

The first scientific manuscript produced by the RPI partners, was authored by Dr. Chris Farmer, Dr. David Hussell and Dr. David Mizrahi and is entitled "Detecting population trends in migratory birds of prey". This paper describes the statistical model and how it was selected. It evaluates the model using the data sets from Hawk Mountain and Cape May and presents trends for the two sites (see Appendix C). Plans are underway in Year two for presenting the scientific trend analyses for all sites analysed in Year one and subsequent years in a symposium and written report at the Raptor Research Foundation join meeting with the Hawk Migration Association in autumn 2007. Prior to that trend estimates will be presented on the RPI website, newly inaugurated in Year one (www.rpi-project.org).

8) Produce popular papers and presentations on the RPI network and goals and population trends derived, and provide preliminary results on the web for use by general public and researchers.

Beginning in March 2005, the RPI partners prepared periodic RPI updates for distribution to contributors, members and other interested people (see RPI update in Appendix C). Bi-annual articles were published in the partner newsletters to update organization members (including over 10,000 individuals continent-wide) (Appendix C). A general press release to scientific and birding organizations resulted in articles in *Wingspan* (Raptor Research Foundation newsletter) and *Birding*, the magazine for the American Birding Association. Notes were also published in Bird Watcher's Digest. In addition, two full color reports were produced for contributors and members reporting on overall results. Letters were also mailed to 42 state non-game biologists for states that house existing hawk watch sites. The letter described the availability of data and trend estimates from the RPI network (Appendix C).

The RPI project manager, Dr. Ruelas Inzunza, promoted the project among the hawk-watcher citizen scientists by visiting nine or more hawk watch site during fall and spring seasons and by giving presentations on a regular basis through the year. Nearly 20 presentations were given by RPI project manager, Dr. Ruelas Inzunza, and Dr. Chris Farmer, North American Monitoring Coordinator (Table 1). Presentations included scientific talks at the North American Wildlife Society meeting, a *Partners in Flight* meeting, a scientific meeting, and more popular presentations given to several regional hawk watcher conferences and public venues such as the Hawk Mountain lecture series. The BirdHawk listserve with over 300 subscribers was also regularly notified of the RPI project goals and the need for hourly data to derive trends. Phone calls from project staff to key watch sites particularly western sites also proved effective in garnering interest in participation.

Table 1. Raptor Population Index Project Staff Presentations January 2005- April 2006

Date	Forum	Author(s) / Title
7 July 2005	Cornell Lab of Ornithology, Ithaca, New York	Ernesto Ruelas Inzunza – The Raptor Population Index Project
28 July 2005	Kittatinny Roundtable Meeting of PA HawkWatches	Laurie Goodrich and Chris Farmer—the Raptor Population Index Project (Population Trends and Database Updates)
27 August 2005	American Ornithologists' Union Annual Meeting, Santa Barbara, California	E. Ruelas I., C. Farmer, J. Sodergren, D.J.T. Hussell, K.L. Bildstein, L.J. Goodrich, S.W. Hoffman, D. Mizrahi, and J.P. Smith -- The Raptor Population Index project: a system to monitor populations of migratory raptors from regional to continental scales
11 September 2005	Partners in Flight Implementation Committee Meeting, Brentwood, Tennessee	Ernesto Ruelas Inzunza -- The Raptor Population Index Project
13 September 2005	International Association of Fish and Wildlife Agencies, Nashville, Tennessee	Ernesto Ruelas Inzunza -- The Raptor Population Index Project, a citizen science system to monitor migrant raptors from regional to continental scales
12 October 2005	Raptor Research Foundation Annual Meeting, Green Bay, Wisconsin	Ernesto Ruelas Inzunza -- The Raptor Population Index Project, a citizen science system to monitor migrant raptors from regional to continental scales

12 October 2005	Hawk Mountain Autumn Lecture Series	Chris Farmer--Making Every Hawk Count: the North American Monitoring Program
16 October 2005	Midwest Birding Symposium, Davenport, Iowa	Ernesto Ruelas Inzunza -- The Raptor Population Index Project, a citizen science system to monitor migrant raptors from regional to continental scales
18 March 2006	North East Hawkwatch Annual Meeting, Holyoke, Massachusetts	Ernesto Ruelas Inzunza -- The Raptor Population Index Project, a citizen science system to monitor migrant raptors from regional to continental scales
18 March 2006	North East Hawkwatch Annual Meeting, Holyoke, Massachusetts	Chris Farmer –Population Trends of Buteos and Falcons in the Northeast
24 March 2006	Eastern Bird Banding Association, Bethlehem, PA	Chris Farmer—Population Trends of Migratory Raptors in Northeastern North America
14 April 2006	Presque Isle Audubon Society, Erie, Pennsylvania	Ernesto Ruelas Inzunza -- Wind turbines, are they safe for birds? (other participants in the forum were Kim Van Fleet and Gil Randell)
29 April 2006	Niagara Peninsula Hawkwatch, Grimsby, Ontario, Canada	Ernesto Ruelas Inzunza -- The Raptor Population Index Project, a citizen science system to monitor migrant raptors from regional to continental scales
1 May 2006	Bird Studies Canada, Port Rowan, Ontario, Canada	Ernesto Ruelas Inzunza -- The Raptor Population Index Project, a citizen science system to monitor migrant raptors from regional to continental scales

A new web-page was designed and opened to the public at the close of Year One, www.rpi-project.org. Sample pages from the web site are enclosed in Appendix A and include pages on analysis and results, background, etc.. The web page is intended to provide results of the analyses to the hawk watch sites, general public, and resource agencies. Links to the web page are in place from the database entry site, www.hawkcount.org and vice-versa. The site metadata and mapping tools are already linked for the eastern sites where results have been compiled. Site summary tools, such as comparison of annual counts among years, are available in HawkCount currently but in Year two we intend to expand the summary tools to provide hawkwatches with summaries of their data. With this approach we hope to provide products to the citizen scientists participating in hourly data entry to sustain the data flow into the RPI network. The RPI manager will also draft regular updates for participating sites beginning in Year two.

9) Write two draft species conservation assessments based on RPI trend analyses and data sets from other monitoring efforts such as the Breeding Bird Survey (BBS) and Christmas Bird Count (CBC).

Preliminary species conservation assessments were written by Dr. Farmer for three species based on northeastern data sets and by comparing results from the BBS and CBC: Peregrine Falcon, Bald Eagle, and American Kestrel (see Appendix C). More comprehensive conservation assessments including western data were prepared for six more species and are currently under review. Conservation assessments are available on the Hawk Mountain website and linked to the RPI website for use by researchers and the general public (www.hawkmountain.org).

Conclusions

The Raptor Population Index project is envisioned as a three-year pilot project to establish a continent-wide program to monitor the population status and trends in North American migratory raptor populations. In Year One, the RPI partners, Hawk Mountain, Hawk Migration Association of North America and HawkWatch International, made substantial progress towards this goal and met or exceeded all of the identified objectives for Year one. Despite the additional time needed in data entry and scientific review, Year One was completed successfully.

In Year One, a network of electronically-linked citizen scientists was firmly established with the number of count sites contributing data on an annual or seasonal basis exceeding 150 sites from Canada, United States, and Mexico. A robust statistical approach was developed, reviewed by U.S. Geological Survey and Canadian Wildlife Service scientists, and accepted in a peer-reviewed scientific journal. Model co-variables such as wind speed and direction, and aspects such as number of days a site was monitored were evaluated to better understand the best approach to establishing a long-term monitoring station. Data from 15 or more fall count sites was entered, proofed, and provided for analysis. Analyses and trend estimates were derived for 14 species from western and eastern flyways. Results of analyses were provided on the web and preliminary results of some sites made available through articles in RPI partner journals reaching over 10,000 members of the general public. Other articles and presentations describing the network and its goals were prepared and published reaching audiences such as birdwatchers, raptor scientists, and wildlife managers. A standard protocol was developed and promoted among participating sites. A project website was established to provide results to the public and citizen scientists as well as wildlife managers. Links to larger biological database nodes were explored including NBII and Avian Knowledge Network to provide the database to a larger audience of scientists. In summary, the results of Year One indicate strongly that a continent-wide program to monitor North American migratory raptors using migration counts from a network of sites is feasible and achievable. The initial network sites from Year one (see Appendix B) represent the foundation from which the RPI network will expand and strengthen in Year two and three.

Acknowledgments

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The Raptor Population Index Project: A scientific system to monitor North American raptor populations

A report to the National Fish and Wildlife Foundation
On Project 2004-0153-000

January 1, 2005 to April 30, 2006

Appendices

HMANA

HAWK MOUNTAIN

HawkWatch INTERNATIONAL

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Appendix A. Migration Database and website.

hawkcount.org data inventory

Main

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Month Summaries

Day Summaries

Account Request

Changelog
About...

Total active sites	178
Total active sites with data	163
Total active sites with hourly data	122
Total active sites with daily data	106

Sort by years
Sort by hourly reports
Sort by daily reports
Sort by site name

Site (id)	Data Years	Years: Hourly	Years: Daily	Years: Mixed D/H	Hourly Reports	Daily Reports	Data Years Hourly Daily Mixed Hourly/Daily
Allegheny Front (111)	5	0	1	4	258	541	2002 2003 2004 2005 2006
Bake Oven Knob (399)	4	0	4	0		420	2002 2003 2004 2005
Bald Eagle Mountain (635)	1	0	1	0		2	2005
Bare Mountain (308)	1	1	0	0	6		2004
Barre Falls (181)	5	5	0	0	374		2002 2003 2004 2005 2006
Beamer Backup (625)	27	27	0	0	1840		1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2006
BEAMER CA Auxiliary Sites (633)	1	0	0	0	4		
Beamer Conservation Area (389)	1	0	0	0	467	15	
Belvédère Raoul-Roy, Parc national du Bic (615)	5	2	0	3	186	108	2002 2003 2004 2005 2006
Bent of the River (538)	4	0	4	0		37	2001 2002 2003 2004
Bentsen Rio Grande Valley State Park (468)	0	0	0	0			
Big Bald (622)	2	1	0	1	36	6	2004 2005
Blueberry Hill (107)	6	3	0	3	497	3	2001 2002 2003 2004 2005 2006
Bonney Butte (601)	1	0	0	0	602		
Booth Hill (125)	3	0	3	0		4	2003 2004 2005

Borrego Valley (545)	4	4	0	0	279		2003 2004 2005 2006
Botsford Hill (126)	16	12	2	2	96	21	1985 1986 1989 1990 1991 1992 1993 1994 1995 1996 1997 2001 2002 2003 2004 2005
Bradbury Mountain State Park (616)	3	3	0	0	44		2004 2005 2006
Braddock Bay (353)	4	3	0	1	284	2	2003 2004 2005 2006
Brady's Bend (108)	2	1	0	1	52	1	2001 2002
Bridger Mountains (590)	1	0	0	0	713		
Briggs Hill (539)	3	1	2	0	3	9	2002 2004 2005
BroadwingSEPT - Buckingham (405)	4	0	4	0		42	2002 2003 2004 2005
BroadwingSEPT - Core Creek (406)	4	0	4	0		43	2002 2003 2004 2005
BroadwingSEPT - Lake Nockamixon (407)	4	0	2	2	3	43	2002 2003 2004 2005
BroadwingSEPT - Lehigh (411)	2	0	2	0		5	2002 2003
BroadwingSEPT - Peace Valley (408)	4	0	4	0		41	2002 2003 2004 2005
BroadwingSEPT - Pipersville (409)	4	0	4	0		38	2002 2003 2004 2005
BroadwingSEPT - Pleasant Valley (410)	4	0	4	0		36	2002 2003 2004 2005
Bullhead Mountain (293)	1	1	0	0	33		2006
Cadillac Mt., Acadia N.P. (280)	3	2	0	1	173	1	2003 2004 2005
Caesars Head Hawk Watch (551)	3	2	0	1	192	3	2003 2004 2005
Candler Mountain (487)	4	4	0	0	56		2002 2003 2004 2005
Cape Henlopen Hawk Watch (169)	5	0	5	0		492	2002 2003 2004 2005 2006
Cape May (328)	4	0	4	0		354	2002 2003 2004 2005
Carvins Cove (645)	1	1	0	0	47		2006
Chelan Ridge (611)	1	0	0	0	478		
Chequamegon Bay (514)	2	2	0	0	168		2003 2004
Chestnut Hill (128)	4	1	2	1	9	40	2002 2003 2004 2005

Chestnut Ridge (534)	3	0	2	1	2	65	2001 2002 2003
Concordia (515)	6	0	6	0		208	1983 1999 2002 2003 2004 2005
Congaree Bluffs (552)	1	0	0	1	20	11	2003
Corpus Christi (470)	1	0	0	0	807		
Courtney Farm (554)	0	0	0	0			
Cranberry Marsh (391)	4	1	3	0	98	303	2002 2003 2004 2005
Cromwell Valley Park (621)	2	0	0	2	6	62	2004 2005
Derby Hill Bird Observatory (358)	4	0	2	2	82	252	2003 2004 2005 2006
Eagle Crossing, SW Quebec, Canada (540)	6	6	0	0	405		2001 2002 2003 2004 2005 2006
East Shore Park (529)	4	2	0	2	12	15	2002 2003 2004 2005
Fire Island (359)	3	0	1	2	21	97	2003 2004 2005
Flat Hill (132)	1	1	0	0	10		2005
Flirt Hill (532)	4	1	3	0	18	36	2002 2003 2004 2005
Fort Smallwood Park (272)	7	7	0	0	518		2000 2001 2002 2003 2004 2005 2006
Franklin Mt. (361)	13	10	0	3	1006	5	1989 1990 1991 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Glassy Mountain (548)	0	0	0	0			
Good Hill (133)	2	0	1	1	1	16	2002 2003
Grimsby Air Park (632)	1	0	0	0	9		
Guana Reserve (639)	1	1	0	0	16		2005
Gunsight Mountain (549)	4	0	4	0		85	2003 2004 2005 2006
Hamburg Hawk Watch (364)	5	2	0	3	305	79	2002 2003 2004 2005 2006
Hanging Rock Tower (519)	3	3	0	0	151		2003 2004 2005
Harvey\'s Knob (482)	1	0	0	1	97	13	2005
Hawk Cliff Hawkwatch (392)	4	1	0	3	257	28	2002 2003 2004 2005
Hawk Mountain Sanctuary (109)	6	0	4	2	50	689	2001 2002 2003 2004 2005 2006
Hawk Ridge (288)	35	0	34	1	1	3033	1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Hazel Bazemore County Park (471)	0	0	0	0			

Heritage Village (136)	2	1	1	0	7	7	2003 2004
High Park (393)	4	4	0	0	301		2002 2003 2004 2005
Hitchcock Nature Center (172)	4	0	4	0		458	2002 2003 2004 2005
Holiday Beach (100)	31	25	0	6	2499	56	1974 1975 1976 1977 1978 1979 1980 1981 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Hook Mountain (368)	4	1	0	3	42	127	2002 2003 2004 2005
Huntington State Park (452)	3	1	2	0	3	8	2002 2003 2005
I-84 Overlook (565)	0	0	0	0			
Illinois Beach State Park (527)	6	0	4	2	184	310	2000 2001 2002 2003 2004 2005
Interlakes Elementary School (315)	1	1	0	0	2		2005
Iroquois Shoreline (395)	0	0	0	0			
Jacks Mountain (104)	5	5	0	0	308		2001 2002 2003 2004 2005
Jarrett Prairie (537)	0	0	0	0			
Johnycake Mountain (137)	4	0	4	0		36	2002 2003 2004 2005
Kekoldi (620)	1	0	1	0		56	2005
Kestrel Haven (597)	1	0	1	0		94	2005
Kiptopeke State Park (484)	4	1	0	3	274	86	2002 2003 2004 2005
Kirkridge (638)	1	0	1	0		10	2005
Kitsilano (628)	1	0	1	0		1	2004
Kittatinny Mountain (332)	5	5	0	0	277		2002 2003 2004 2005 2006
La Trinidad (619)	0	0	0	0			
Lagoon Valley (642)	1	0	1	0		13	2005
Lehigh Gap Hawkwatch (110)	3	0	2	1	2	52	2002 2003 2004
Lenoir Wildlife Sanctuary (112)	4	4	0	0	167		2002 2003 2004 2005
Lighthouse Point (138)	3	0	3	0		167	2002 2004 2005
Lipan Point, Grand Canyon (576)	1	0	0	0	1014		
Little Gap (420)	4	1	3	0	96	277	2002 2003 2004 2005
Little River Lookout (558)	2	2	0	0	61		2003 2004
Little Round Top (317)	3	3	0	0	49		2003 2004 2005

Loma Flores, Escobal (557)	0	0	0	0			
Lost Mound Refuge (173)	1	1	0	0	1		2004
Mahogany Rock (300)	3	3	0	0	210		2003 2004 2005
Maltby Lakes (140)	2	0	2	0		36	2002 2003
Manchester Ridges (617)	1	1	0	0	2		2004
Manitou Island (562)	0	0	0	0			
Manzano Mountains (596)	21	21	0	0	1351		1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Meadowbrook Migration Area (630)	1	0	1	0		1	2005
Meadowood Bird Observatory (560)	2	0	2	0		29	2003 2004
Middle School (535)	4	0	1	3	20	62	2002 2003 2004 2005
Militia Hill (423)	2	0	2	0		122	2004 2005
Mohonk Preserve (371)	4	3	0	1	77	1	2002 2003 2004 2005
Montclair Hawk Lookout (334)	9	2	6	1	302	366	1976 1977 1989 1993 2002 2003 2004 2005 2006
Montreal West Island Hawkwatch (541)	6	6	0	0	505		1997 2001 2002 2003 2004 2005
Mount Peter (372)	5	1	3	1	71	181	1999 2002 2003 2004 2005
Mount Pisgah (303)	4	4	0	0	119		2002 2003 2004 2005
Mount Tom, Massachusetts (227)	1	0	0	1	3	1	2003
Mount Wachusett (228)	4	3	0	1	42	1	2002 2003 2004 2005
Mount Watatic (229)	4	1	1	2	35	29	2002 2003 2004 2005
Muskegon (629)	1	0	1	0		67	2005
NJWMP at Chimney Rock (330)	1	1	0	0	71		2005
NJWMP at Duke Farms (634)	2	2	0	0	71		0000 2005
Observatoire d\'oiseaux de Tadoussac (572)	2	0	0	2	6	201	2004 2005
Osborne Hill (145)	6	0	4	2	3	40	1999 2000 2001 2002 2004 2005

Pack Monadnock Raptor Migration Observatory (320)	3	3	0	0	74		2003 2004 2005
Pea Island NWR (305)	2	1	1	0	16	8	2003 2004
Peak Mountain (553)	4	2	0	2	210	9	2003 2004 2005 2006
Peaked Hill (321)	0	0	0	0			
Pembina Valley (646)	0	0	0	0			
Peter Wood Hill (322)	1	1	0	0	1		2003
Phoenix Mountain Hawk Watch (555)	1	1	0	0	14		2003
Picatinny Peak (338)	9	9	0	0	770		1994 1995 1996 1997 1998 2002 2003 2004 2005
Pilgrim Heights (113)	5	5	0	0	253		2002 2003 2004 2005 2006
Pilot Mountain State Park (306)	13	4	9	0	119	293	1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003
Pinnacle Rock (239)	1	0	1	0		2	2005
Plateau de Beaupre (442)	1	1	0	0	29		2003
Plum Island MA (115)	1	0	1	0		2	2006
Port Huron (284)	4	4	0	0	146		2003 2004 2005 2006
Prairie Ridge Migration Watch (559)	0	0	0	0			
Putney Mountain VT (506)	3	0	3	0		81	2003 2004 2005
Quaker Ridge (149)	4	0	3	1	57	251	2002 2003 2004 2005
Raccoon Ridge (339)	4	0	3	1	3	137	2002 2003 2004 2005
Reed's Beach Autumn Hawk Watch (106)	1	0	1	0		23	2001
Ripley Hawk Watch (381)	4	3	0	1	240	58	2003 2004 2005 2006
Rockfish Gap Hawk Watch (491)	4	0	4	0		356	2002 2003 2004 2005
Rocky Point Bird Observatory (550)	1	0	1	0		46	2003
Rose Tree Park (105)	6	4	0	2	596	113	2001 2002 2003 2004 2005 2006
Sandy Hook Migration Watch (340)	1	0	0	1	42	20	2004

Scotts Mountain (342)	4	0	0	4	110	248	2002 2003 2004 2005
Second Mountain (432)	5	5	0	0	594		2002 2003 2004 2005 2006
Semaphore Hill (Canopy Tower) (627)	1	1	0	0	1		2004
Shatterack Mountain (626)	2	2	0	0	57		2004 2005
SHORT HILL Mountain (493)	0	0	0	0			
Smith Point (563)	9	9	0	0	823		1997 1998 1999 2000 2001 2002 2003 2004 2005
SMRR- Lake Erie Metropark (285)	4	0	2	2	155	193	2002 2003 2004 2005
SMRR- Pointe Mouillee State Game Area (631)	2	1	0	1	22	1	2004 2005
Snickers Gap (494)	4	0	0	4	202	156	2002 2003 2004 2005
Southbury Training School Farm (156)	1	0	1	0		3	2004
Sparta Migration Watch (546)	2	0	2	0		33	2003 2004
St. Adolphe Hawkwatch (643)	1	1	0	0	53		2006
State Line Hawkwatch (343)	1	0	0	1	7	5	2005
Stone Mt., Pa. (436)	11	9	0	2	686	3	1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Straits of Mackinaw (613)	1	0	1	0		45	2004
Summitville Hawkwatch (624)	2	2	0	0	52		2004 2005
Sunrise Mountain (345)	4	0	4	0		160	2002 2003 2004 2005
Taine Mountain (158)	1	1	0	0	2		2005
Tara Woods East Collierville (636)	1	0	1	0		6	2005
Thunder Cape Bird Observatory (561)	3	2	0	1	206	32	2003 2004 2005
Tlacotalpan Veracruz MX (544)	4	0	1	3	5	118	2003 2004 2005 2006
Trezevant\'s Landing (618)	2	2	0	0	20		2004 2005
Turkey Point (278)	3	0	0	3	175	16	2003 2004 2005
Tuscarora Summit (437)	3	3	0	0	274		2003 2004 2005

Tussey Mountain (438)	4	0	3	1	1	242	2003 2004 2005 2006
Tuttle Hill (530)	1	1	0	0	2		2002
Veracruz River of Raptors, MX (528)	4	0	4	0		385	2002 2003 2004 2005
Waggoner\'s Gap (439)	54	25	22	7	3135	479	1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Washington Monument State Park (279)	5	1	2	2	98	146	2002 2003 2004 2005 2006
Wellsville Mountains (606)	1	0	0	0	1068		
West Skyline Hawk Count (543)	7	0	7	0		613	2000 2001 2002 2003 2004 2005 2006
White Clay Creek State Park - Carpenter Recreation Area (614)	1	1	0	0	4		2004
White Memorial Foundation (623)	0	0	0	0			
Whitefish Point (286)	1	1	0	0	42		2006
Wildcat Ridge (103)	6	0	6	0		851	2001 2002 2003 2004 2005 2006
Yaki Point, Grand Canyon (578)	1	0	0	0	667		

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HAWK MOUNTAIN

Hawk Mountain Sanctuary

HMANA

Hawk Migration Association of North America

HawkWatch INTERNATIONAL

HawkWatch International

The **Raptor Population Index** (RPI) project represents a partnership between three leading hawk watch and migration research organizations: the Hawk Migration Association of North America (HMANA), Hawk Mountain Sanctuary (HMS), and HawkWatch International (HWI).

Accurate knowledge of population status and change is fundamental for bird conservation. Lack of reliable information on populations of many raptors forms a conspicuous gap in North American bird monitoring. The vision of the RPI partners is to contribute to effective conservation of migratory raptors through continent-wide long-term monitoring of raptor migration, scientifically sound assessments of population status, and public outreach and education.

The specific objectives of the Raptor Population Index (RPI) program are to:

- Produce statistically defensible indices of annual abundance and trends for each species of migratory raptor from as many count sites as possible
- Provide frequently updated assessments of the status of each species
- Make these results widely available, i.e. to participating count sites, the scientific community, conservation agencies, and the public.

National Fish and Wildlife Foundation

Support for the RPI project has been provided in part by a generous challenge grant from the National Fish and Wildlife Foundation as well as by private donations from HMANA members and friends, and in-kind support from the three partner organizations, HMANA, Hawk Mountain Sanctuary, and HawkWatch International.

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RPI Sites

The initial RPI analysis effort examined hourly raptor migration count data from seven hawk watch sites in Canada and the United States.

- Cape May, New Jersey, USA
- Hawk Mountain, Kempton, Pennsylvania, USA
- Hawk Ridge, Duluth, Minnesota, USA
- Holiday Beach, Amherstburg, Ontario, Canada
- Lighthouse Point, New Haven, Connecticut, USA
- Montclair Hawk Lookout, Montclair, New Jersey, USA
- Waggoner's Gap, Pennsylvania, USA

The second stage of RPI analysis examines hourly raptor migration count data from the following ten sites:

- Chelan Ridge, Washington, USA
- Bonney Butte, Oregon, USA
- Goshute Mountains, Nevada, USA
- Bridger Mountains, Montana, USA
- Wellsville Mountains, Utah, USA
- Lipan Point, Arizona USA
- Yaki Point, Utah, USA
- Manzano Mountains, New Mexico, USA
- Corpus Christi, Texas USA

Raptor Population Index

RPI Analysis

The initial RPI analysis effort examined hourly raptor migration count data from seven hawk watch sites in Canada and the United States. Select a site to view a summary of the initial RPI analysis for that site:

- Cape May, New Jersey, USA
- Hawk Mountain Sanctuary, Pennsylavania, USA
- Hawk Ridge, Duluth, Minnesota, USA
- Holiday Beach, Amherstburg, Ontario, Canada
- Lighthouse Point, New Haven, Connecticut, USA
- Montclair Hawk Lookout, Montclair, New Jersey, USA
- Waggoner's Gap, Pennsylvania, USA

Long-term series of data from additional selected sites are currently under analysis. The models to generate annual indices and to calculate long term trends have been described by Farmer et al. (unpublished ms submitted to The Auk in Spring 2006.) In summary, the procedure described by Chris Farmer (North American Monitoring Coordinator, HMSA) standardizes the count day/season at each monitoring site and also allows compensation for missing days and additional covariates (e.g. weather.)

For each species, the model:

- (1) Identifies the daily window during which 95% of the migrants are counted;
- (2) Selects the seasonal passage window when the middle 95% of the individuals were counted across all years;
- (3) Models curvilinear effects of wind speed and direction on number of hawks counted;
- (4) Calculates an indices of passage rate [date-adjusted estimated geometric means];
- (5) Obtains trends in annual passage rates by fitting a polynomial regression model to the time series of annual indices; and
- (6) Re-parameterizes the year terms to determine the significance of these trend estimates (fide Francis and Hussell 1998; Farmer et al. unpublished ms.)

RPI has transferred a series of robust data sets to electronic form for analysis. The analyses underway include the initial seven sites from the Northeast/Great Lakes Region, twelve sites from the Intermountain West Region, and following those there will be a Gulf Region analysis.

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RPI Data Collection

The raptor migration data analyzed by the RPI project has been collected over many years at many independant raptor migration watch sites, each operating within their established protocols. Much of this data has been recorded on paper forms and more recently in online databases; many efforts are now underway to pull the historical paper forms into online databases such as hawkcount.org.

HMANA has established various data recording standards for use at hawk watch sites. As part of the RPI project, HMANA has generated a first version of a generalized site data collection protocol. This protocol may be used by individual hawk watch sites as a starting point in the generation of their own operating protocols.

Hawkcount.org is an online raptor migration database established by HMANA as a repository for raptor migration count data. It also allows hawk watch sites to distribute their observations during the migration season through email lists and the World Wide Web. The data entry procedure implemented at hawkcount.org follows the HMANA data collection protocols and standards. As a component of the RPI project, hawkcount.org also exports the raptor migration datasets in a format suitable for the project's statistical analysis procedures.

HawkCount

HMANA

Main

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[Find a Hawk Watch]

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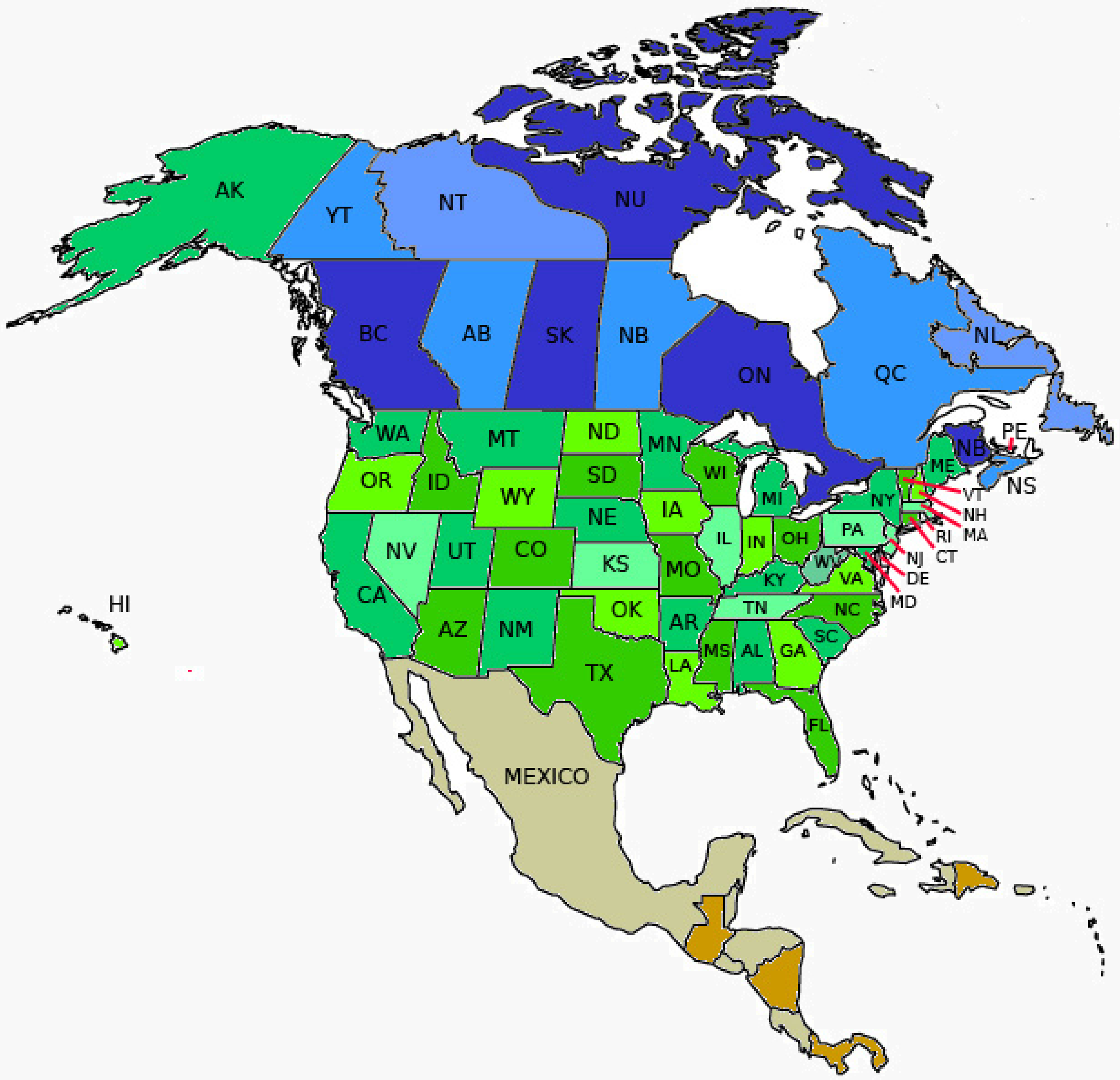
Hawk Watch Site Selection

Select a country, state or province:



Canada	Mexico
British Columbia Manitoba Ontario Quebec	Veracruz

United States

Alaska	Arizona	California	Connecticut	Delaware
Florida	Illinois	Iowa	Maine	Maryland
Massachusetts	Michigan	Minnesota	Montana	New Hampshire
New Jersey	New Mexico	New York	North Carolina	Oregon
Pennsylvania	South Carolina	Tennessee	Texas	Utah
Vermont	Virginia	Washington	West Virginia	Wisconsin

Hawkcount.org is a project of the Hawk Migration Association of North America.
To help support this project, please consider HMANA membership.

HawkCount

HMANA

Hawk Watch Site Profile

Holiday Beach

N 42° 1' 59.4", W 83° 2' 43.8"
(N 42.03317, W 83.0455)

Ontario, Canada

http://hbmo.org/
[Latest count data]

Map

General Site Information


Hawk Counters on the tower

Holiday Beach Conservation Area was formerly a Provincial Park, but is now administered by the Essex Region Conservation Authority (ERCA). It is strategically located at the extreme southwestern tip of southern Ontario. The park is on the eastern end of a large freshwater estuary known as Big Creek. (Specifically the site is 1.1 miles south of the junction Highway 20 (old 18) and Essex Road 50, Town of Amherstburg).


The Hawk Tower at Holiday Beach

The Holiday Beach Migration Observatory (HBMO) (founded in 1986) is a non-profit, volunteer organization formed to promote the study and protection of migrating birds. Activities focus primarily on fall migration of raptors and other species. This site is in Essex County, Ontario, on the north shore of Lake Erie near the Detroit River. In 1988, HBMO persuaded Detroit Edison to donate a 40 foot Hawk Tower which is now at the site.

Southwestern Ontario has a funneling effect on migrating raptors due to the geography of the nearby lakes and the reluctance of most raptors to cross large bodies of water. Birds gain altitude over the flat farmland to the north and east, rising easily with the thermals that such areas provide in abundance. As the birds head south they meet Lake Erie and, reluctant to cross it , turn west. With appropriate wind and weather conditions, birds pile up along the lake shore and move west until they reach the narrow crossing at the Detroit River (or island hop within the river mouth).

Photo: Brian Barker

Photo: Bob Pettit

Site Contacts

Name	Role	Email	Phone
Bob Hall-Brooks	Chair	bhall-brooks@cogeco.ca	
Jason Sodergren	Data	jason@taiga.com	907-226-2076

Migratory Raptors Observed at Holiday Beach

Species	Avg. count / season	Max. Year	Min. Year	Peak Days
Turkey Vulture *(Cathartes aura)*	13675	41543 (2005)	486 (1975)	20032 (Oct 09,2005) 7312 (Oct 20,2006) 5544 (Oct 05,2006)
Osprey *(Pandion haliaeetus)*	97	175 (1987)	21 (1975)	27 (Sep 21,1987) 24 (Sep 09,1978) 24 (Sep 18,1987)
Bald Eagle *(Haliaeetus leucocephalus)*	45	124 (2006)	1 (1974)	26 (Sep 09,2003) 23 (Sep 17,1998) 18 (Sep 11,2006)

Northern Harrier *(Circus cyaneus)*	805	1616 (1993)	189 (1974)	258 (Oct 31,1993) 155 (Nov 18,1986) 142 (Oct 20,1985)
Sharp-shinned Hawk *(Accipiter striatus)*	12678	18175 (1987)	5506 (2004)	2407 (Oct 17,2001) 2130 (Sep 14,1988) 2124 (Sep 15,1981)
Cooper's Hawk *(Accipiter cooperi)*	549	1082 (1991)	49 (1975)	289 (Oct 03,1987) 227 (Oct 18,1979) 210 (Oct 09,1986)
Northern Goshawk *(Accipiter gentilis)*	32	77 (1991)	5 (1976)	28 (Nov 10,1991) 15 (Nov 01,1993) 13 (Nov 08,1997)
Red-shouldered Hawk *(Buteo lineatus)*	799	1667 (1993)	59 (1975)	430 (Oct 17,1978) 403 (Oct 18,1991) 364 (Oct 20,1985)
Broad-winged Hawk *(Buteo platypterus)*	36494	110271 (1984)	4887 (2002)	95499 (Sep 15,1984) 63400 (Sep 18,1993) 53273 (Sep 19,1996)
Red-tailed Hawk *(Buteo jamaicensis)*	6004	10987 (1995)	830 (1974)	3002 (Nov 11,1994) 2724 (Nov 10,1980) 1936 (Nov 08,1997)
Rough-legged Hawk *(Buteo lagopus)*	115	308 (1977)	6 (1974)	73 (Nov 05,1977) 71 (Oct 23,1978) 70 (Oct 27,1991)
Golden Eagle *(Aquila chrysaetos)*	51	134 (1999)	5 (1976)	35 (Oct 21,2000) 34 (Oct 27,1999) 26 (Nov 07,1999)
American Kestrel *(Falco sparverius)*	2981	5644 (1989)	1040 (1974)	1105 (Oct 17,1989) 1059 (Oct 01,1986) 852 (Sep 17,1994)
Merlin *(Falco columbarius)*	52	122 (2006)	2 (1975)	16 (Sep 20,2005) 13 (Sep 21,2002) 12 (Sep 20,2002)

Peregrine Falcon *(Falco peregrinus)*	36	114 (2006)	4 (1974)	18 (Oct 01,1995) 15 (Oct 04,2002) 14 (Sep 26,2006)
Black Vulture *(Coragyps atratus)*	1	1 (1979)	1 (1991)	1 (Sep 22,1979) 1 (Oct 31,1991)
Swainson's Hawk *(Buteo swainsoni)*	2	3 (2006)	1 (1998)	2 (Sep 16,1993) 1 (Oct 04,1998) 1 (Sep 15,2006)
Short-eared Owl *(Asio flammeus)*	1	1 (1986)	1 (1986)	1 (Oct 17,1986)
Gyrfalcon *(Falco rusticolus)*	1	1 (1991)	1 (1991)	1 (Nov 10,1991)

Count Season

Fall: Sep 01 to Nov 30

Procedures/Protocols

HBMO Field Manual (2002)

Data Inventory (at hawkcount.org, as of Dec 07, 2006)

Data Summary

32 years (2645 days) of data saved:

26 years of hourly totals,
0 years of daily totals, and
6 years of mixed hourly/daily totals.

Data Years Click year links for year's data calendar

				1974	1975	1976	1977	1978	1979
1980	1981		1983	1984	1985	1986	1987	1988	1989
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2000	2001	2002	2003	2004	2005	2006			

Color Key: Hourly Totals Daily Totals Mixed Hourly/Daily

Site History

Site Topography

Southwestern Ontario is largely an area of flat, featureless farmland. There are only two geographic features of note in the region. One is the proximity of the Great lakes, which influence bird migration in the area to a great extent, The second is the shape of the province, roughly funnel-shaped with the narrow end to the southwest. These features confine south-bound bird migrants, especially hawks, to specific flight corridors.

Directions to Site

Entering Canada from Detroit at the Ambassador Bridge:
After Canadian Customs, stay left 50 yards, passing over the railroad tracks.
You are now on Huron Church Road leading to Highway 401 and Highway 3. Continue east 3.8 miles to the intersection with Todd and Cabana roads. Go through the intersection, staying to the right. In less than 100 yards the main road splits; 401 and 3 continue to the left as the main road and Huron Church narrows and angles to the right. Follow Huron Church right for 0.5 miles to Disputed Road. After anglign a right turn onto Disputed Road, travel south. At 4 miles Disputed Road intersects with Townline Road, and the name changes to Concession 5. Continue south 5 miles and Concession 5 "T"'s with South Townline Road. Turn left and travel east 0.2 miles, turning right (south) onto Concession 6. Continue south for 3.4 miles to the intersection with Highway 20 at Malden Centre in the town of Amherstburg. There is a restaurant/convenience/gas store on the southeast corner of the intersection. Go through the intersection south onto Route 50 for 1.3 miles. The entrance to the Holiday Beach Conservation Area is on the right. Pay entry fee and continue to the Hawk Tower at the south end of the park. Park vehicle and walk to the tower.

West bound on Routes 401 and 3

Howard Avenue, Route 9, intersects Routes 401 and 3 east of Windsor. Take Howard Avenue south to Highway 20 ("T"'s) and turn left (west) traveling to Malden Centre in the town of Amherstburg. A restaurant/convenience/gas store is on the left. Turn left (south) on to Route 50 for 1.3 miles; the entrance to HBCA is on the right.

Pan: Click and drag the map with the mouse pointer.
Zoom: Select the zoom level with the control at the left of the map.

A STANDARD DATA COLLECTION PROTOCOL FOR RAPTOR MIGRATION MONITORING STATIONS

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1. INTRODUCTION

A monitoring program should provide three types of information: (1) An estimate/sample of population size, (2) An estimate of demographic parameters (e.g. information on population structure provided by data on species' sex and age classes), and (3) A measure of the environmental variables believed to affect the first two estimates (Hutchinson 1978, Ralph et al. 1993).

Effective long-term monitoring program a standard protocol for a site and recording that protocol for use by researcher The Hawk Migration Association of North America (HMANA) has promoted the use of a standard data collection protocol for raptor migration monitoring ever since its foundation in 1974. This protocol has been improved several times since its inception and the current data collection form and a brief set of instructions are made widely available to monitoring sites across North, Middle, and South America via the HMANA website (www.hmana.org) .

Although most hawk watchs are using HMANA data forms, each site may have slightly different ways of collecting the data at their site. To improve the utility of the data collected, it is important to describe the ways data are collected and any changes that have occurred over time.

Here, we present a recommended set of items to be considered in establishing a protocol for a new watch site, and in recording protocols for established sites. It is expected that this protocol and its revised contents continue to be clear, simple, and practical for citizen scientists and field biologists collecting data in the field, but also useful and informative for the needs of managers, conservationists, and scientists in later data analysis (Beissinger et al. 2006). This protocol can be easily customized for the particularities of a specific site.

1.2. Objectives of this protocol. The purpose of this document is to describe a standard data collection protocol for raptor migration counts. Although the forms and sets of instructions for such protocol already exist, there is very little information on the rationale and background of such instructions (Fuller and Mosher 1987, Kerlinger 1989). This protocol has three specific objectives: (1) Provide standard instructions for raptor migration count data collection across sites, (2) Present the rationale of why these data should be collected and expand specific instructions for data collection procedures, (3) Introduce improvements to basic HMANA protocol that have been in use for many years. This protocol is not intended to replace former protocols, but to stimulate raising the quality of data collection and to facilitate the access and use of information for analysis. And, because every site may conduct the count differently, it is important that every site establish a written protocol describing their data collection techniques and site.

1.3. Organization of this protocol. The current set of HMANA (2006a) standards, termed “Protocol 1” in this document, have been in use since 1976 and revised in 1979 and 1986. This description follows the same format and structure: it starts with a description of the location and coverage where data are collected, the set of target species and population parameters that are recordable under field conditions for that particular site, and instructions for weather and flight recording conditions. This protocol encourages the use of metric system units at all times. Monitoring site specifics, species coverage, and data collection instructions should be carefully documented in a Seasonal Metadata Form (Appendix 2).

2. MONITORING SITE SPECIFICS

2.1. Location. This field includes a description of the localities' specifics, including coordinates in latitude/longitude format, elevation (in meters above the sea level [mASL]), and the choice between a Fixed versus a Mobile monitoring site. Photographs of the 360 degree view from each site for each year may be of use to document other reasons affecting count records, e.g. new human-made structures or growth of trees that block the field of view, whether counts are done from a tower or from the ground.

A fixed location is the specific point from where migration counts are done throughout the season. Some sites, however, shift between two or more closely-located sites (e.g. <1-2 km apart) according to wind speed and direction, from where they can observe more migrants.

For monitoring purposes, counting more birds is not the goal but collecting systematic data from one site. No birds (e.g. many zeros) are as informative as many birds recorded. Sites that operate with professional field biologists and volunteers that acknowledge the higher value of data collected from fixed locations should avoid conducting counts from mobile sites. However, since many of these sites are run by citizen scientists whose goals are also recreational, it is very important that those mobile sites clearly label their counts as conducted from a mobile site and be able to differentiate between the locations used under the same general location name (e.g. Observation Site A, B, or C). If there are guidelines for when different sites are monitored, (i.e. different wind directions) then these decision rules should be written in the protocol description.

Some monitoring sites along diversion lines (e.g. coast lines) run counts from several sites at a time to cover the width of the flight's front. If these localities are fixed and operate in a coordinated fashion, they should be labeled as part of a "Survey Line". Other specifics of a Survey Line such as distance between sites, the estimated number of birds that may be double counted (if any), and active communication system in operation should also be documented.

2.2. Seasons and dates of operation. Note the season, spring or fall, season of operation, and the start and end date of field season. If the coverage has changed over the years, note any changes that have occurred in the past. The seasonal timing of migrant raptor species often have skewed distributions with "long, tails" (a species comes by in low numbers for a long time, then increases in numbers, reaches a peak, and decreases to low numbers for a long time). For new sites, seasonal timing charts of target monitoring species should be used in the choice of seasonal coverage so that the dates of operation match the largest proportion (e.g. 95% of the migration period or migration window) in as many species as possible. Once dates of coverage have been chosen, the same sampling period should be used annually.

The length of the field season has a strong influence on our abilityto use count data to estimate trends. Lewis and Gould (2000) estimate that autumn counts collected over periods of 30 or 60 days have a lower statistical power than counts done over a period of 90 days. The ability of shorter field seasons to estimate population trends decreases because the proportional variation of annual counts increases in samples composed of fewer consecutive days of counts. Counts done over periods of >90 days can attain comparable statistical power than counts done over 90 consecutive days. I don't understand this last statement.

2.3. Daily times of operation. Start and end times of daily field work should also be planned based on a more detailed knowledge of the diurnal timing of migration at the site. Coastal sites, for example, have a tendency to have an earlier period of migration activity than inland sites (Kerlinger 1989) and appropriate coverage of the 95% window of daily migration should be planned to capture this particularity. The use of standard versus daylight savings times in data sheets, protocol, and reports should be clearly noted.

Several monitoring sites do not operate on a daily basis. Some of them operate only on weekends and others only do so on days with "favorable" weather when observers believe more migrants can be recorded.

The optimal coverage of a field site is done through daily observations. Therefore the use of counts done over consecutive days is encouraged, since the monitoring usefulness of those data collected over non-consecutive days (e.g. weekend counts), or counts done over a structured sampling calendar (e.g. two days on, one day off), have not been tested. Check with chris farmer on this

Observers must clearly document the reason why a count has been interrupted or when a count day was missed, e.g. due to shortage of observers, or low number of birds recorded, rain or snow. The same judgment applies to sites that only operate on days with “favorable” weather conditions. the data generated on days with adverse data is as valuable as the one collected in days with good weather, but if days are missed or skipped, it is recommended that it be indicated in the protocol when this occurs and within a season, a form be filled out even if the day is not covered, indicating the reason the day was missed, Notes such as “rain-out” or “no observer” can simply indicate the reason for missing days or hours.

2.4. General description of the flight. Hawks constrain their migration to routes defined by favorable flight conditions. Site descriptions must select between (1) Diversion Line (a geographic or topographic feature that causes migrants to alter their course so as to avoid crossing the line, making them appear to follow it, e.g. a shoreline followed by hawks avoiding to cross over a large water body); and (2) Leading Line (a geographic or topographic feature that has properties that induce migrants to change their direction of travel so as to follow them, e.g. a mountain ridge with updrafts along its crest) (Mueller and Berger 1967).

3. SPECIES COVERAGE

3.1. Species covered. Each site must clearly define the species focus of their observations. The majority of monitoring sites include mostly raptors, but many of them also record vultures, and other non-raptor diurnal migrants. Some sites also record the age and sex of a proportion of the migrants. Such data are useful in a long-term monitoring program and should be recorded if the site is able to do so. There are standard codes for species, sex, and age classes, color morphs, and subspecies listed in Table 1. Observers should be encouraged to be as accurate as possible with the identification of migrants but to also acknowledge that it is impossible to identify, sex, and age, every single migrant. the percentage of unidentified migrants from multiple sites usually ranges from 1-2%.

3.2. Migrants and non-migrants. When migrating, raptors can remain in stopover areas for several days and move back and forth past the observation point. In some localities, determining whether a species is migrating or not is difficult to discern. Each site must clearly determine what constitutes a migrant (e.g. "a hawk that flies past the observation point and does not come back") and observers must follow clearly written rules to make decisions regarding classifying an individual as a migrant or a "local" hawk. These rules should be recorded in the site protocol.

4. DATA RECORDING AND DATA STORAGE

4.1. Equipment and materials in use. The evolution of optical equipment, field guides, and other field equipment has certainly changed the way migration counts are conducted in recent years and it has also improved the number of birds correctly detected, identified, and quantified. For this reason, there should be accurate notes on optic equipment in use, data recording equipment and hand instruments (includes instruments in use for collection of weather data and estimations of flight variables such as range-finders and ornithodolite-type equipment [Pennycuick 1982] and electronic weather station information). If changes in procedure occur within or among years, such as using scopes for spotting birds, the date or time this began should be noted in the protocol.

Because fatigue influences the quality of data collected, observers should provided a list of personal care equipment and materials at the monitoring site, such as chairs, umbrellas, sunglasses, and other items that reduce fatigue. Other materials that seem of minor importance such as use of an owl decoy, availability of drinking water, and others should also be recorded. Such variables affect either bird behavior or counter behavior and can affect the volume counted.

4.2. Weather variables and flight recording conditions. Weather and flight-recording conditions are perhaps the most central variables required for data analysis. Variables recorded at monitoring sites include Wind Speed (Table 2), Precipitation (Table 3), Wind Direction, Cloud Cover, Humidity, Temperature, and Barometric Pressure (see details in Appendix 1 and Tables 2-4). Although Cloud Type recordings are not part of the standard protocol, cloud type may be of help in interpreting conditions of the boundary layer of the atmosphere in the absence of other data such as barometric pressure, humidity, wind, and precipitation.

Some sites obtain data from airports and nearby weather stations, but careful records of the location of such sources of information should be noted. Although some variables may not vary greatly at a regional scale (e.g. barometric pressure and humidity) others such as wind speed and direction vary widely within short distances. Notes on the type of instruments used in these records are important, e.g. humidity and barometric pressure are collected more accurately in weather stations and airports than with hand instruments.

Some count sites record weather variables and flight conditions at the beginning of the hour or at half hour. Either choice should be clearly noted as well. What does HMANA procedure recommend? Perhaps we should say

4.3. Identification, detection, and estimation. Sites should describe a scanning technique in use. Scanning should be actively done with naked eye and 8-10x binoculars, telescopes should not be used to find migrants, but only used for identification. YES Detectability varies in locations along diversion and leading lines and a detailed description of scanning technique per site is important. This is a lot to ask, maybe just say describe scanning technique used by the site.

Observers must record the identification aids available (books such as Dunne et al. 1988, Wheeler and Clark 2003, Liguori 2005). This version of the protocol for data collection introduces the use of sex and age classes, color morphs, and subspecies information whenever it is possible under field conditions. Although it is acknowledged that it is not possible to determine all the features requested for each record, this information, even if only determined in a low proportion of the records, may be of help in determining population parameters of importance for explaining population trends (e.g. the high proportion of juveniles versus adults in migration counts is an indicator of high recruitment in a given year).

A clear description of flock estimation methods is also important for locations and species that migrate in flocks using cross-country flights (sensu Pennycuick 1998). The dynamics of these flights involve migrants entering rising thermals from the bottom and gaining altitude as they circle around the center of the thermal to take advantage of the lifting warm air to gain height. Once the top of the thermal is reached, species exit the column in a gliding flight in their desired direction and start the process again when they have lost height.

It is not possible to conduct a good estimation of the number of hawks when they are circling and migrants should be counted when streaming between thermals through the use of hand (clicker) tally counters. Flocking hawks should be directly counted (1, 2, 3, 4…) when possible, or estimated (in groups of 3, 5, 10, 50…). Observers should be aware that the higher the multiple used in these estimates the higher the error estimating the right number of birds. cite? Lower multiples should be chosen whenever possible (e.g. 3, 5,?).

4.4. Personnel and site/personnel coverage, visitors. The number and skill of observers in charge of counts also has a strong influence in the number of migrants recorded. The number of observers that actively participate in the count might be difficult to determine in some stations, since visitors play an active role in spotting birds that the main observer may have not recorded. It is recommended to keep separate track of the counts recorded by "official" and visitor observers. This is hard and unrealistic since some birds pointed out by visitors would be seen by official person anyway, unless you mean that birds that are only seen by visitors and never seen by an official observer yet included... I think we should recommend counts of number of observers, and maybe number of helpers, number of visitors total might assist with this. Clear documentation can help researchers estimate count trends more accurately.

Disturbance at the site as a consequence of visitors should also be recorded using the following code: 0=none, 1=low, 2=moderate, and 3=high. These codes are subjective, but may be of help in later data interpretation. Many sites solve the problem of distracting interactions with visitors through the use of brochures and handouts with education and project/organizational outreach materials. Or just count the number of visitors?

Sites should have a clear "job description" of count coordinator, main counter(s), and count assistant(s) (paid, volunteer, etc.). A simple documentation of the qualifications of the team may be of importance when interpreting data. Describe the count team, the system, and their roles and if it varies among days and years.

Site count instructions for counters should include the division of work at monitoring site and whether there is a clear training scheme for observers. Training is believed to help in reducing inter-observer variation in counts and result in an overall reduction of count variability across years. Training workshops should include (1) Detailed descriptions of protocol in use, (2) Site-specific procedures, (3) Detection and identification of migrants and estimation of flocks, and (4) Record-keeping and data case/management instructions as well as decision rules on topics listed above such as when a bird is considered 'local' versus 'migrant'.

4.5. Data collection and management. Data collected in the field should be transferred to a safe location at the end of the work day. Many localities collect field data in field notebooks and data is then transferred to official data forms or electronic spreadsheets or databases soon thereafter. If followed appropriately, this procedure reduces the problem of a lost field notebook, since data is already safely stored. Data transfer should be done carefully and proof-read preferably by a different person than the one doing data entry.

Site coordinators must ensure data is safely stored, either in electronic data warehouses such as HawkCount.org (preferred) or in HMANA's paper archive (as a safe backup for electronically-submitted information) or both. HawkCount.org has clear provisions for data use and intellectual proprietary rights and data storage safety procedures (HMANA 2006b). For long-term data sets, storage of a second copy of paper forms or electronic data is recommended for long-term safe-keeping. Many sites have found forms misplaced as site coordinators change over time, and having a back up copy in another location, such as the HMANA fire-proof archives is extremely important.

Another important point to review with volunteer or paid counters is that (1) It is more important to collect data consistently than recording more birds per site, (2) It is better to err on the side of being conservative than inaccurate, (3) Identifications and estimations should also be conservative since a perfect record of identifications of species, sex and age classes, and other data per record is not possible under most field conditions. Unidentified raptors are expected at every site and for every observer.

4.6. Seasonal metadata. Filling a Seasonal Metadata Form at the end of a field season is and easy and important way to determine when changes in the data collection protocol have occurred across years. Metadata forms should be kept with the file of hard copy forms? And filed at hawkcount? Information in this form is very useful in the interpretation of data by researchers (Appendix 2).

SOURCES OF INFORMATION AND LITERATURE CITED

This protocol was generated from existing data collection protocols of HMANA, Hawk Mountain Sanctuary Association, HawkWatch International, Illinois Beach State Park, Holiday Beach Migration Observatory, Hawk Ridge, Pronatura Veracruz, Hawk Cliff, and Braddock Bay Bird Observatory. Jeff Smith, Laurie Goodrich, Steve Hoffman, and Sue Ricciardi provided comments on an earlier manuscript. Concepts of leading and diversion lines were obtained from an unpublished manuscript by Keith Bildstein and Chris Farmer.

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APPENDIX 1
WEATHER AND OBSERVATION CODES AND TABLES

Notes: The following tables (Appendix 1 and Tables 1-4) describe standards for data collection. Protocol 1 (HMANA 2006a) is the minimum, most basic hawk count method available and the one most HMANA counters have used.The protocols grow in complexity with increasing level number, e.g. Protocol 3 is more specific than 1 and 2. One of the main changes in Protocol 1, which uses categorical data for different variables, are changes in the way data are recorded and replaces preset categories for longitudinal values. This protocol uses Metric System units. A site may use elements of different protocol levels, which should be documented on the seasonal metadata form at the end of each field season (Appendix 2). HMANA recommends recording weather and observation variables at the beginning of the hour, however if different it should be noted in written site protocol. ON DATA FORMS, use continuity lines to indicate conditions that remain the same between hours, or write the code. Blanks on forms are interpreted by researchers as missing data.

Variable	Protocol 1	Protocol 2	Protocol 3	Notes
Wind speed	Use category codes in Table 2	Data collected with standard hand instruments and recorded in precise units, not categories Maximum Wind speed then? Since is always varies in a one minute period	Data collected with high precision instruments or electronic weather station Same questions	Data recorded at ground level unless otherwise noticed. Wind speed is recorded in km/h - kilometers per hour. To transform miles into km, multiply km x 1.609
Wind direction	Enter compass direction from which the wind is coming (16 possible categories) i.e. N, NNE, SE, etc. if variable, enter VAR. Data collected from site exposed to wind, with limited local interference	Use of a compass and wind vane to determine wind direction in degrees. Data collected from site exposed to wind, with limited local interference	Data collected with high precision instruments or electronic weather station	Use of a wind vane or marker to determine wind direction WHAT IF NO WIND? LEAVE BOTH SPPED AND DIR BLANK
Temperature	Temperature recorded with hand thermometer placed in shaded area of monitoring site	Temperature recorded with hand thermometer placed in shaded area of monitoring site	Data collected with high precision instruments or electronic weather station	Temperature is recorded in ºC degrees centigrades. To covert ºF to ºC, substract 32 to ºF and divide by 1.8
Humidity	Record the percent relative humidity	Record the percent relative humidity	Data collected with high precision	optional

	with hydrometer	with hydrometer	instruments or electronic weather station	
Barometric pressure	Record barometric pressure with barometer in inches of Mercury (inHg)	Record barometric pressure with barometer in inches of Mercury (inHg)	Data collected with high precision instruments or electronic weather station WHERE DOES USE OF WEATHER STATION NEARBY COME IN AND HOW RECORD AS NOT AT SITE	Metric system recordings in hPa or mbar (hectopascal, identical to millibar). To transform inHg to mbar, multiply inHg x 33.86
Cloud cover	Record percentage of sky with background cloud cover	Record percentage of sky with background cloud cover	Record percentage of sky with background cloud cover	
Cloud type	Not included	Four categories	??	Make this protocol 3 only
MAXIMUM Visibility	Estimate clear visibility to the longest view to knowN landscape features with distances calculated from a topographic map	Estimate clear visibility to the longest viewUSING knowN landscape features with distances calculated from a topographic map	Estimate clear visibility to the longest view to know landscape features with distances calculated from a topographic map	To convert miles to km multiply miles x 1.1609 Judge from your longest view and enter MAXIMUM distance in km
Precipitation	Use category codes in Table 3	Use category codes in Table 3	Data collected with high precision instruments or electronic weather station. Detailed notes on distribution of precipitation per hour	To convert inches to mm, multiply in x 25.4
Flight direction	Enter compass direction migrants are heading (16 possible categories) S, SW, SSW, etc.	Enter compass direction migrants are heading (16 possible categories) S, SW, SSW, etc.	Enter compass direction migrants are heading in degrees	Enter flight direction and flight altitude at end of hour
Height of flight	Use category codes in Table 4	Use category codes in Table 4	Calculated with instruments such as radar, thermal imager, range finder, ornitholodolite, etc.	Standards in protocols 1 and 2 refer to the height of flight of "most" migrants for the hour. Standards in protocol 3 refer to data from individual birds

				and it is only expected from specific research projects
Observers	Number of trained observers contributing to the count for the hour noted	Coverage by standard number of trained official observers, either professional or volunteer	Coverage by standard number of official trained professional of volunteer observers	
Duration of observation	Specify time in minutes	Specify time in minutes	Specify time in minutes	

Table 1. Species names and sex, age, and color morph codes

Notes: Protocol 1 does not require identification of sex, age, and color morph classes. Identifiable sex and age classes fide Wheeler and Clark (2003) and other sources. The term Juvenile refers to birds in prebasic/preformative molts and Adult to birds in basic plumages (fide Howell et al. 2003, Pyle 2006). Two-letter species codes are those in use in Protocol 1 (HMANA 2006a).

The list is arranged in phylogenetic order according to AOU (1998) and subsequent supplements. New World Vultures (Black and Turkey Vultures) were placed within the Ciconiiformes in 1998 (AOU 1998), but still are considered in this table to allow consistence with earlier protocol.

* Denotes codes used in this document for the first time, not in the original source of Alpha Codes (Pyle and DeSante 2003).

** Denotes many species that have up to five 'juvenile' successive forms (prebasic/ preformative molt stages) that can be distinguished. The term "Basic" as used by Wheeler and Clark (2003) is used in this protocol as Prebasic/Preformative (Pyle 2006).

English name	Scientific Name	HMANA Code	Alpha Code	Protocols 2 and 3
Black Vulture	*Coragyps atratus*	BV	BLVU	
Turkey Vulture	*Cathartes aura*	TV	TUVU	U - unknown J - juvenile A - adult
Osprey	*Pandion haliaetus*	OS	OSPR	U - unknown J – juvenile A – adult
Swallow-tailed Kite	*Elanoides forficatus*	SK	STKI	U - unknown J – juvenile A - adult
White-tailed Kite	*Elanus leucurus*	WK	WTKI	U - unknown J – juvenile A - adult
Mississippi Kite	*Ictinia mississippiensis*	MK	MIKI	U - unknown J – juvenile A – adult Males and females can be distinguished in the field only under exceptional conditions
Plumbeous Kite	*Ictinia plumbea*	PK	PLKI	U - unknown J – juvenile A - adult
Hook-billed Kite	*Chondrohierax uncinatus*	HK	HBKI	U - unknown JL – juvenile light morph FL – adult female light morph

				ML – adult male JD – juvenile dark morph FD – adult female dark morph MD – adult male dark morph
Bald Eagle	*Haliaetus leucocephalus*	BE	BAEA	U - unknown J – juvenile PB I and II – “white-bellied” PB III – “Osprey-head” SA – subadult (either PB I, II, or III) A – adult**
Northern Harrier	*Circus cyaneus*	NH	NOHA	U - unknown J – juvenile F – adult female Br – (brown) juvenile or female M – adult male
Sharp-shinned Hawk	*Accipiter striatus*	SS	SSHA	U - unknown J – juvenile A – adult
Cooper’s Hawk	*Accipiter cooperii*	CH	COHA	U - unknown J – juvenile A – adult
Northern Goshawk	*Accipiter gentilis*	NG	NOGO	U - unknown J – juvenile A – adult
Gray Hawk	*Asturina nitida*	GH	GRHA	U - unknown J – juvenile A - adult
Common Black Hawk	*Buteogallus anthracinus*	CB	COBH	U - unknown J – juvenile A - adult
Harris’s Hawk	*Parabuteo unicinctus*	HH	HASH	U - unknown J – juvenile A - adult
Red-shouldered Hawk	*Buteo lineatus*	RS	RSHA	U - unknown J – juvenile A - adult
Broad-winged Hawk	*Buteo platypterus*	BW	BWHA	U - unknown J – juvenile A – adult D – juvenile or adult dark morph
Short-tailed Hawk	*Buteo brachyurus*	ST	STHA	U - unknown JL – juvenile light morph AL – adult D – juvenile or adult dark morph

Swainson's Hawk	*Buteo swainsoni*	SW	SWHA	U - unknown J – juvenile A – adult JD –juvenile dark or intermediate/rusty morph AD – adult dark or intermediate/rusty morph ** Note that dark morphs may include rufous morphs and these two are lumped into a single category
White-tailed Hawk	*Buteo albicaudatus*	WT	WTHA	U - unknown J – juvenile A – adult**
Zone-tailed Hawk	*Buteo albonotatus*	ZT	ZTHA	U - unknown J – juvenile A – adult
Red-tailed Hawk	*Buteo jamaicensis*	RT	RTHA	U - unknown J – juvenile A – adult JD –juvenile** intermediate/dark morph AD – adult** intermediate/dark morph ** Note that dark morphs may include rufous morphs and these two are lumped into a single category
Ferruginous Hawk	*Buteo regalis*	FH	FEHA	U – unknown JL – juvenile light morph AL – adult light morph JD – juvenile dark morph AD – adult dark morph
Rough-legged Hawk	*Buteo lagopus*	RL	RLHA	U – unknown JL – juvenile light morph AL – adult JD – juvenile dark morph AD – adult dark morph
Golden Eagle	*Aquila chrysaetos*	GE	GOEA	U – unknown J – juvenile S - subadult

				A – adult**
Crested Caracara	*Caracara cheriway*	CC	CRCA	U – unknown J – juvenile A – adult
American Kestrel	*Falco sparverius*	AK	AMKE	U – unknown F- female M – male
Merlin	*Falco columbarius*	ML	MERL	U – unknown BR – brown, female or juvenile M – male (subspecies: black [*F.c. suckleyi*], taiga [*F.c. columbarius*], and prairie [*F.c. richardsoni*])
Gyrfalcon	*Falco rusticolus*	GY	GYRF	U – unknown JW – juvenile white AW – adult white JG – juvenile gray AG – adult gray JD – juvenile dark morph AD – adult dark morph
Peregrine Falcon	*Falco peregrinus*	PG	PEFA	U – unknown J – juvenile A – adult
Prairie Falcon	*Falco mexicanus*	PR	PRFA	
Unidentified Vulture		UV	UNVU*	
Unidentified Accipiter		UA	UNAH	
Unidentified Small Accipiter	*Accipiter striatus* or *A. cooperii*	SA	UNSA*	
Unidentified Large Accipiter	*Accipiter cooperii* or *A. gentilis*	LA	UNLA*	
Unidentified Buteo		UB	UNBH*	
Unidentified Eagle		UE	UNEA*	
Unidentified Falcon		UF	UNFA*	
Unidentified Raptor		UR	UNRA*	
Other Raptor		OO		

Table 2. Wind speed codes in HMANA Protocol 1

0 – less than 1 km/h (calm, smoke rises vertically)
1 – 1-5 km/h (smoke shift shows drift direction)
2 – 6-11 km/h (leaves rustle, wind felt on face)
3 – 12-19 km/h (leaves, small twigs in constant motion; light flag extended)
4 – 20-28 km/h (raises dust, leaves, loose paper; small branches in motion)
5 – 29-38 km/h
6 – 39-49 km/h (larger branches in motion; whistling heard in wires)
7 – 50-61 km/h (whole trees in motion; resistance felt walking against the wind)
8 – 62-74 km/h (twigs, small branches broken off trees, walking generally impeded)
9 – Greater than 75 km/h

Table 3. Precipitation codes in Protocol 1

0 – none
1 – Haze or fog
2 – Drizzle
3 – Rain
4 – Thunderstorm
5 – Snow
6 – Wind driven dust, sand, or snow

Table 4. Height of flight codes in Protocol 1

Notes: The estimation of height of flight is a function of the location of the monitoring site, in which case an accurate description of the monitoring site is important. For example, a site located in a mountain ridge may likely have birds above oR below the horizontal. In this case, this protocol follows the recommendations of HawkWatch International's protocol – hawks below the horizontal will be added a positive or negative sign if above or below the horizontal, respectively. Negative values are naturally only limited to the lower categories of this scale. Height of flight categories apply to vertical height, which should be carefully recorded and not to be confused with side distance. I worry about using the negative sign on forms and it getting lost. Can it be instead a B1, b2 b3 system?

0 – Below eye level
1 – Eye level to about 30 meters
2 – Birds seen easily with unaided eye (eyeglasses not counted as aids)
3 – At limit of unaided vision
4 – Beyond limit of unaided vision but visible with binoculars – to 10x
5 – At limit of binoculars
6 – Beyond limit of binoculars 10x or less, but can detect with binoculars or telescope of greater power (mark "1" in comment box and note magnification)
7 – No predominant height seen in migrants

APPENDIX 2
SEASONAL METADATA FORM
Need instructions here even if to say circle appropriate categories

Recorder name	
Position at monitoring site	
Mailing address	
Phone number	
E-mail	
Date filled	

Monitoring Site Specifics	
Can we make this if did not change	Location name
Between seasons they just note same?	County/Municipality
	State/Province
	Country
	Latitude
	Longitude
	Elevation
Topographic maps Published literature Geographic Positioning System (GPS)	Data source
Fixed Mobile	Type of location (fixed or mobile) if mobile, label each location separately (e.g. site A, B, or C) and provide latitude, longitude, and elevation for each site. Add additional sheets if necessary.
Yes No	Part of survey line?
Attached?	Photo documentation of 360 degree view of site?
Yes No	Tower, building, or vantage point used (attach photo)
Spring Fall	Seasonal coverage
Daily Regular not daily (est. no days/ week) Weekend Irregular	Periodicity of operation
	Start and end dates of coverage
	Daily times of operation (start/end times)
Diversion Line Leading Line	Type of migration

BV TV OS SK WK MK PK HK BE NH SS CH NG GH CB HH RS BW ST SW WT ZT RT FH RL GE CC AK ML GY PG PR	Species covered (See Table 1 for species codes) what is recorded here? Just check?
Yes No	Sex, age, color morph, and subspecies data available?

Data Recording and Data Storage	
Protocol	
1 2 3	Wind speed
1 2 3	Wind direction
1 and 2 3	Temperature
1 and 2	Humidity

3	
1 and 2 3	Barometric pressure
1, 2, and 3	Cloud cover
??	Cloud type
1 2 and 3	Visibility
1 and 2 3	Precipitation
1 and 2 3	Flight direction
1 and 2 3	Height of flight
1 2 and 3	Observers
1, 2, and 3	Duration of observation
This is hard to do for sites with a lot of observers. Maybe 'main observer only'	Binoculars (List brand name and power of each observer's binoculars, e.g. Zeiss Conquest 10x40, Leica Trinovid 10x40, etc.)
I think it is sufficient to say scope used or not. Quality of scope is only an ID issue	Telescope(s) and eyepieces (ibid, e.g. Leica straight/angled 77 mm, 20-60 zoom eyepiece, etc.)
Clark and Wheeler. Hawks of North America Wheeler and Clark. A photographic guide to North American raptors Dunne et al. Hawks in Flight Liguori. Hawks from Every Angle Sibley. The Sibley guide to the birds (or Eastern, Western version of it) Other: _____________	Identification aids in use at monitoring site
	Tally counters?
Electronic weather station Manual weather station Hand electronic Hand manual	Hand weather recording equipment (list all, include brand name and model of each, e.g. Thermometer Forestry Supplies model B in degrees centigrades, Windmeter xxx, etc. Electronic hand weather meter (e.g. Kestrel xxx)
Yes No	Owl decoy?
	Other personal care equipment available on site
1 2 3	Regular number of observers on site

4 Other: ___	
1 field season of experience 2-5 field seasons of experience 6-10 field seasons of experience >11 field seasons of experience	"Average" experience of observers (add comments at the end of this form if necessary – list team's complete names and field seasons of experience of each observer)
Yes No	Are there written "job descriptions" for members of the team?
	No. of professional (paid) observers in team
	No. of volunteer (unpaid) observers in team
0 None 1 Low 2 Moderate 3 High	Disturbance on site
Yes No	Is there a detailed training scheme for team members before the season start? (attach documents as necessary, e.g. training workshop contents)
HawkCount.org Other electronic databases Paper forms	Data storage
HawkCount.org HMANA's paper archive Other: ___________________ (give address where data is physically stored and name of data curator)	Location of data storage
	Comments and attachments

Prepared by Ernesto Ruelas Inzunza. Version 11 April 2006

Appendix B. Statistics, Population Trends, and Analyses results.

The Raptor Population Index:

Statistical Methods for Population Trend and Index Development

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Hawk Mountain Sanctuary Association
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and
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Raptor Population Index Advisor
Ontario, Canada

We compared effort-adjusted arithmetic-mean passage rates to five geometric-mean migration indexes (Farmer et al., attached). We used re-parameterized polynomial regression to estimate trends in each of the six indexes and to test the significance of long-term trends for 12 species. We used the root mean squared error (RMSE) of trend models to compare methods of deriving a migration index. In addition to complete datasets from Hawk Mountain Sanctuary and Cape May Point, we also compared RMSEs for trend analyses on simulated datasets derived by removing 2 days per week, 5 days per week, and blocks comprising 1/3 of all observation days from datasets at both sites. Effort-adjusted arithmetic-mean indexes corresponded to more sophisticated indexes on the complete datasets, but did not perform well on simulated data with missing observation days. We therefore chose to use a regression-based, date-adjusted migration index for the analysis of hawk-count data. This index produced trends similar to other geometric-mean indexes, performed well on datasets simulating reduced sampling frequency, and outperformed other indexes on datasets with large blocks of missing observation days. Correspondence between trends at the watchsites and trends from Breeding Bird Surveys (BBS) suggests that migration counts provide robust estimates of population trends for raptors. Furthermore, migration counts allow the monitoring of species not detected by BBS and produce trends with greater precision for species sampled by both methods

Final Index Model

Based upon the index development study described above, we are deriving annual indexes using a regression-based model:

$$\ln(N_{ij} + 1) = a_0 + \sum_{j=1}^{J} a_j Y_j + \sum_{k=1}^{4} b_k i^k + e_j \qquad (1)$$

where N_{ij} is the number of one species counted during the standard hours on day i in year j, Y_j is a series of dummy variables which are set equal to 1 when year = j and are zero in all other years, i^k are 1st through 4th order terms in date, a_0 is the intercept estimated by the regression, a_j, b_k, c_{jk} and d_l are coefficients estimated by the regression representing the effects of each independent variable on $\ln(N_{ij}+1)$, and e_{ij} is an error term representing unexplained variation. The log-transformed index is back-transformed and weighted inversely to its variance to provide an estimate of the number of birds per standard observation day. This regression model is a one-way ANCOVA in which year terms are factors and all other independent variables are covariates. Regression analyses are weighted in proportion to the number of hours of observation on each day, h_{ij}. The regression model truncates counts to 95% season and 95% daily observation windows to provide a distribution of residuals fitting the assumptions of linear regression. To make this possible, it is necessary to have datasets containing hourly records of migration.

Trend Analysis

A best-fitting polynomial trajectory model is identified for each species using a three-step process designed to minimize overfit while maximizing model likelihood. Trend estimates and their significance are derived by re-parameterizing the year terms of the regression. This method takes into account the trend within the set of years being compared (e.g. 1976-1978 versus 2001-2003) and makes use of the variance around the entire trajectory when estimating trend. It provides greater statistical power for the detection of trends than linear regressions that do not truly fit the trajectory of the index (Figs. 1-6). The re-parameterization transforms year terms so that the first-order year term estimates the rate of change between the two sets of years and is therefore equivalent to the slope of a log-linear regression. To reduce the potential effect of extreme trajectories at the ends of the polynomial model, we compare the mean indexes for the three-year periods at either end of the time period of interest. These estimates of mean index are influenced by the observed index values in all years, thereby accounting for any trend within the averaged years. Similarly, tests of trend significance are based on the mean squared deviation from the regression curve of all index values, not just those in the averaged years.

Status of Trend Analyses

To date, trend estimates have been developed for 14 raptor species for 1974-2004 (and decades nested within that period) for seven watchsites that monitor approximately 250,000 migrants annually in eastern North America (Tables 1-5). Short-term trends have also been estimated for 1994-2004 at one additional site in eastern North America. Trend analysis is currently underway for nine autumn watchsites in western North America, with analyses completed for five sites thus far (Tables 6-10). The trend analyses for western watchsites were originally scheduled to be completed by this point in the project. However, early model development indicated that it was desirable to have hourly count data for the longest possible time series at each site, and this necessitated a delay in analysis while existing hard-copy data were converted to electronic format.

Long-term trend estimates for the two watchsites used for index development (Hawk Mountain and Cape May) show a 1:1 correspondence to Breeding Bird Survey (BBS) trend estimates for eastern North America, but are more precise for most species (Fig. 7). Our analysis of multiple watchsites in eastern North America has made it possible to characterize geographic patterns in population trends for 14 raptor species (Figs. 8-22). The American Kestrel, for example, (Fig.18) shows a clear pattern of widespread population decreases in northeastern North America. The magnitude of declines is greatest near the Atlantic coast and decreases inland, becoming non-significant at Waggoner's Gap, Pennsylvania and Holiday Beach, Ontario. An increasing trend for this species was noted at Hawk Ridge, Minnesota, which collects migrants primarily from the region North and West of the Great Lakes. The Broad-winged Hawk (Fig. 14) underwent non-significant decreases in the coastal portion of northeastern North America, decreased significantly at inland sites at Hawk Mountain, Pennsylvania and Holiday Beach, Ontario, and increased non-significantly at Hawk Ridge, Minnesota. Trend information for this species is particularly important, because much of its breeding range is in the boreal forest of Canada, which is not included in the Breeding Bird Survey. Furthermore, its secretive nesting habits make it difficult to monitor using such surveys, resulting in poor precision (Fig. 7).

Figure 1: Population trajectories and trends for American Kestrel

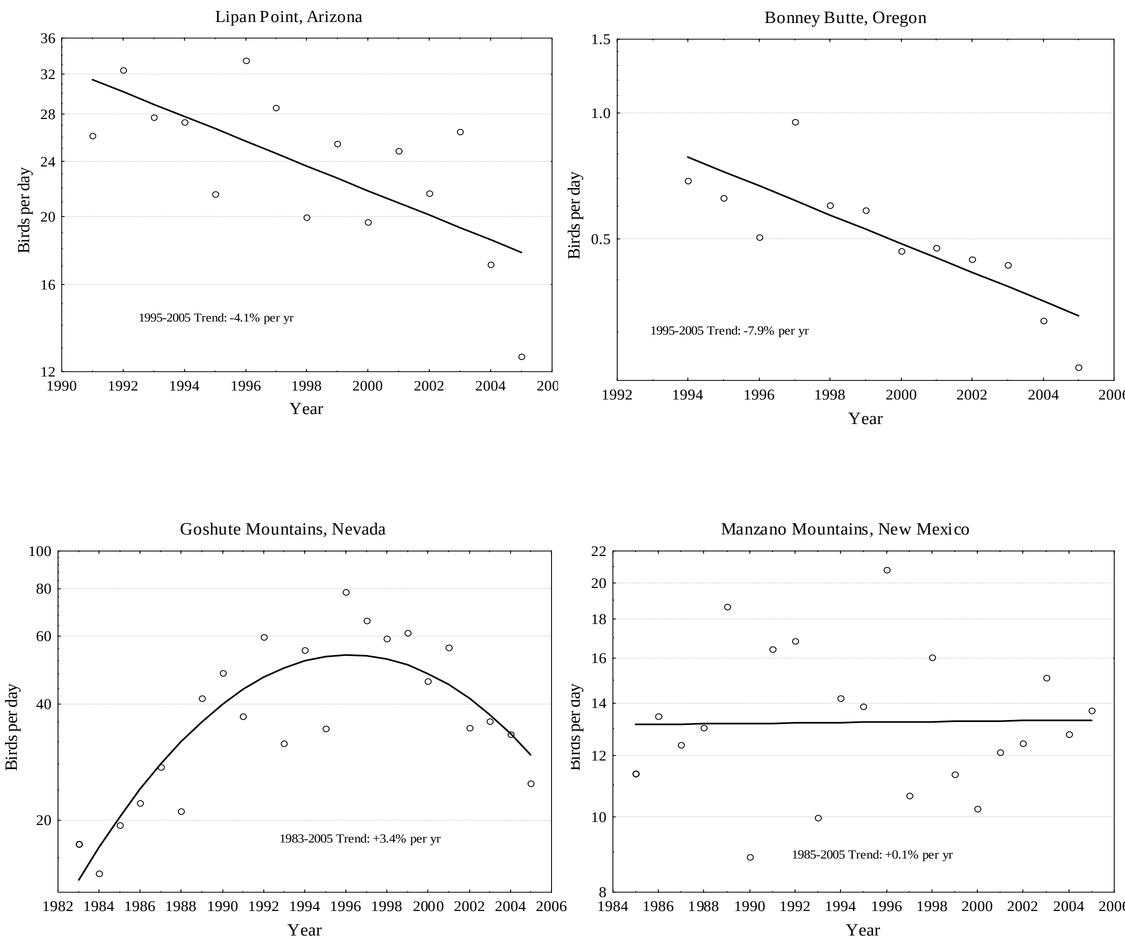

Figure 2: Population trajectories and trends for American Kestrel

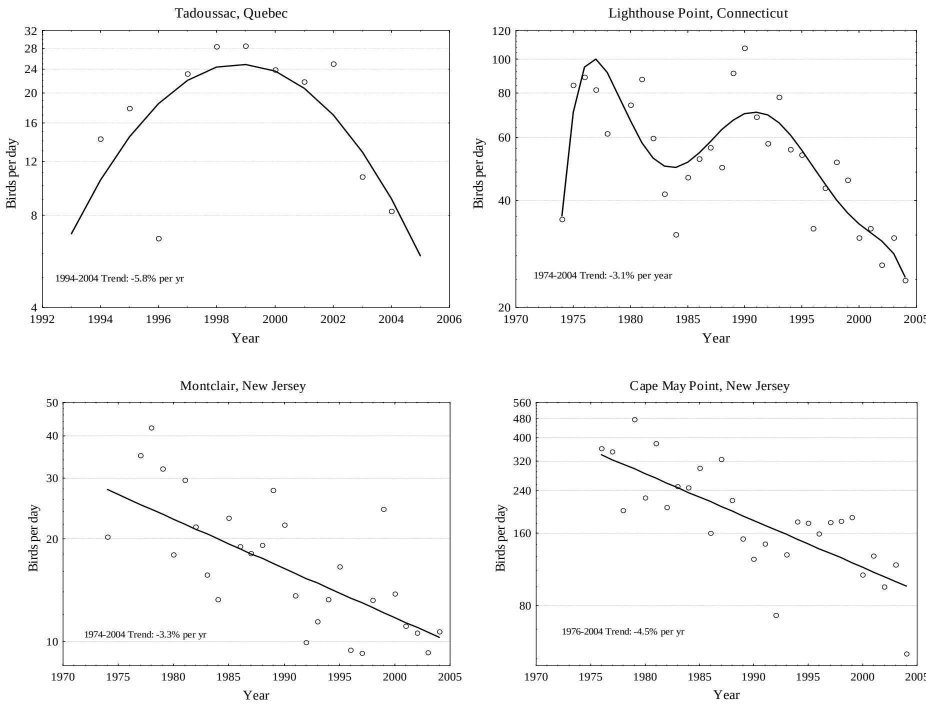

Figure 3: Population trajectories and trends for American Kestrel

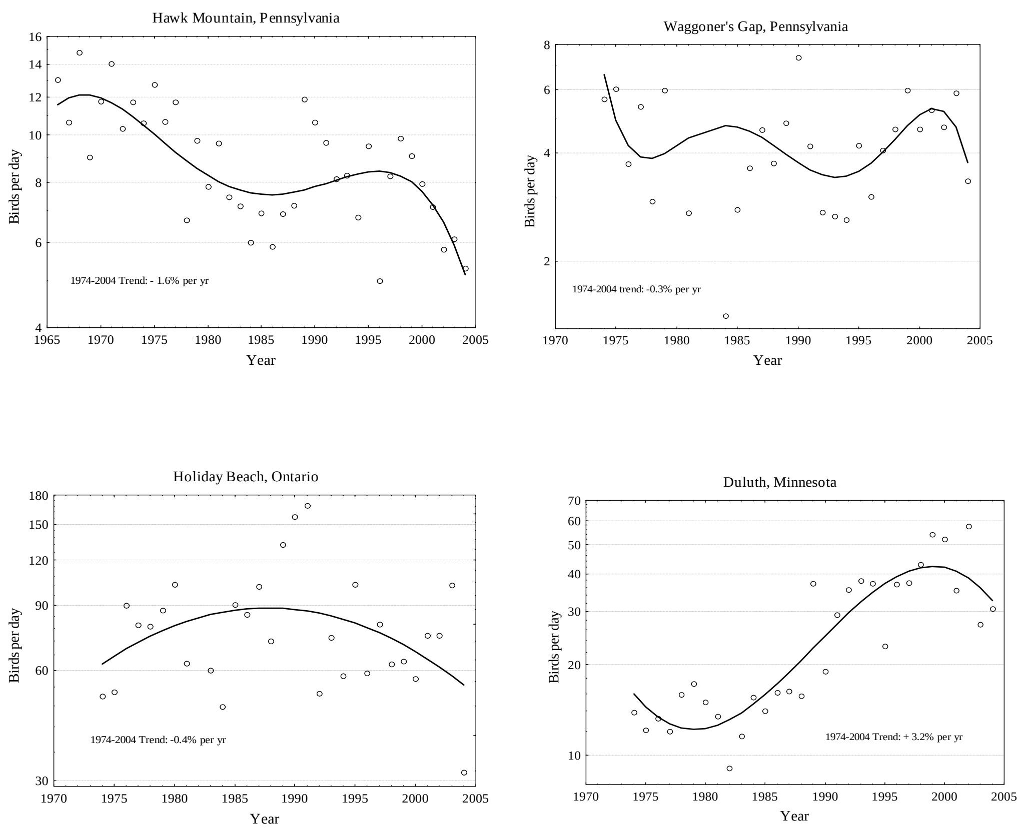

Figure 4: Population trajectories and trends for Broad-winged Hawk

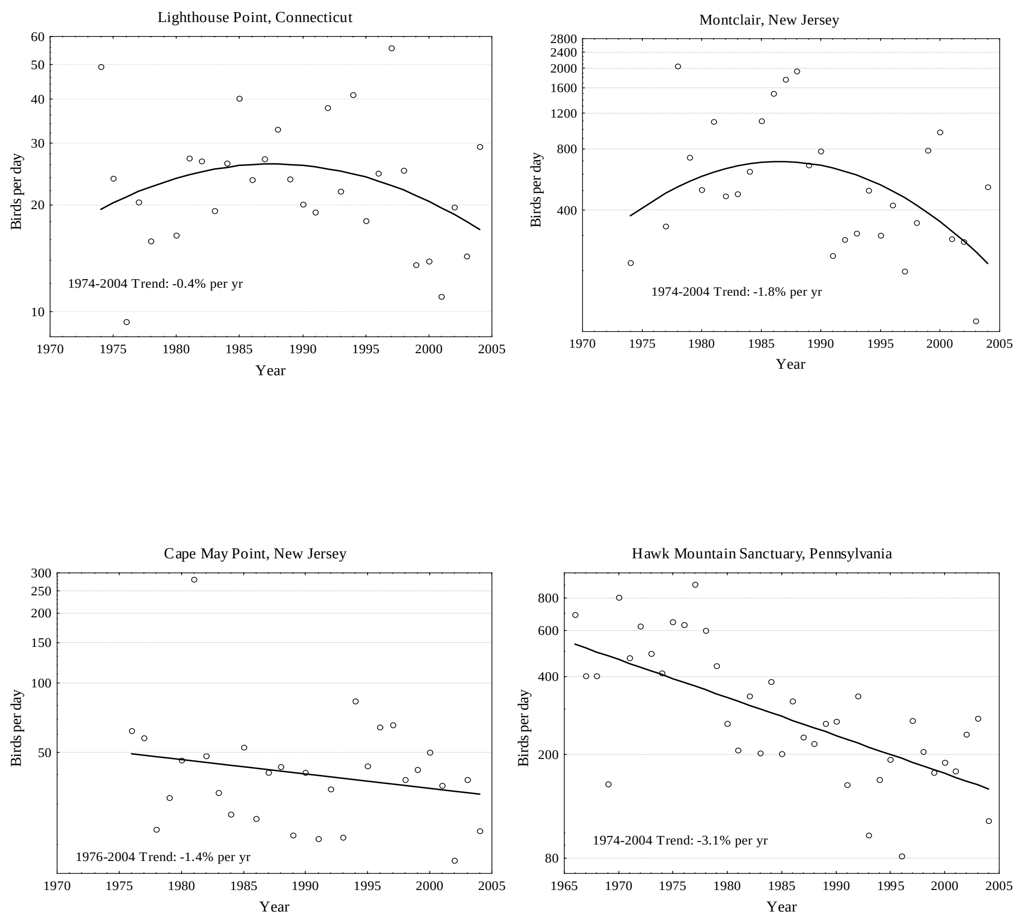

Figure 5: Population trajectories and trends for Broad-winged Hawk

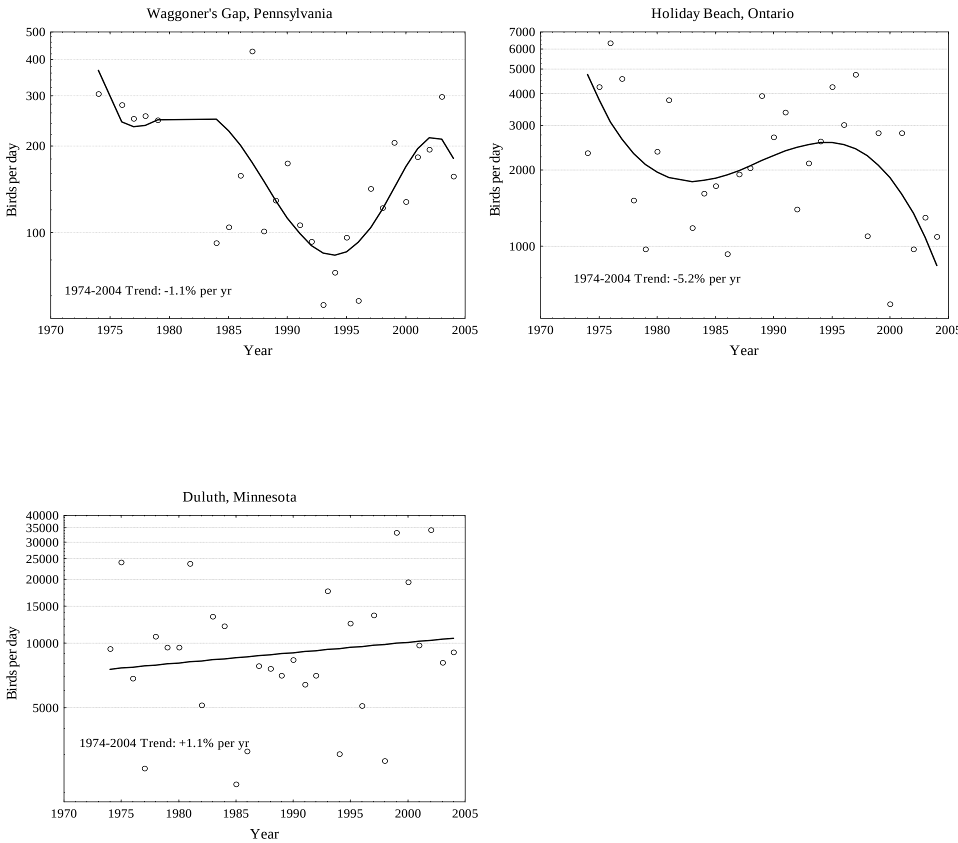

Figure 6: Population trajectories and trends for Broad-winged Hawk

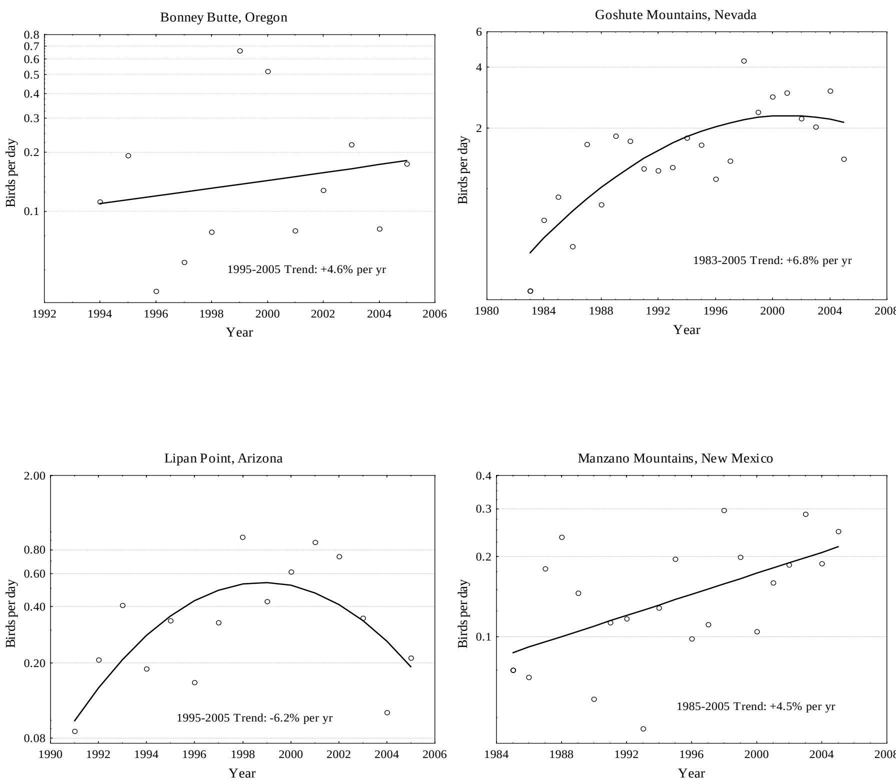

Figure 7: Precision of trend estimates of Breeding Bird Survey (a) and migration counts at Cape May Point, NJ (b) and Hawk Mountain Sanctuary, PA (c).

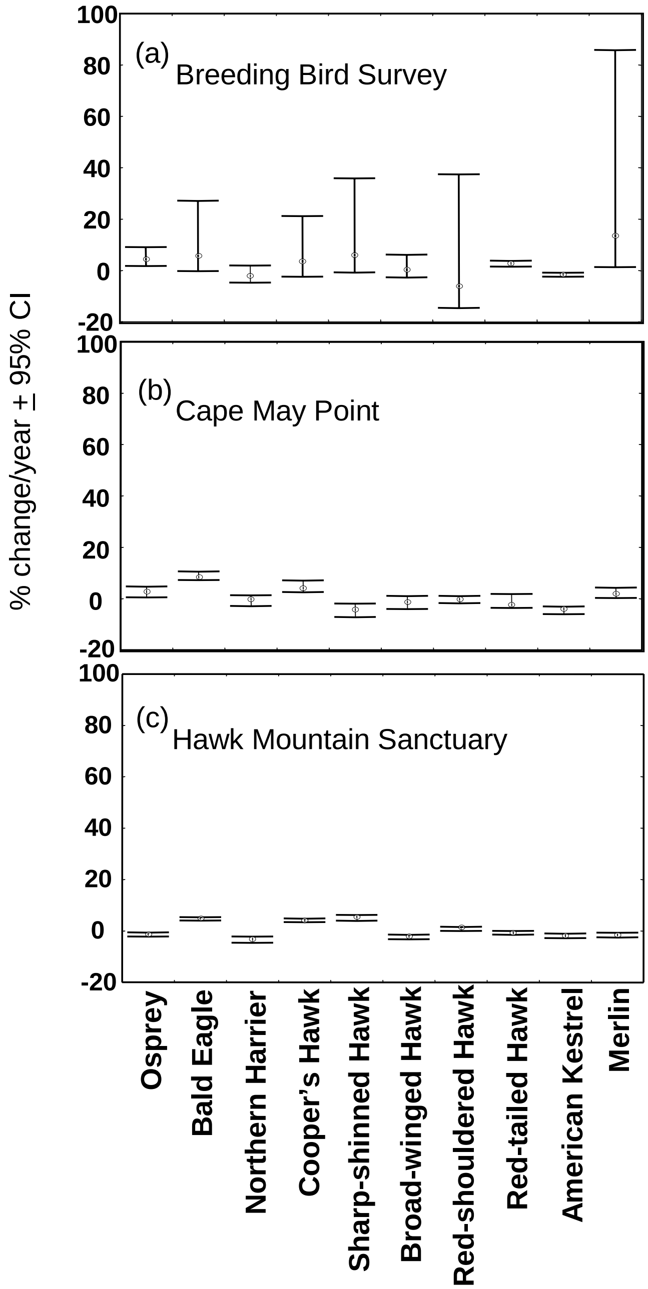

Figure 8: Regional population trends for Osprey, 1974/76-2002/04

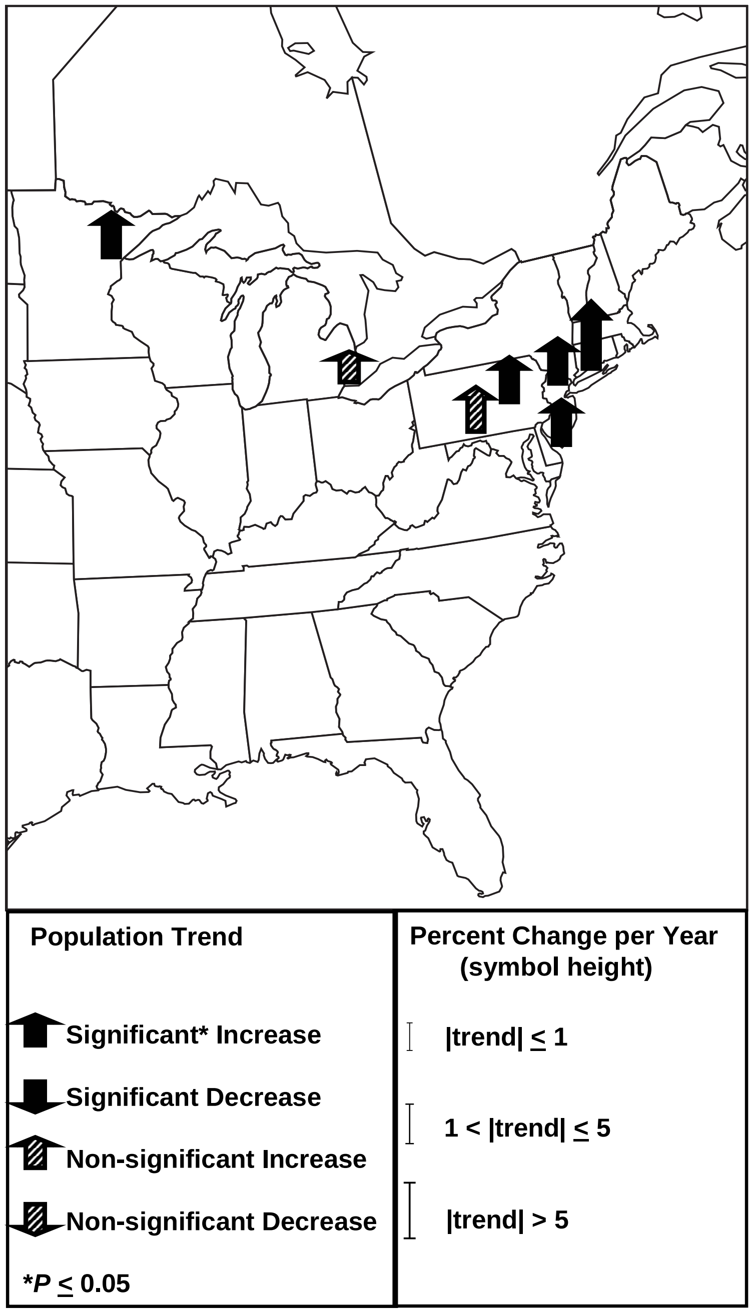

Figure 9: Regional population trends for Bald Eagle, 1974/76-2002/04

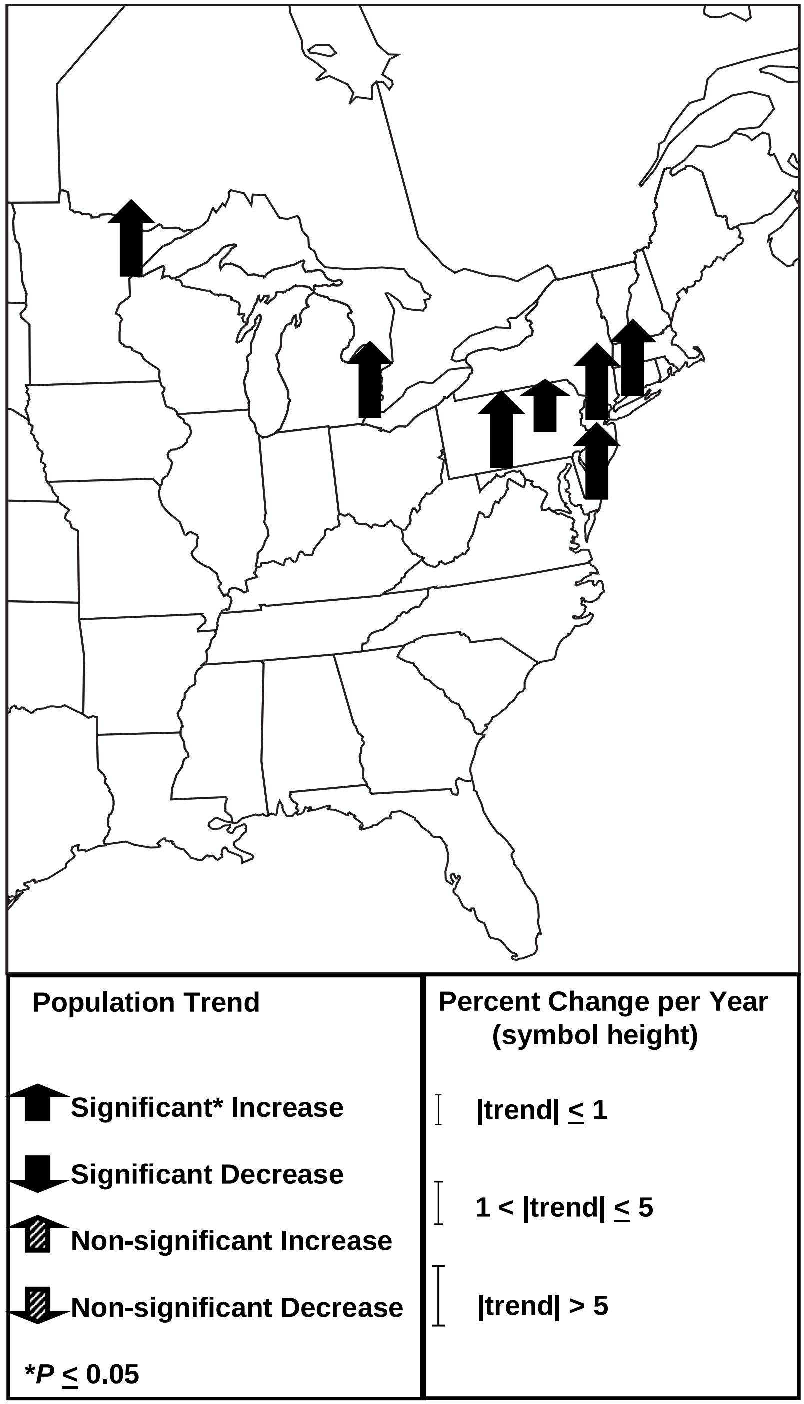

Figure 10: Regional population trends for Northern Harrier, 1974/76-2002/04

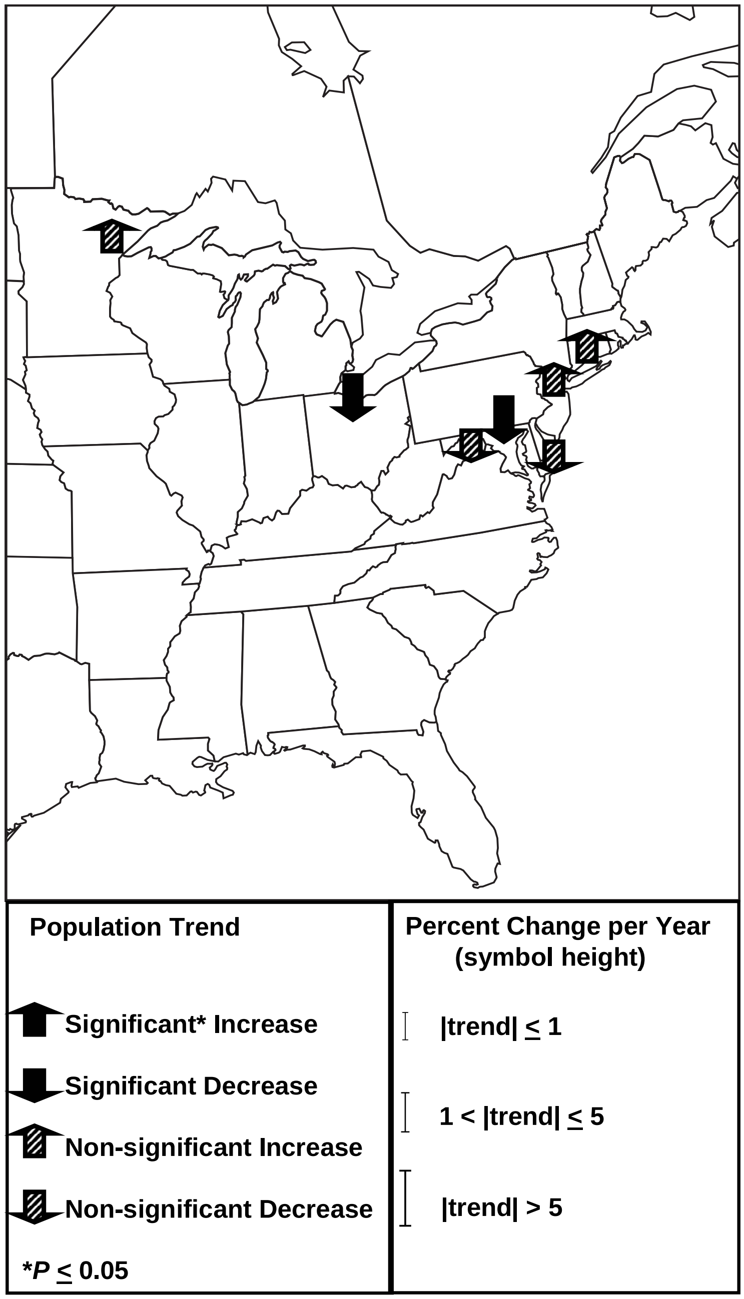

Figure 11: Regional population trends for Sharp-shinned Hawk, 1974/76 - 2002/04

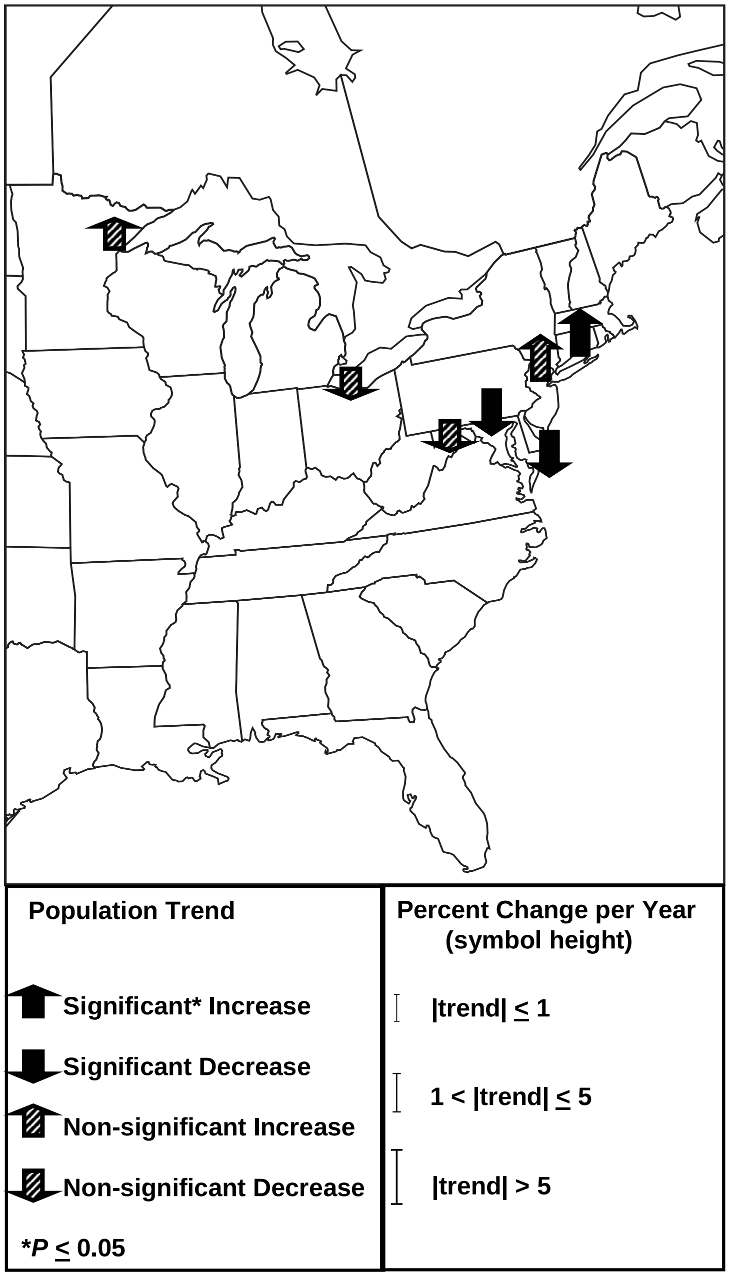

Figure 12: Regional population trends for Cooper's Hawk, 1974/76-2002/04

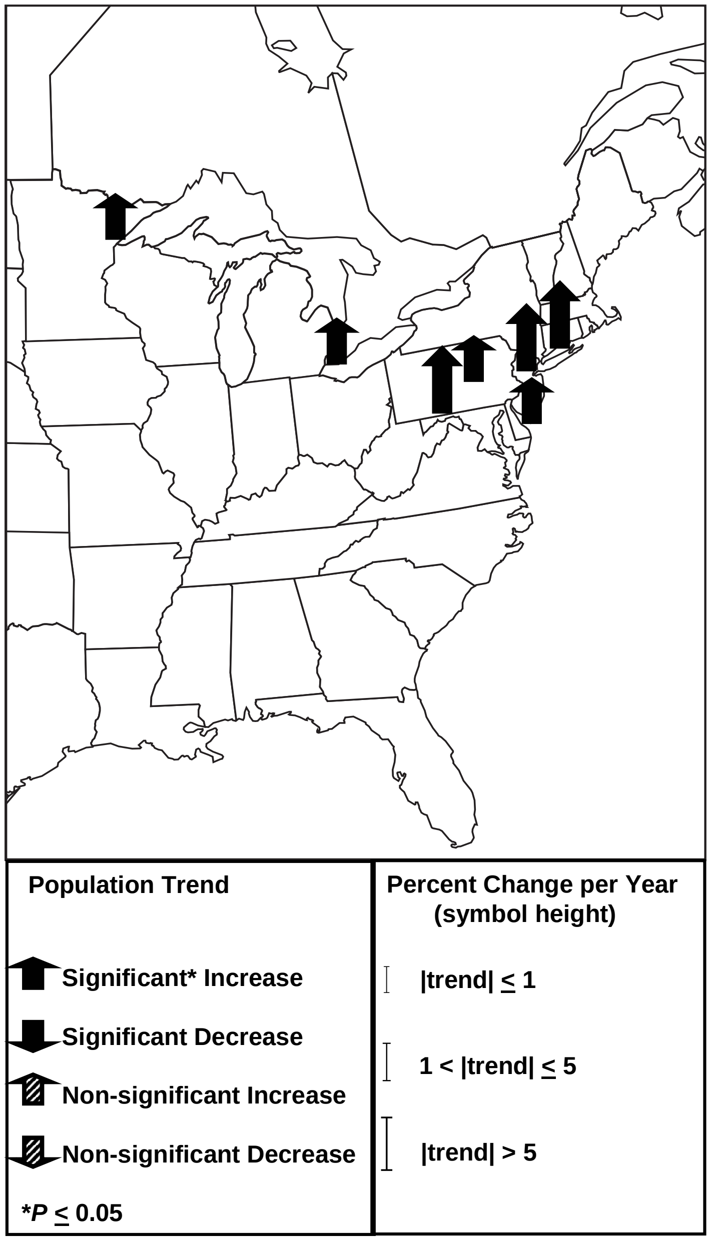

Figure 13: Regional population trends for Northern Goshawk, 1974/76-2002/04

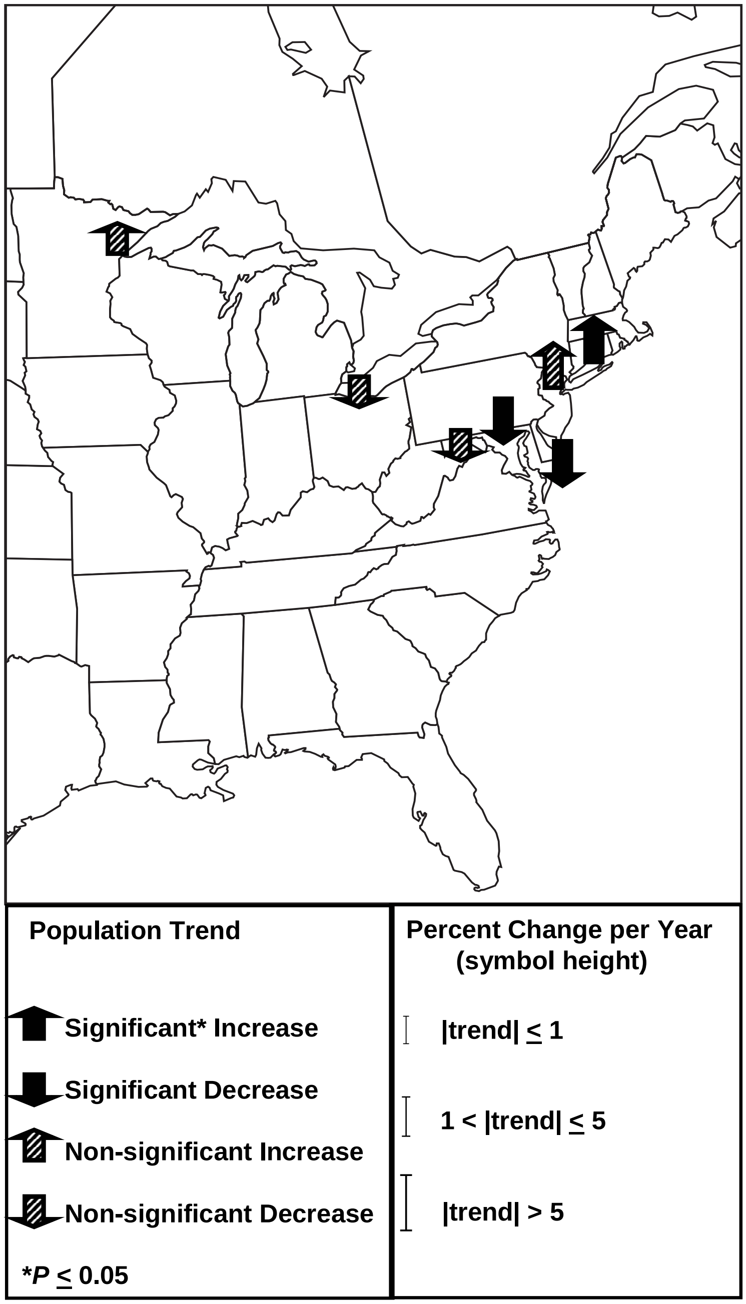

Figure 14: Regional population trends for Broad-winged Hawk, 1974/76-2002/04

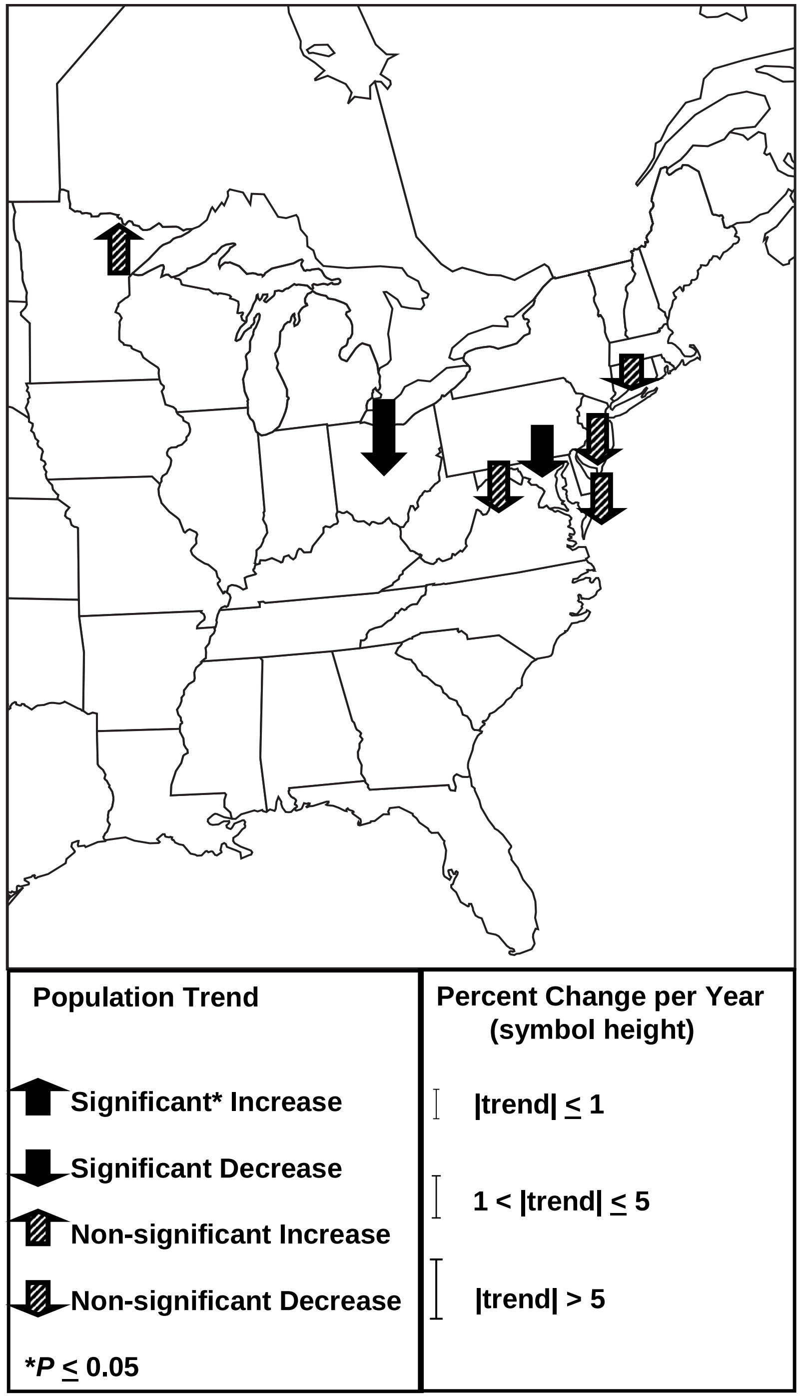

Figure 15: Regional population trends for Rough-legged Hawk, 1974/76-2002/04

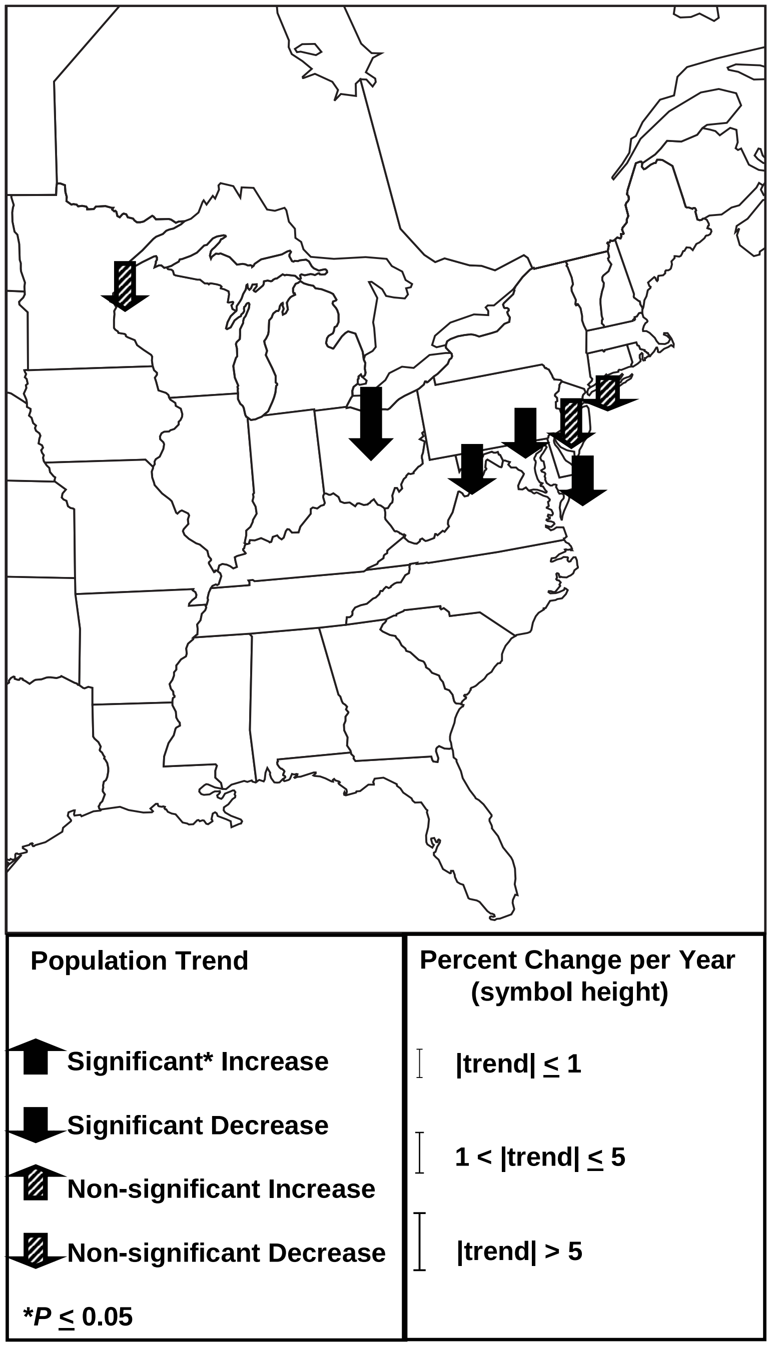

Figure 16: Regional population trends for Red-shouldered Hawk, 1974/76-2002/04

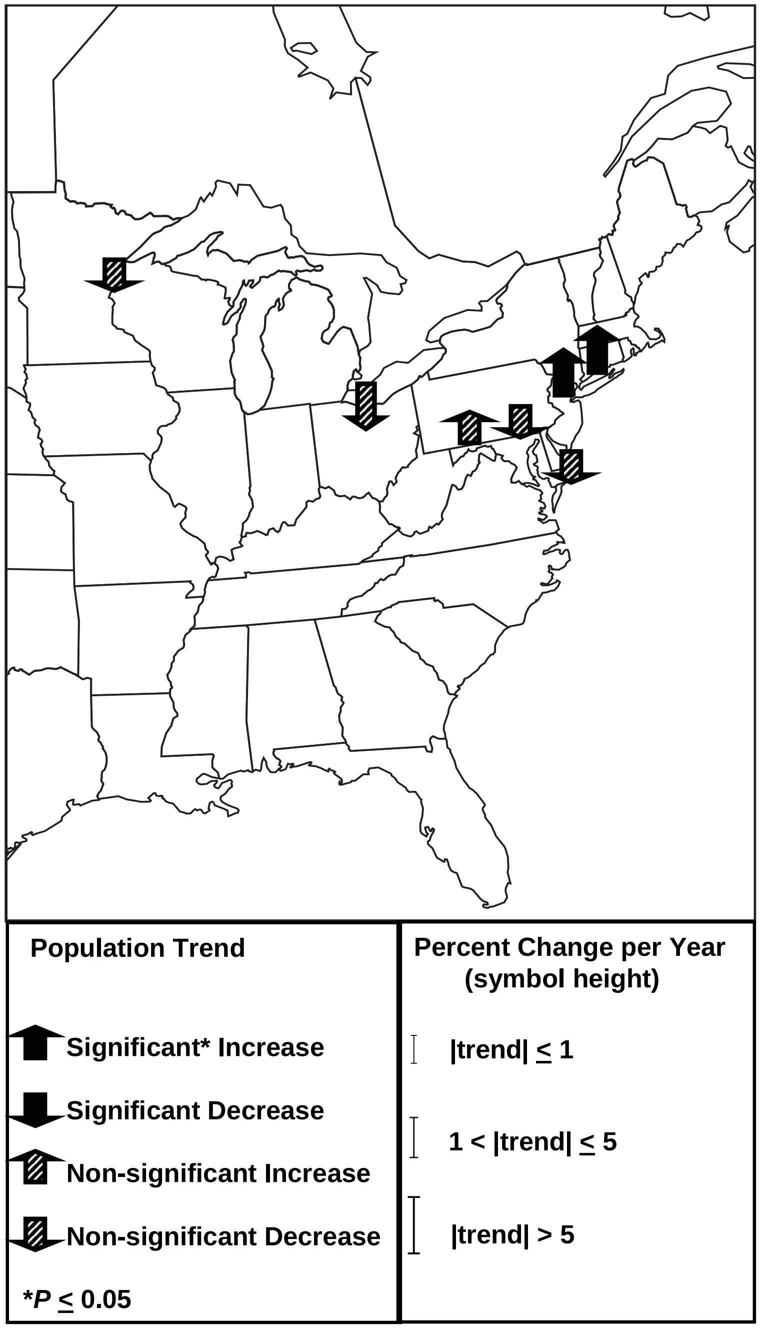

Figure 17: Regional population trends for Red-tailed Hawk, 1974/76-2002/04

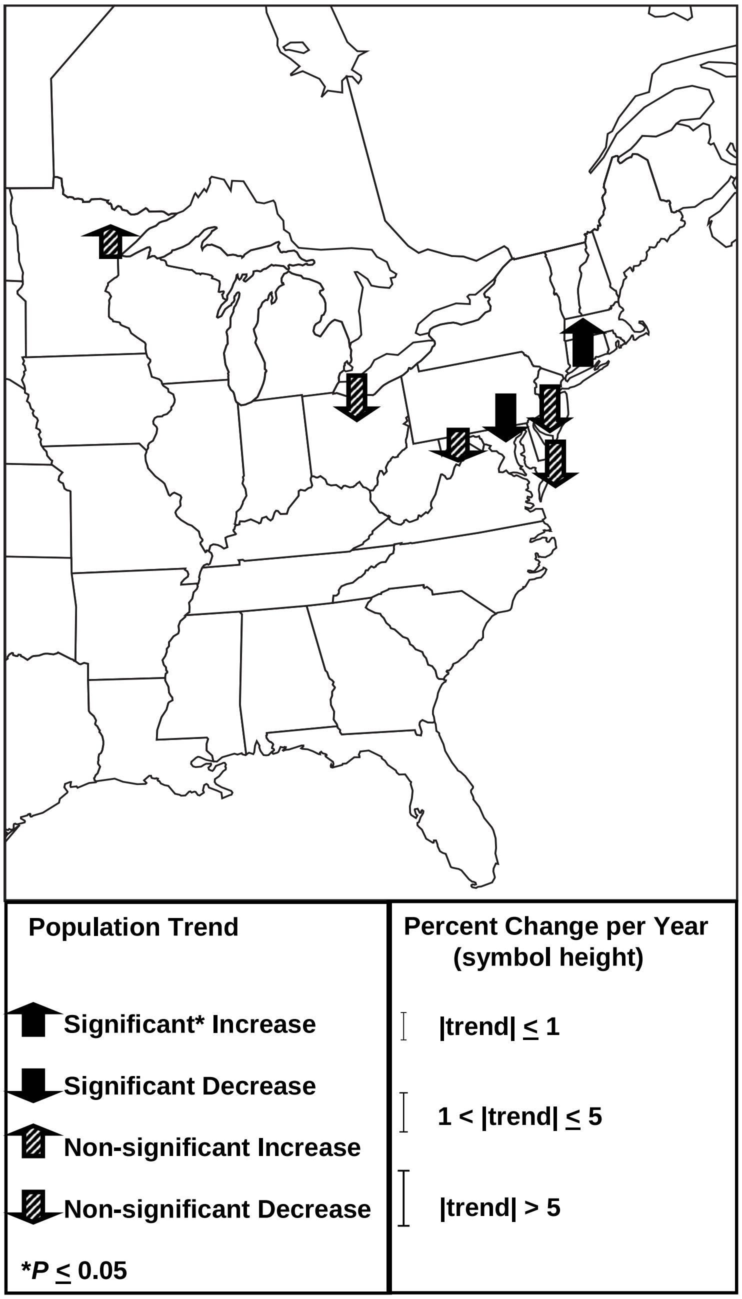

Figure 17: Regional population trends for Golden Eagle, 1974/76-2002/04

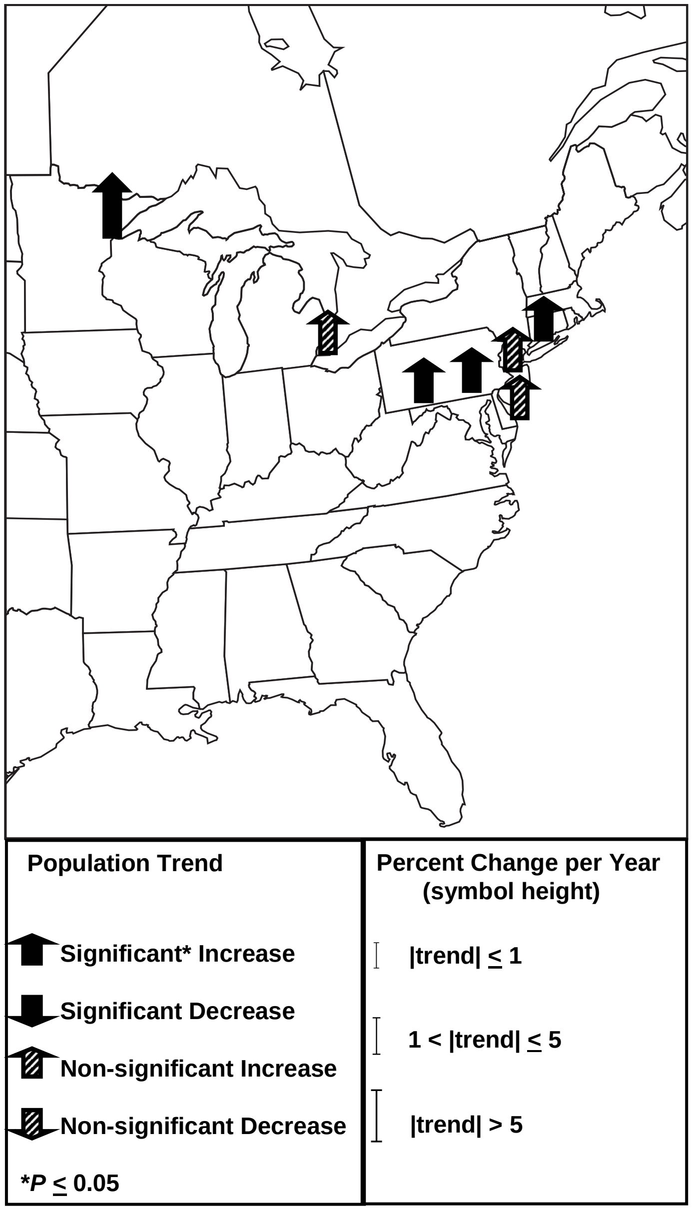

Figure 18: Regional population trends for American Kestrel, 1974/76-2002/04

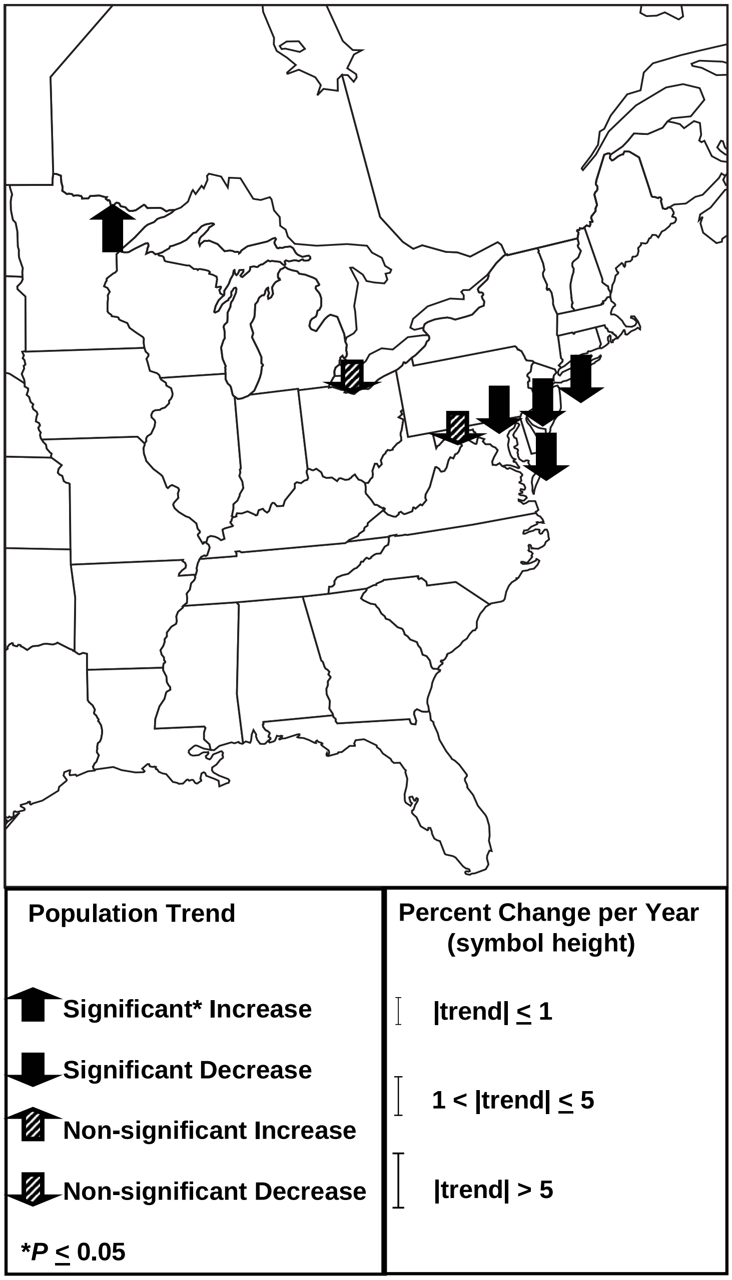

Figure 19: Regional population trends for Merlin, 1974/76-2002/04

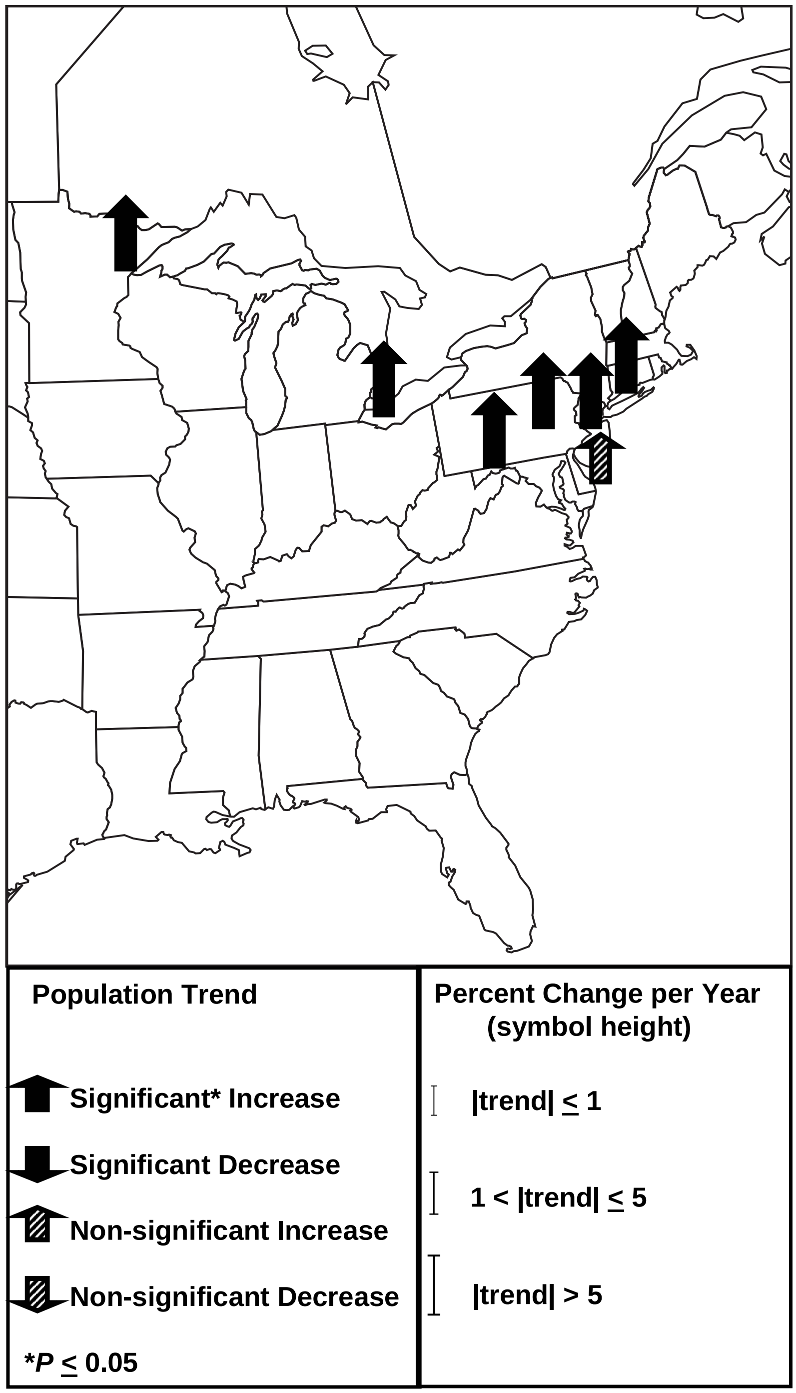

Figure 20: Regional population trends for Peregrine Falcon, 1974/76-2002/04

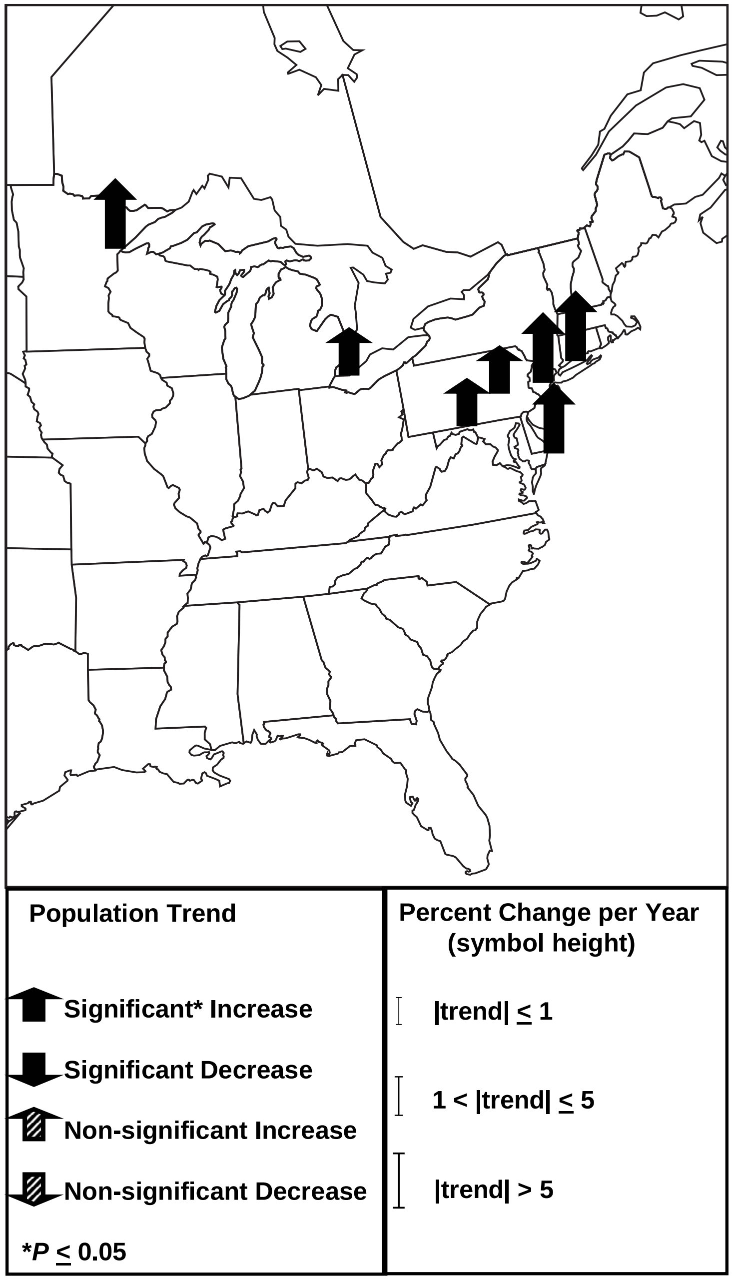

Figure 21: Regional population trends for Black Vulture, 1974/76-2002/04 (Cape May Point), and 1990-2004 (Hawk Mountain).

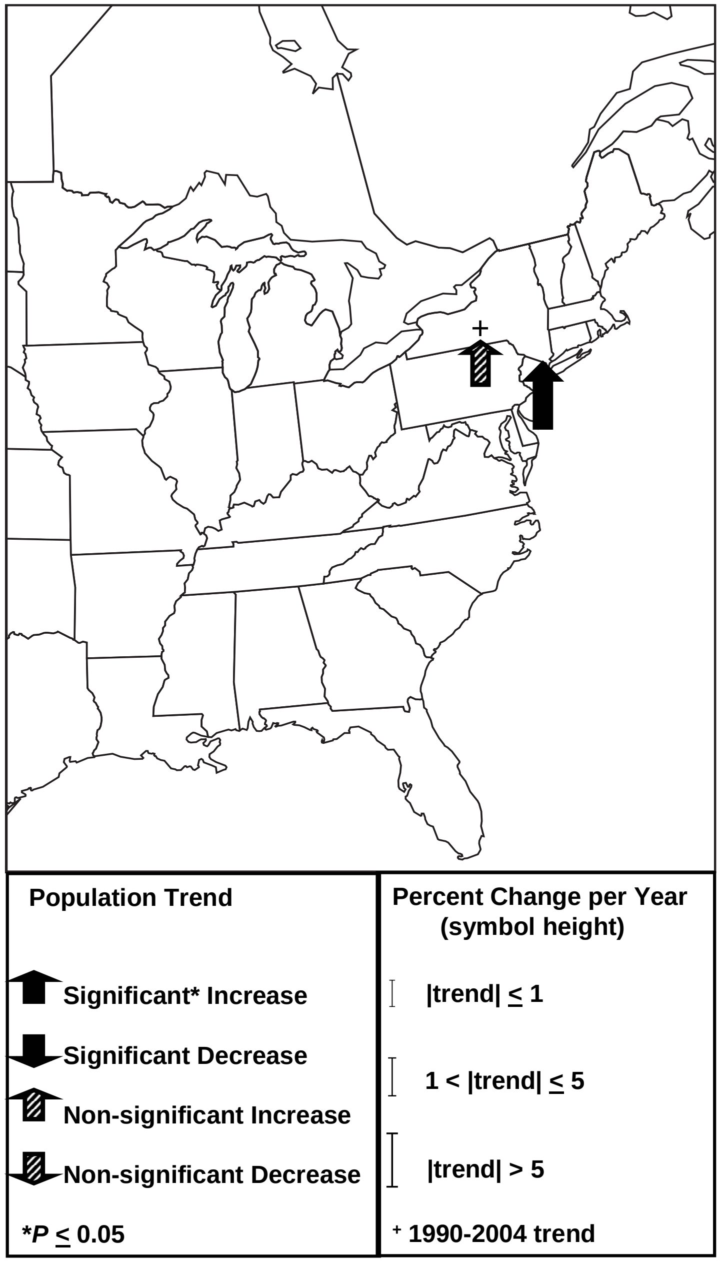

Figure 22: Regional population trends for Turkey Vulture, 1974/76-2002/04

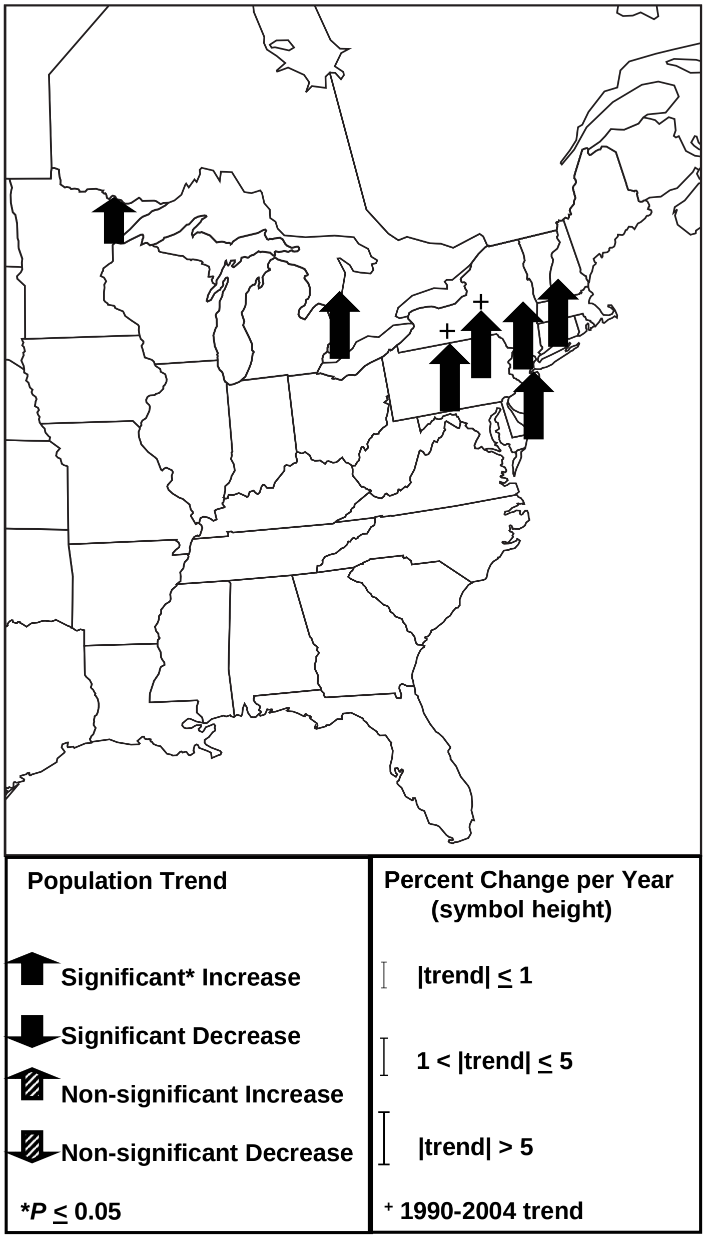

Table 1. Population trends for 14 raptor species at 7 watchsites from 1980-1990.

Species	Hawk Ridge	Holiday Beach	Waggoner's Gap	Hawk Mountain	Montclair	Cape May	Lighthouse Point
Osprey	4.14**	3.12**	0.94	3.11**	0.34	5.40**	14.12**
Bald Eagle	8.35**	2.58	5.43**	5.06**	14.07**	9.55**	26.58**
Northern Harrier	0.56	7.16**	-2.68	-1.28**	-3.35+	-0.74	2.45*
Cooper's Hawk	10.99**	5.16**	5.12**	4.06**	10.17**	8.15**	9.39**
Northern Goshawk	1.67	2.05	0.13	-4.82**	-0.29	1.59	5.95*
Sharp-Shinned Hawk	3.95**	-0.7	-0.59	-0.46	-3.39*	-10.00**	-1.04
Broad-winged Hawk	1.12	1.7	-8.33*	-3.13**	-1.29	-1.42	-0.75
Rough-legged Hawk	-1.16	1.45	-2.9*	-6.8**	-16.86**	-4.75**	-2.07
Red-shouldered Hawk	-0.73	4.67**	0.4	-0.57	1.27*	-0.31	9.19**
Red-tailed Hawk	-1.43	0.65	-0.1	-1.87**	-3.89+	1.39	3.13**
Golden Eagle	5.68**	7.36**	2.42**	-2.12**	1.07	2.73+	4.66*
American Kestrel	7.03**	1.04	-1.05	-0.19	-3.31**	-4.49**	0.45
Merlin	17.61**	10.61**	10.97**	8.18**	10.47**	1.62	15.54**
Peregrine Falcon	7.77**	9.84**	4.81*	9.88**	11.34**	10.2**	12.92**

+ $P \leq 0.10$ * $P \leq 0.05$ ** $P \leq 0.01$

Table 2. Population trends for 14 raptor species at 7 watchsites from 1990-2000.

Species	Hawk Ridge	Holiday Beach	Waggoner's Gap	Hawk Mountain	Montclair	Cape May	Lighthouse Point	Tadoussac[1]
Osprey	3.59	2.02*	-0.88	-2.59**	-1.22	-0.71	-8.98**	-4.66
Bald Eagle	16.13**	3.82+	4.42**	5.94*	9.21**	10.76**	8.78**	3.34+
Northern Harrier	0.56	-8.19**	-0.76	-3.03**	0.66	-0.74	-1.93+	-0.64
Cooper's Hawk	8.05**	-1.16	5.12**	4.06**	10.17**	3.27	-4.01+	na
Northern Goshawk	1.67	0.18	0.13	-2.22	-0.29	-2.74+	-3.59+	-3.60
Sharp-Shinned Hawk	2.32+	-1.78+	-0.59	-3.34**	0.20	3.01	-3.27*	-1.01
Broad-winged Hawk	1.12	-2.22	4.1+	-3.13**	-6.41**	-1.42	-2.34+	na
Rough-legged Hawk	-1.16	-7.84**	-2.9*	-4.17**	-2.93	-4.75**	-4.88	-5.71
Red-shouldered Hawk	-0.73	-5.01**	1.04	-0.57	1.27*	-0.31	-2.13	na
Red-tailed Hawk	6.14**	-3.35+	4.31*	-1.87**	-2.83	0.33	3.13**	1.56
Golden Eagle	5.68**	1.06	2.96**	2.12**	1.07	0.16	4.66*	-3.23
American Kestrel	5.26**	-2.64+	3.06+	0.14	-3.31**	-4.49**	-7.13**	-5.83
Merlin	3.69**	3.03	10.97**	4.1**	3.95+	0.21	-3.73	-3.65
Peregrine Falcon	7.77**	4.57**	2.12	1.58	3.32+	3.38+	-0.45	3.53

[1] Trends for Tadoussac are 1994-2004

+ $P \leq 0.10$ * $P \leq 0.05$ ** $P \leq 0.01$

Table 3. Population trends for 14 raptor species at 7 watchsites from 1974-2004[1].

Species	Hawk Ridge	Holiday Beach	Waggoner's Gap	Hawk Mountain	Montclair	Cape May	Lighthouse Point
Osprey	4.30**	0.75	1.95	1.49**	2.43**	2.35*	5.13**
Bald Eagle	10.44**	7.82**	6.69*	4.74**	7.70**	8.39**	15.67**
Northern Harrier	0.56	-2.58*	-0.39	-1.99**	0.56	-0.74	0.69
Cooper's Hawk	3.96**	2.63**	5.12**	4.06**	10.17**	4.59**	7.48**
Northern Goshawk	1.67	4.39**	0.13	-2.7**	-0.29	-0.58	6.11**
Sharp-Shinned Hawk	0.67	-0.48	-0.59	-1.06**	1.40+	-4.51**	1.81*
Broad-winged Hawk	1.12	-5.19**	-1.14	-3.13**	-1.79	-1.42	-0.43
Rough-legged Hawk	-1.16	-6.57**	-2.9*	-3.85**	-1.12	-4.75**	-0.56
Red-shouldered Hawk	-0.73	-1.31	0.21	-0.57	1.27*	-0.31	3.32**
Red-tailed Hawk	0.86	-2.35	-0.2	-1.87**	-1.71	-1.78	3.13**
Golden Eagle	5.68**	1.47	3.05**	2.12**	1.07	1.43	4.66*
American Kestrel	3.23**	-0.44	-0.31	-1.6**	-3.31**	-4.49**	-3.09**
Merlin	12.04**	11.89**	10.97**	5.07**	7.15**	1.8+	7.81**
Peregrine Falcon	7.77**	4.67**	2.34*	4.3**	12.27**	6.01**	7.77**

[1]Trends for Cape May are for 1976-2004 + $P \leq 0.10$ * $P \leq 0.05$ ** $P \leq 0.01$

Table 4. Average annual total (cv) count of 14 raptor species and average total count of all species at 7 watchsites from 1974-2004

Species	Hawk Ridge	Holiday Beach	Waggoner's Gap	Hawk Mountain	Montclair	Cape May[1]	Lighthouse Point	Tadoussac[1]
Osprey	269 (52)	92 (40)	289 (52)	500 (31)	521 (27)	2346 (60)	1250 (65)	575 (19)
Bald Eagle	1351 (111)	37 (64)	65 (85)	77 (76)	35 (98)	87 (95)	21 (109)	101 (49)
Northern Harrier	448 (57)	663 (61)	230 (44)	268 (29)	144 (37)	1657 (45)	433 (44)	273 (34)
Cooper's Hawk	100 (87)	514 (51)	425 (70)	520 (50)	120 (104)	2497 (53)	635 (84)	na
Northern Goshawk	687 (130)	30 (65)	71 (68)	78 (50)	5 (59)	34 (63)	12 (82)	231 (32)
Sharp-Shinned Hawk	13329 (34)	12494 (27)	4850 (44)	6079 (34)	3345(35)	27224 (50)	6790 (29)	4766 (30)
Broad-winged Hawk	37414 (87)	36723 (70)	4257 (69)	8653 (59)	14330 (72)	2344 (119)	2126 (115)	na
Rough-legged Hawk	326 (71)	107 (71)	11 (63)	11 (51)	2 (77)	4 (75)	2 (118)	423 (63)
Red-shouldered Hawk	7 (133)	752 (53)	241 (43)	268 (28)	165 (40)	444 (44)	74 (132)	na
Red-tailed Hawk	6199 (58)	5700 (43)	3250 (38)	3730 (21)	994 (32)	1943 (60)	340 (81)	4819 (48)
Golden Eagle	59 (105)	46 (74)	114 (56)	72 (51)	2 (55)	12 (60)	2 (124)	47 (44)
American Kestrel	1316 (63)	2948 (42)	212 (54)	533 (25)	775 (36)	9106 (45)	2309 (47)	1386 (38)
Merlin	121 (82)	46 (68)	29 (106)	75 (69)	45 (78)	1463 (40)	245 (96)	175 (40)
Peregrine Falcon	37 (77)	30 (70)	29 (74)	28 (65)	19 (76)	632 (65)	32 (65)	65 (44)
TOTAL HAWKS	66,236	72,102	14,684	21,192	21,132	51,297	14,651	14,375

[1] Counts for Cape May are 1976-2004 and for Tadoussac are 1994-2004

Table 5. Average passage rates (hawks/10hr) (CV) within 95% species seasonal window of 14 raptor species at 7 watchsites from 1974-2004. To limit the effect of population trend, CVs were calculated for couplets of adjacent years prior to averaging.

Species	Hawk Ridge	Holiday Beach	Waggoner's Gap	Hawk Mountain	Montclair	Cape May[1]	Lighthouse Point	Tadoussac[1]
Osprey	4.7 (18.8)	1.7 (25.2)	4.0 (22.1)	5.8 (15.1)	9.2 (17.2)	31.4 (22.1)	32.7 (19.4)	7.4 (36.1)
Bald Eagle	22.3 (26.3)	0.6 (31.0)	0.8 (26.7)	0.8 (17.2)	0.6 (34.1)	1.1 (26.0)	0.4 (52.7)	1.1 (27.9)
Northern Harrier	8.3 (41.3)	11.0 (31.0)	3.8 (30.7)	3.2 (22.9)	2.6 (25.4)	22.3 (26.0)	11.9 (23.8)	3.5 (34.4)
Cooper's Hawk	17.0 (32.7)	8.4 (22.2)	5.3 (33.4)	5.7 (25.2)	1.8 (33.5)	33.1 (25.4)	15.6 (20.5)	na
Northern Goshawk	13.7 (53.3)	0.5 (39.7)	1.1 (48.4)	1.0 (48.2)	0.1 (62.6)	0.5 (47.0)	0.3 (67.8)	3.0 (27.9)
Sharp-Shinned Hawk	239.2 (14.9)	226.2 (21.9)	79.0 (25.0)	75.9 (20.8)	59.3 (18.6)	376.3 (22.3)	199.0 (14.2)	61.5 (31.3)
Broad-winged Hawk	677.2 (47.9)	679.2 (51.8)	66.7 (35.2)	111.4 (36.5)	254.6 (52.1)	31.6 (56.5)	58.3 (68.4)	na
Rough-legged Hawk	5.7 (37.8)	1.8 (47.6)	0.2 (52.2)	0.1 (31.7)	0.0 (71.8)	0.1 (56.5)	0.1 (77.5)	5.5 (40.1)
Red-shouldered Hawk	0.2 (59.5)	12.3 (30.3)	3.7 (24.8)	3.2 (20.4)	2.8 (23.0)	6.0 (25.6)	1.8 (58.6)	na
Red-tailed Hawk	109.9 (32.2)	94.9 (28.6)	51.2 (17.3)	45.0 (15.9)	17.7 (18.4)	26.3 (25.9)	7.9 (44.2)	63.8 (40.6)
Golden Eagle	1.0 (24.7)	0.7 (32.5)	1.6 (14.4)	0.8 (21.5)	0.0 (51.6)	0.2 (33.0)	0.0 (92.3)	0.6 (33.2)
American Kestrel	22.9 (26.7)	52.1 (25.6)	3.0 (18.5)	6.4 (17.3)	13.7 (18.4)	126.6 (23.3)	70.1 (18.1)	18.6 (29.3)
Merlin	2.1 (22.6)	0.7 (32.5)	0.3 (32.6)	0.8 (25.6)	0.7 (27.4)	19.6 (21.4)	6.1 (38.5)	2.3 (31.4)
Peregrine Falcon	0.6 (37.3)	0.5 (26.7)	0.4 (31.0)	0.3 (25.5)	0.3 (39.8)	8.3 (22.8)	0.8 (30.9)	0.7 (25.7)
TOTAL/10 HR	1183.5	1286.6	228.3	263.8	374.0	703.1	415.4	186.8

[1] Counts for Cape May are 1976-2004 and for Tadoussac are 1994-2004

Table 6. Population trends for 17 raptor species at western watchsites from 1986-1997 (*el Nino* years).

Species	Bonney Butte	Bridgers[1]	Goshutes	Lipan Point[1]	Manzanos
Osprey		-5.27	6.69**	10.88**	6.39**
Bald Eagle		0.38	-0.77	-2.54	12.69*
Northern Harrier		-2.35	7.84**	-5.31*	2.48
Cooper's Hawk		8.98	5.22**	2.17	4.47**
Northern Goshawk		-4.56	6.67*	24.25*	1.58
Sharp-Shinned Hawk		5.88	1.81	-3.38*	2.24*
Broad-winged Hawk		3.67	9.2**	26.69**	4.54**
Ferruginous Hawk		39.78+	5.7**	-2.96	-5.99*
Rough-legged Hawk		-1.14	-1.04	na	-3.83
Red-tailed Hawk		-2.15	2.03*	3.63	2.08*
Swainson's Hawk		-11.11+	5.35**	5.48**	17.30**
Golden Eagle		-7.05*	3.47**	-9.98**	3.63*
American Kestrel		8.68	7.26**	-4.06**	0.07
Merlin		-4.04	15.94**	-4.26	9.51**
Peregrine Falcon		-0.02	14.39**	2.93	19.26**
Prairie Falcon		-0.21	11.01**	0.34	7.46**
Turkey Vulture		-0.84	5.49**	-20.66**	10.30**

[1]Trends for Bridgers and Lipan Point are for 1992-1997

+ $P \leq 0.10$ * $P \leq 0.05$ ** $P \leq 0.01$

Table 7. Population trends for 17 raptor species at western watchsites from 1998-2005 (*la Nina* years).

Species	Bonney Butte	Bridgers	Goshutes	Lipan Point	Manzanos
Osprey	2.17	-5.27	-2.32	-9.02**	-11.02
Bald Eagle	1.97	0.38	-0.77	-2.54	-24.82**
Northern Harrier	-3.27	-2.35	-10.57**	-5.31*	-8.18**
Cooper's Hawk	-0.91	-5.64	-9.33**	-18.24**	4.47**
Northern Goshawk	-2.29	-4.56	-13.89**	-19.11+	-6.36
Sharp-Shinned Hawk	-0.10	-6.29	1.81	-3.38*	2.24*
Broad-winged Hawk	4.63	3.67	-0.38	-14.43+	4.54*
Ferruginous Hawk	-15.44	-1.62	-8.30**	-23.65**	5.05+
Rough-legged Hawk	-5.11	-1.14	-23.81**	na	-3.83
Red-tailed Hawk	-1.70	-2.15	2.03*	-14.33**	2.08*
Swainson's Hawk	-11.02	-11.11+	5.35**	5.48**	-7.33
Golden Eagle	-3.77	1.29	-12.55**	-9.98**	-9.63
American Kestrel	-7.9**	-13.79+	-8.22**	-4.06**	0.07
Merlin	2.06	-4.04	-11.63**	-4.26	-1.68
Peregrine Falcon	21.34**	-.02	-11.50**	2.93	-2.08
Prairie Falcon	-2.15	-0.21	-17.09**	0.34	-9.10*
Turkey Vulture	5.46	-0.84	0.79	-20.66**	-12.85*

+ $P \leq 0.10$ * $P \leq 0.05$ ** $P \leq 0.01$

Table 8. Long-term population trends for 17 raptor species at western watchsites from 1983-2005[1].

Species	Bonney Butte	Bridgers	Goshutes	Lipan Point	Manzanos
Osprey			4.44**		3.77**
Bald Eagle			-0.77		-0.44
Northern Harrier			0.42		-1.25
Cooper's Hawk			1.58+		4.47**
Northern Goshawk			-4.72**		-.088
Sharp-Shinned Hawk			1.81		2.24*
Broad-winged Hawk			6.80**		4.54**
Ferruginous Hawk			2.20*		-2.35*
Rough-legged Hawk			-2.61		-3.83
Red-tailed Hawk			2.03*		2.08*
Swainson's Hawk			5.35**		3.90
Golden Eagle			-2.43**		-1.88*
American Kestrel			3.39**		0.07
Merlin			9.05**		5.59**
Peregrine Falcon			7.14**		9.61**
Prairie Falcon			-2.07*		1.96
Turkey Vulture			4.31**		2.34

[1]Trends for Manzanos are for 1985-2005 + $P \leq 0.10$ * $P \leq 0.05$ ** $P \leq 0.01$

Table 9. Average annual total (cv) count of 18 raptor species and average total count of all species at western watchsites .

Species	Bonney Butte	Bridgers	Goshutes	Lipan Point	Manzanos
Osprey	66 (31)	6 (77)	86 (48)	74 (32)	30 (59)
Bald Eagle	47 (25)	82 (30)	13 (52)	19 (61)	3 (78)
Northern Harrier	30 (46)	49 (111)	170 (43)	80 (43)	58 (44)
Cooper’s Hawk	341 (27)	168 (47)	3155 (46)	115 (97)	1024 (36)
Northern Goshawk	26 (41)	35 (67)	103 (57)	9 (123)	16 (59)
Sharp-Shinned Hawk	1119 (32)	340 (35)	4534 (44)	1420 (29)	1482 (30))
Broad-winged Hawk	8 (252)	9 (106)	45 (80)	10 (104)	7 (65)
Ferruginous Hawk	1 (104)	2 (87)	16 (42)	6 (63)	13 (41)
Rough-legged Hawk	13 (59)	35 (59)	14 (78)	na	na
Red-tailed Hawk	607 (24)	107 (51)	3002 (91)	1624 (37)	656 (27)
Swainson’s Hawk	1 (136)	2 (128)	222 (90)	42 (66)	553 (284)
Zone-tailed Hawk	na	na	na	na	1 (118)
Golden Eagle	95 (35)	1463 (17)	254 (26)	26 (64)	117 (28)
American Kestrel	22 (33)	76 (56)	1870 (46)	1076 (23)	562 (27)
Merlin	67 (39)	9 (62)	38 (64)	11 (49)	25 (57)
Peregrine Falcon	7 (77)	8 (61)	10 (84)	8 (42)	49 (76)
Prairie Falcon	5 (67)	13 (31)	26 (55)	5 (55)	20 (57)
Turkey Vulture	302 (44)	1 (229)	320 (51)	115 (97)	394 (62)
TOTAL HAWKS	2,898	2,112	14,430	5,891	5,208

Table 10. Average passage rates (hawks/10hr) (CV) within 95% species seasonal window of 18 raptor species at western watchsites. To limit the effect of population trend, CVs were calculated for couplets of adjacent years prior to averaging.

Species	Bonney Butte	Bridgers	Goshutes	Lipan Point	Manzanos
Osprey	1.9 (23.5)	0.2 (51.1)	1.3 (23.7)	1.5 (14.8)	0.6 (27.4)
Bald Eagle	1.3 (13.0)	2.6 (18.4)	0.1 (27.2)	0.4 (39.7)	0.1 (67.0)
Northern Harrier	0.9 (30.9)	1.5 (59.6)	2.6 (17.7)	1.7 (22.2)	1.1 (25.2)
Cooper's Hawk	10.0 (28.8)	5.2 (19.5)	48.8 (27.1)	0.2 (75.2)	20.1 (23.5)
Northern Goshawk	0.8 (34.5)	1.1 (52.2)	1.6 (31.1)	0.2 (66.2)	0.3 (48.8)
Sharp-Shinned Hawk	32.2 (25.2)	10.5 (17.7)	69.0 (24.6)	21.2 (18.6)	29.4 (24.1)
Broad-winged Hawk	0.2 (100.1)	0.3 (61.3)	0.7 (34.8)	33.2 (17.6)	0.1 (45.9)
Ferruginous Hawk	0.0 (87.1)	0.1 (74.0)	0.2 (40.3)	0.1 (37.6)	0.3 (28.4)
Rough-legged Hawk	0.4 (49.5)	1.1 (46.8)	0.2 (52.1)	na	0.0 (106.8)
Red-tailed Hawk	17.7 (23.9)	3.3 (32.0)	45.6 (17.6)	21.5 (15.4)	13.0 (17.4)
Swainson's Hawk	0.0 (97.8)	0.1 (86.9)	3.4 (57.7)	0.9 (21.8)	11.1 (83.8)
Zone-tailed Hawk	na	na	na	na	0.0 (106.3)
Golden Eagle	2.7 (27.0)	46.0 (9.9)	3.9 (16.3)	29.4 (9.6)	2.3 (19.9)
American Kestrel	0.6 (19.5)	2.3 (41.6)	28.3 (22.5)	0.2 (35.2)	11.2 (21.8)
Merlin	1.9 (30.1)	0.3 (46.2)	0.6 (31.2)	0.1 (45.8)	0.5 (31.3)
Peregrine Falcon	0.2 (59.3)	0.3 (48.1)	0.2 (46.5)	0.2 (22.1)	0.9 (31.0)
Prairie Falcon	0.1 (58.4)	0.4 (31.7)	0.4 (29.9)	0.1 (45.8)	0.4 (29.7)
Turkey Vulture	8.5 (27.4)	1.1 (52.2)	4.8 (23.2)	2.3 (52.0)	7.7 (35.2)

Appendix C. Publications on the RPI Project.

RPI: THE NETWORK TO TAKE THE PULSE OF RAPTOR MIGRATION:

DRAFT ARTICLE for BIRDING magazine,

the publication for American Birding Association

by Ernesto Ruelas Inzunza

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RPI stands for Raptor Population Index. RPI is a new citizen science initiative to monitor raptor populations. There is a RPI Project and a RPI Partnership, which oversees the developments of RPI. Clear? Well, the story is a little longer, it started several decades ago somewhere in the northeastern United States.

Hawkwatching formally started in the Americas in the fall of 1934, when Maurice Broun started counts of migrating hawks atop of the Kittatinny Ridge, one of the southernmost mountain ridges of the Appalachians. Conservationist Rosalie Edge had recently purchased several hundred acres to protect a raptor migration site near Kempton, Pennsylvania, and hired Broun and his wife Irma to be caretakers of the newly founded Hawk Mountain Sanctuary.

Broun's self-imposed mission was to investigate raptor migration while young and brave Irma kept hawk gunners from entering the property. Broun kept counting migrants every fall and quickly developed a method to track them annually in a systematic way. He kept detailed counts and notes (and when reading Broun's journal entries, one can not but wonder, what is this? A genuine scientific study or a way to indulge his eyes with the beauty and mastery of flight of eagles, falcons, and hawks?)

Years after, Broun's initiative was followed in other locations, first in the northeast, but then elsewhere. Over the years him and other hawkwatchers slowly, but successfully, transformed the hobby of shooting hawks into the hobby of watching hawks.

Many years after, in 1974, a group of northeastern hawkwatchers founded the Hawk Migration Association of North America (HMANA), an organization dedicated to conserve raptor populations through the scientific study, enjoyment and appreciation of raptor migration. HMANA set formal standards for data collection and actively promoted citizen science groups to establish hawkwatches across North America.

First isolated dots in a large map, then clusters of hawkwatches, started to appear in the northeast in the 1970s and 1980s. Cape May and Montclair in New Jersey, Whitefish Point in Michigan, Lighthouse Point in Connecticut. Derby Hill and Braddock Bay in New York, Golden Gate in California. Many of them, in fact too many to name individually. Hundreds of hawkwatchers kettled to migration monitoring sites and sat in exposed lookouts waiting for the next migrant to provide good views and an opportunity to practice identification skills.

HMANA got busier too. Individual sites started reporting daily standardized counts in data sheets and submitted them to HMANA to form the largest archive of raptor migration data in the world. Over 400 localities have submitted more than a million hours of observations in more than 75,000 data sheets.

Hawkwatching also changed, and became a task for advanced amateur hawkwatchers and professionals. Hawkwatching was mainly a recreational activity that brought hundreds of people to famous hawkwatches along well-know migration routes, but the Midwest and Intermountain West remained largely unexplored.

In the late 1970s, Steve Hoffman, an energetic and contagiously enthusiastic biologist from Pennsylvania who got infected with hawkwatching passion in Hawk Mountain, started exploring the migration of birds diverted by the Great Salt Lake in the west. Migrant hawks reluctant to cross over the salty flats, devoid of appropriate habitat, were found migrating along mountain ridges adjacent to both sides of the lake. But the localities to monitor these migrations were far and some, like the Goshute Mountains, required a good drive to the middle of nowhere and then a hike with a large elevation gain through a steep slope. Not precisely a site that would attract volunteers to spend the day and then drive home for supper, it required professional hawkwatchers capable of enduring field work under harder conditions.

Today's network of raptor migration monitoring sites, affectionately called hawkwatches, has changed. It is now run by a mix of professional biologists and volunteer citizen scientists that collect systematic, standardized data. Each hawkwatch is a data-contributing point. Many data points contribute today to create a large-scale picture of migration. Similar networks run by volunteer citizen scientists, such as Cornell Lab of Ornithology's Project FeederWatch, USGS's Breeding Bird Survey, and others, are changing the way we conceive the science of bird population ecology.

Citizen science projects involve several elements: a large research or monitoring goal, a network of data-contributing points, a standard mechanism to record and report data, a centralized database to collect information, and analytical tools to extract the information needed to close the cycle and address the central research or monitoring goal. The contribution of bird- and hawkwatchers, now more skilled than ever, armed with powerful, high quality optics, and excellent identification tools, is unprecedented. At present, citizen scientist-based projects are gaining respect among the scientific community and it is no longer rare to see many of these initiatives funded by the National Science Foundation or to be published in Science or Nature, perhaps the highest aim for a scientific project outcome.

But back to the original questions, what is the rationale for RPI? The idea behind it is to create a mechanism to collect data from many sites and to archive in a database. Data in archives does not seem to serve any purpose if not used. RPI includes among its goals the task to analyzing the data to estimate population trends based on migration counts and to make this information available to the general public, the scientific community, and agencies charged with management and conservation measures.

The task is of enormous proportions. The tedious transfer of the old paper archive to electronic format is currently underway, with one of us (LJG) is leading the process with the help of dedicated volunteers at Hawk Mountain. Once the data transfer is complete, comes the analysis of that information. David Hussell, a scientist of the Ontario Ministry of Natural Resources and chair of both the Science Advisory and Management Committees of RPI, developed a statistical model capable of detecting and quantifying population trends from migration count data over 20 years ago.

RPI's partner Hawk Mountain hired Chris Farmer as North American Monitoring Coordinator to lead the RPI analysis unit. Farmer, a PhD from the State University of New York in Syracuse with a strong background in statistical analysis, collaborated with Hussell to further develop the early regression model to fit the RPI datasets. Analyses are underway: the first turn is for the more robust datasets available, sites with 10-25 years of data available.

Citizen science projects have increased its potentials only recently thanks to the internet and developments in database software applications. A systems engineer from Detroit which is also an avid birder and a HMANA board member, Jason Sodergren, developed HawkCount.org, an information system on-line to collect data from RPI sites that function as the new archive for HMANA's datasets as well as an interface with the network of hawkwatches. Sodergren's plan is for HawkCount.org to become the central bank where these data are stored and also a data exploration tool for contributors. Directions to sites, maps, summary statistics of count data, site photos, and other information are expected to be part of HawkCount.org reporting capabilities.

The contribution of hawkwatchers to raptor monitoring is growing as new sites join RPI. Why? Because no other North American bird monitoring scheme such as the Breeding Bird Survey (BBS) or the Christmas Bird Count (CBC) seems to sample raptor populations in a proper way. Raptors are elusive, live at low densities, are difficult to detect from BBS routes. Or spend the winter outside the CBC coverage area. Perhaps Red-tailed Hawks (*Buteo jamaicensis*) and American Kestrels (*Falco sparverius*) can be properly sampled along BBS routes, since they occupy disturbed habitats and do not avoid roads or human settlements the way Cooper's Hawks (*Accipiter cooperii*) or Mississippi Kites (*Ictinia mississippiensis*) do, but most species are overlooked in these surveys.

Low densities of raptors are another problem. Even if detected regularly, the sample sizes collected does not allow well-supported statements about their demographics. Raptor migrations seem an ideal opportunity to attempt the feat. These migrants are diurnal, conspicuous, and relatively easy to track as they aggregate along landscape features such as mountain ridges and shorelines, a magic opportunity that combines enjoying the aesthetic beauty of raptors and also contributes to the knowledge of raptor migration ecology.

Most hawkwatches, however, are still clustered in the northeast. The high density of hawkwatches in Pennsylvania, New Jersey, Massachusetts, and New York is a result of the high density of hawkwatchers and the relative ease of access of these sites. The density of data points contrasts abruptly with the lack of sites along the Midwestern states of Missouri, Illinois, and Iowa, to name a few.

HawkWatch International, a non-profit organization based in Salt Lake City and a partner in RPI, runs the network of professionally-staffed sites across several states the network covers portions of two complete flyways in the west. The coverage, though, is thin.

A view to the geography of raptor migration in North America seems to depict the veins of a circulatory system peppered with dots along its route where hawkwatchers take its pulse. The further north you go (e.g. into Canada), these veins get thinner. What happens at those places outside southern Canada and the United States where multiple routes converge and turn a small creek into a torrent of migrants?

RPI currently has only a few sites contributing data from outside Canada and the United States, one site in Mexico and one in Costa Rica. The most abundant migrants recorded in these localities, Turkey Vultures (*Cathartes aura*), Broad-winged Hawks (*Buteo platypterus*), Swainson's Hawks (*Buteo swainsoni*), and Mississippi Kites, migrate through these localities in impressive quantities, up to several million of them are recorded in one locality over one field season. A large proportion of the global population of these species flies through these sites, and these are all species with a very incomplete coverage in North America.

Does the existence of these sites make the operation of other hawkwatches unnecessary? No. Each site, even those who contribute data on only a few species or that track a migration of a small volume, contributes valuable information that supplements the one obtained in other sites.

In 1990, Hawk Mountain scientists published an article in The Auk with an analysis of count data collected in the period 1934-1986. For each species, they plotted the number of birds recorded per 10 hours of observation against the year, and obtained a series of points showing the ups and downs of its populations over time. Different species showed different trends. A species like the Osprey (*Pandion haliaetus*) showed a series of points with an upward trend, a tendency that fitted to a regression line proved that these increases were statistically significant and not simply a random oscillation of count results through time.

Peregrine falcons showed declines in the years following World War II through the mid 1970s and followed by an upward trend that continues to this date. These trends can be directly linked to stories familiar to all of us: Rachel Carson brought the attention of the public to the problem of excessive use of DDT and other organochlorine pesticides and its secondary metabolites in her book Silent Spring published in 1962. Migration counts had detected these negative trends already, but together with the work of other researchers documenting the negative effects of DDT in thinning the eggshells of Peregrine Falcons (*Falco peregrinus*) and other raptors, this information ended with the ban of DDT use in 1972. Since then, raptor species negatively affected during the DDT era have experienced a demographic rebound visible in more recent trend analyses based on migration counts.

Steve Hoffman and Jeff Smith published a similar paper in The Condor in 2003, this one a much more complex mosaic derived from six different locations operated by HawkWatch International along two different flyways in the Intermountain and Rocky Mountain Flyways. The story is similar: different species showing different trends. But these stories are subject to different interpretations: Hoffman and Smith estimate the positive trends found in Ospreys are a result of an increase in water reservoirs, those in Turkey Vultures to the fact that this species is expanding its range northward, and the fluctuations found in Northern Goshawks (*Accipiter gentilis*) as a consequence of its boreal irruptions.

In both scientific publications, data transformed into information helped to take the pulse of raptor migration, and in some cases, such as the Peregrine Falcon's, has prompted action.

RPI intends to produce bi-annual assessments of population trends, the first one scheduled for the fall of 2007. From then on, HawkCount.org, the on-line system of RPI, will be the main source of information for all of its target audiences: the general public, the scientific community, and wildlife management and conservation authorities.

Hawkwatching is an opportunity to enjoy and learn raptor migration. But perhaps more importantly, it may be the opportunity where the network of citizen scientists can actively contribute to generate the information critically needed to conserve our majestic and powerful raptors. Who said the joys of hawkwatching can not be combined with the science of its conservation?

Box 1.

The ABC of RPI

The Raptor Population Index Project (RPI) is a collaborative project of three leading raptor conservation organizations: Hawk Migration Association of North America, Hawk Mountain Sanctuary, and HawkWatch International.

The goals of RPI are (1) to produce statistically defensible indices of abundance of migratory raptors from as many sites as possible, (2) to provide frequently updated assessments of the status of each species, and (3) to make those results widely available to participating monitoring sites, the scientific community, conservation agencies, and the public.

RPI is a product of the collaboration of tens of independent raptor monitoring sites that submit data to a centralized information system (HawkCount.org). Data stored in these databases are expected to be analyzed to make population trend estimates for as many species as possible, using a recently developed statistical model.

What is the status of data collection and analyses?

Data collection is a huge task. It involves engaging independent sites to enter their hourly count data into HawkCount.org. At present, over 150 sites contribute data through HawkCount.org. But this mechanism is fairly new, as data were submitted to HMANA in paper forms in the past -- we have close to one million hours of observations from some 400 sites in paper forms, and the transfer is going to take some time and a significant effort to be completed.

Data has been transferred into electronic form for some of the longest datasets and are currently under analysis. There is a comprehensive assessment of population trend analyses of 14 species from seven sites across the northeastern and the Great Lakes regions which is currently in preparation for publication. Following that is an analysis of population trends from the multi-site network of HawkWatch International in the western United States and other analyses pending to be completed. We expect to complete a comprehensive coverage within a few years and then move into producing biannually updated assessments.

What have we learned from the data that has been analyzed so far?

Perhaps the most interesting findings are not the trends itself, but the complexity of a multi-site perspective. Let's compare two famous localities for raptor migration monitoring, Hawk Mountain and Cape May. During the period 1976-2003, there are increases in Bald Eagles (*Haliaetus leucocephalus*) and Cooper's Hawks, decreases in Sharp-shinned Hawks (*Accipiter striatus*) and American Kestrels (*Falco sparverius*), and non-significant trends in Red-shouldered Hawks (*Buteo lineatus*) and Northern Harriers (*Circus cyaneus*). When one zooms out to a larger picture that includes localities further inland, American Kestrel declines are more or less restricted to sites closer to the coast and there are many species with puzzling patterns of increases and declines across the region of coverage.

More of these trend estimates will be assembled during the next two years and we will be able to observe a larger picture of migrant raptor population trends across significant portions of the range for some species.

Just like any other citizen science project, RPI can deliver a wealth of information with direct applications to management and conservation. There are two items that are essential to RPI: The participation of raptor monitoring sites, most of them operated by volunteer citizen scientists and (of course!) money. RPI is currently funded through a matching grant from the National Fish and Wildlife Foundation. For 2006, we need to raise additional $55,000 dollars to cover personnel running the project, for the management of our information system, to cover data analysis, and to strengthen the collaboration and recruitment of more monitoring sites.

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RH: *Detecting Raptor Population Trends*

DETECTING POPULATION TRENDS IN MIGRATORY BIRDS OF PREY

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ABSTRACT

Counts of visible migrants at traditional watchsites throughout North America provide an opportunity to augment population monitoring efforts for birds of prey. We analyzed hourly counts of migrating raptors at one inland (Hawk Mountain Sanctuary, Pennsylvania) and one coastal (Cape May Point, New Jersey) watchsite in northeastern North America. Hourly counts of migrants have been collected for 38 years at Hawk Mountain Sanctuary and 28 years at Cape May Point. We compared effort-adjusted, arithmetic-mean passage rates to five geometric-mean indexes for 12 species. We used re-parameterized polynomial regression to estimate trends in the indexes and to test the significance of trends from 1976-1978 (average index over three-year period) to 2001-2003. Effort-adjusted, arithmetic-mean indexes corresponded to more sophisticated indexes on the complete datasets, but did not perform well on simulated data with missing observation days. We recommend the use of a regression-based, date-adjusted index for the analysis of hawk-count data. This index produced trends similar to other geometric-mean indexes, performed well on datasets simulating reduced sampling frequency, and outperformed other indexes on datasets with large blocks of missing observation days. Correspondence between trends at the watchsites and trends from Breeding Bird Surveys (BBSs) suggests that migration counts provide robust estimates of population trends for raptors. Furthermore, migration counts allow the monitoring of species not detected by BBS and produce trends with greater precision for species sampled by both methods. Analysis of migration counts with appropriate methods holds considerable promise for contributing to the development of integrated strategies to monitor raptor populations.

Key words: Falconiformes, migration monitoring, population index, population trends, raptors

Long-term monitoring of North American bird populations is crucial to efforts to identify species at risk, suggest potential limiting factors, and provide feedback for management actions (Hussell et al. 1992, Rich et al. 2004, Bart 2005). No single monitoring method provides adequate data for most species, making it desirable to use various programs, including migration monitoring, to supplement one another (Downes et al. 2000). Monitoring predatory species such as raptors, which serve as biological indicators, can integrate signals from numerous processes and geographic scales within ecosystems (Bildstein 2001). Unlike many passerines, raptors typically occur at low densities, are secretive, and often difficult to detect on their breeding and wintering grounds. These characteristics reduce the effectiveness of traditional monitoring techniques, such as Breeding Bird Surveys (BBSs) and Christmas Bird Counts (CBCs) for raptor monitoring (Fuller and Mosher 1981, 1987, Kirk and Hyslop 1998, Dunn et al. 2005). Consequently, most North American raptor populations are not well-monitored, and prospects for improved breeding ground monitoring are not promising for many species (Rich et al. 2004).

In a recent assessment, Dunn et al. (2005) concluded that 11 raptor species in Northeastern North America are insufficiently monitored either because the precision of existing trends is unknown or low, or because >1/3 of the Canadian and U.S. breeding range is not covered by a breeding-season survey. To address these deficiencies, they recommended an integrated approach to monitoring, including expanded BBS coverage, additional breeding-season surveys, improved CBC analyses, and migration monitoring. Such integration will prove valuable, for example, if migration monitoring and CBCs are used to provide early detection of population declines, and breeding-season surveys are used to trace the declines to specific regions of the breeding range (Dunn et al. 2005).

The majority of North American raptor species are partial or complete migrants, and migration monitoring can be an effective component of integrated population monitoring provided there is a robust method of deriving population indexes from counts of migrants. Migrating raptors are relatively easy to sample at geographic features that concentrate them (Titus and Fuller 1990, Bildstein 1998, Dunn and Hussell 1995, Smith and Hoffman 2000, Zalles and Bildstein 2000), and counts of visible raptor migration have long been used to index populations (Spofford 1969, Nagy 1977, Hussell 1985, Dunne and Sutton 1986, Mueller et al. 1988, Bednarz et al. 1990, Titus and Fuller 1990, Kjellén and Roos 2000, Hoffman and Smith 2003). The validity of using migration counts to monitor bird populations has been questioned (Fuller and Mosher 1981, Kerlinger and Gauthereaux 1985, Smith 1985, Kerlinger 1989), but numerous studies have found sufficient correspondence between migration counts and other indicators of population change to conclude that they provide reasonable estimates of population trends (Mueller et al. 1988, Bednarz et al. 1990, Hussell and Brown 1992, Dunn and Hussell 1995, Francis and Hussell 1998, Ballard et al. 2003, Hoffman and Smith 2003).

Migration monitoring derives indexes from daily counts at a fixed location based on the assumption that they sample a bird population as it passes the location (Dunn and Hussell 1995). Daily counts within a season have skewed frequency distributions (Hussell 1981), making the median (or geometric mean) a better estimate of central tendency than the arithmetic mean. Several authors have attempted to address the issue of skew by applying log-transformation to annual count totals (e.g. Hoffman and Smith 2003, Lloyd-Evans and Atwood 2004), but this does not remove biases resulting from the skewed distribution of daily counts. Correction of this bias can be achieved by log-transforming daily counts prior to calculation of an annual index (Hussell 1981, 1985). The effects of date and weather on the behavior and numbers of active migrants are also not accounted for in an arithmetic-mean passage rate, but those variables can be included in a regression-based index (Hussell 1981, 1985, Hussell et al. 1992, Dunn et al. 1997, Francis and Hussell 1998).

We used counts of visible migrants from two long-term raptor migration watchsites in North America, Hawk Mountain Sanctuary, PA, and Cape May Point, NJ to develop annual population indexes and trends for 12 species of migratory raptors that are non-irruptive in their migrations. Arithmetic-mean passage rates are common in the scientific and popular literature, and we compared them with geometric-mean passage rates and four indexes derived from ANCOVA at each watchsite. Our objective was to identify the best index for estimating population trends from migration counts. We examined index performance using one complete and three simulated datasets comprising subsets of the complete counts from each watchsite. Given the functional difference between leading lines and diversion lines (Geyer von Schweppenburg 1963), we expected the two watchsites would differ in the way wind patterns affected migration counts, and in the composition of the count population (sensu Dunn and Hussell 1995). An effective migration index should allow accurate estimation of trends at both types of watchsites.

METHODS

Hawk Counts. - We used hourly counts of visible migrating raptors during autumn migration (August-December) at Hawk Mountain Sanctuary, PA (40° 38' N, 75° 59' W) and Cape May Point, NJ (39° 54' N, 74° 49'W) to develop population indexes. Migration counts have been conducted from the North Lookout at Hawk Mountain Sanctuary since 1934, and data have been recorded in hourly format since 1966. Hourly counts have been conducted from Cape May Point State Park since 1976. At Hawk Mountain Sanctuary, counts were conducted by trained volunteers and staff, with primary responsibility given to one or two people each day (Bednarz et al. 1990) and considerable inter-annual overlap in personnel. At Cape May Point, counts were conducted primarily by one or two trained staff but not the same personnel throughout the study period.

Observations at the two watchsites typically were recorded from 0600 to 1700 hours EST. At both sites, observations sometimes extended beyond these times or terminated earlier. At Hawk Mountain Sanctuary, the mean number of hours of observation each day from 1966 to 2003 ranged from ($\bar{x} \pm SD$) 7.3 $\pm$ 2.5 in 1967 (n = 76 days) to 8.7 $\pm$ 2.6 in 2001 (n = 139 days), with an overall average daily coverage of 8.0 $\pm$ 2.7 (n = 105 days). At Cape May Point, the mean number of hours of observation ranged from ($\bar{x} \pm SD$) 7.3 $\pm$ 1.8 in 1977 (n = 70 days) to 10.8 $\pm$ 2.5 in 1985 (n = 85 days), with an overall average daily coverage of 8.9 $\pm$ 2.20 (n = 86 days). Annual counts of raptors averaged approximately 20,000 at Hawk Mountain Sanctuary and 51,000 at Cape May Point.

Total hours of observation varied from day to day and among years, so we standardized the count day at each watchsite. For each species, we identified a daily passage window during which the middle 95% of individuals were counted. No important differences were found among species' daily windows, so we combined them into a standard period for each site; 0700 to 1600 at Hawk Mountain Sanctuary and 0600 to 1500 at Cape May Point. We excluded raptors counted outside of the daily standard period from analysis. For days with incomplete coverage during the standard period, we estimated the daily count as $N = C * H/h$, where *C* was the count during the standard hours, *h* was the number of hours of observation and *H* was the number of hours in the standard period.

We chose a seasonal passage window for each species that included days when the middle 95% of the individuals of that species was counted across all years. Increases in number of count days across years can increase the frequency of low counts, producing spurious trends in passage rates (Titus et al. 1989). Using a 95% seasonal passage window reduces the effect of changes in coverage.

Weather. - Wind speed and direction are thought to be the weather variables most directly affecting the concentration of raptors near migration watchsites (Mueller and Berger 1961, Haugh 1972, Richardson 1978, Newton 1979, Kerlinger 1989). We obtained hourly surface data from the National Weather Service (N.O.A.A. 2004) for the station nearest to each watchsite. At Hawk Mountain Sanctuary, the nearest station (Lehigh Valley International Airport, 40° 39'N, 72° 27'W) is approximately 47 km east-southeast of the watchsite. At Cape May Point, the nearest station (Atlantic City International Airport, 39° 27'N, 74° 34'W) is approximately 67 km north-northeast of the watchsite. We derived wind variables, E (east), SE (southeast), S (south), and SW (southwest), from vector addition of wind speeds and directions at 0700, 1000, and 1300 h. We calculated vectors so that positive and negative values of E represented east and west winds, respectively, positive and negative values of SE represented southeast and northwest winds, etc. We also used second-order wind variables, enabling us to model curvilinear effects of wind speed and direction (Francis and Hussell 1998).

Migration Count Index. – We compared arithmetic-mean indexes (Bednarz et al. 1990, Titus and Fuller 1990, Hoffman and Smith 2003) to those allowing compensation for missing days and additional covariates (e.g. weather). The latter have been described previously in Hussell (1981), Hussell et al. (1992), Dunn et al. (1997), Hussell (1997), and Francis and Hussell (1998). We also examined two models that included date by year interactions, allowing for the possibility that seasonal patterns of migration may differ among years. In our description of the six methods (brief descriptions below, details in Appendix A), "count" always means the daily number of hawks counted or estimated within the daily and seasonal windows. Adding wind variables in some analyses led to smaller sample sizes because we excluded days for which wind data were missing. In addition, the four methods with date covariates included a regression to eliminate days at the start and end of the seasons that would result in poor distribution of residuals. To keep indexes comparable, we limited the sample size (days) for calculating each index to the smallest set available for any method.

For each watchsite, the annual arithmetic-mean passage rate index (AM) was the mean count of migrants in a standard count day in year *j*, weighted by daily hours of effort. The remaining five indexes were geometric-mean passage rate (GM), date-adjusted estimated geometric-mean (GM[date]), date-adjusted estimated geometric-mean with wind covariates (GM[date, wind]), date-adjusted estimated geometric-mean with date by year interactions (GM[date, date by year]), and date-adjusted estimated geometric-mean with date by year interactions and wind covariates (GM[date, wind, date by year]). These indexes were all estimates of the annual mean daily counts, derived from regression estimates of the "geometric mean" daily count, adjusted for covariates. The full regression model with all covariates was:

$$\ln(N_{ij}+1) = a_0 + \sum_{j=1}^{J} a_j Y_j + \sum_{k=1}^{4} b_k i^k + \sum_{j=0}^{J}\sum_{k=1}^{4} c_{jk}(Y_j i^k) + \sum_{l=1}^{L} d_l W_{lij} + e_{ij} \qquad (1)$$

where N_{ij} was the number of one species counted (or estimated) during the standard hours on day *i* in year *j*, Y_j was a series of dummy variables which were set equal to one when year = *j* and were zero in all other years, i^k were 1st through 4th order terms in date, $(Y_j i^k)$ were year by date interaction terms created by multiplying each Y_j by each i^k, W_{lij} was the value of weather variable *l* on day *i* in year *j*, a_0 was the intercept estimated by the regression, a_j, b_k, c_{jk} and d_l were coefficients estimated by the regression representing the effects of each independent variable on $\ln(N_{ij}+1)$, and e_{ij} represented unexplained variation. This regression model was a one-way ANCOVA with year terms as factors and all other independent variables as covariates. Regression analyses were weighted in proportion to the number of hours of observation on each day, h_{ij}. The method of deriving geometric-mean indexes was similar to those used previously (Hussell 1981, 1985, Hussell et al. 1992, Dunn et al. 1997, Francis and Hussell 1998), except that each index was expressed as the estimated mean count per day.

Significance tests for effects of independent variables in the regression require each day's count to be an independent sample of the monitored population (sensu Dunn and Hussell 1995). This assumption is violated if migrants stop at a watchsite for more than one day or if individual migrants are counted multiple times on the same day. The count protocols described above are designed to minimize these violations, but the assumption probably is violated to varying degrees, depending on the characteristics of the site and species involved. For example, multiple counting is likely to be more frequent at bottlenecks, such as Cape May Point, than at leading lines, such as Hawk Mountain Sanctuary. Moreover, at Cape May Point there are likely to be fewer multiple counts of falcons and harriers, which readily cross water barriers, than of buteos and accipiters, which do not. However, provided that the rate of multiple counting does not change over time, violation of the assumption of independence of daily counts is not critical to the primary goal of our index regression, which is to create a reliable annual index of abundance. Therefore, our assumption is not that daily counts are completely independent samples, but that, for each species at each site, the rate of multiple counting within and between days does not change consistently over time.

Trend Analysis. – Trends in annual indexes were estimated as the geometric-mean rate of change over a specified time interval for each site (Link and Sauer 1997). Preliminary examination of index by year plots suggested that most species did not follow log-linear trajectories. We analyzed trajectories by fitting a polynomial regression to the time series of log $(\text{index})_j$ values. To reduce correlations among the polynomial terms, each regression was centered at the midpoint year in the series.

A best-fitting polynomial model was identified for each species using a three-step process. To avoid overfit, the number of possible models was limited to the set for which the number of regression coefficients was $\leq n/5$, where n was the number of years in the regression (Tabachnick and Fidell 1989: 128-129). Positive and negative autocorrelation indicate poor fit and overfit, respectively, so we identified a subset of candidate models for which autocorrelation of residuals was minimized ($-0.20 \leq a \leq 0.20$). A best-fit model was then chosen from this subset by selecting the single model that minimized Akaike's Information Criterion (AIC_c), corrected for sample size (Burnham and Anderson 2002), retaining all lower-order terms in the model.

Trend estimates and their significance were derived by re-parameterizing the year terms (Francis and Hussell 1998). This method takes into account the trend within the set of years being compared and uses the variance around the entire trajectory. It provides greater statistical power for the detection of trends than linear regressions that often do not fit the trajectory of the index. We chose the proportional rate of change from 1976 to 2003 to compare index models and the trend estimates they produced. The re-parameterization transformed year terms so that the first-order term estimated the rate of change between the two sets of years and was therefore equivalent to the slope of a log-linear regression. To reduce the potential effect of extreme trajectories at the ends of the polynomial model, we compared mean indexes for the three-year periods 1976-78 and 2001-03. These estimates of the mean were influenced by the observed index in all years, thereby accounting for any trend within the averaged years (Francis and Hussell 1998). Similarly, tests of trend significance were based on the mean squared deviation from the regression curve of all index values, not just those in the averaged years.

Index Performance. – We evaluated indexes by measuring the correspondence among migration indexes at the two watchsites and between migration indexes and an independent population survey (BBS). Indexes were compared using the root mean squared error of the best-fit trajectory regression of log $(\text{index})_j$ on year for each method. The root mean squared error served as an estimate of the inter-annual variability that was not assigned to the trajectory described by the regression equation. Annual indexes of biological populations are expected to be autocorrelated, so we view minimal dispersion of indexes around a fitted trajectory as an indication of minimal error in the indexes. Moreover, higher dispersion of the indexes reduces the power to detect trends.

Both datasets had fewer missing days of observation than those from many active migration watchsites. Therefore, we examined root mean squared error values of trend regressions for each index on several reduced datasets to simulate the use of data from watchsites with lower sampling frequencies. The reduced data sets used in the analysis simulated (1) 5-day-per-week, (2) 2-day-per-week, and (3) intermittent sampling (50% of the years were missing large [≤ 55 days], contiguous blocks of days). Missing blocks in simulation (3) were distributed among years so that approximately 1/3 were early-, 1/3 were mid-, and 1/3 were late-season. We used two-way ANOVA and multiple contrasts (Tukey's test, $\alpha = 0.05$) to test for significant differences among root mean squared errors.

Trend estimates for the six indexes were compared to one another and to trend estimates from BBS using Pearson's correlation coefficients and reduced major axis regression, which is more appropriate than ordinary least squares regression when both the independent and dependent variables are measured with error (Sokal and Rohlf 1981). Despite its limitations for monitoring many migratory raptors (see below), the BBS provides the only available large-scale, long-term estimates of population trends for our study species that are completely independent of our migration monitoring methodology. BBS detection rates are low for most raptors and the corresponding trend estimates consequently have low precision (Fig. 1). Moreover, BBS does not survey all areas where migrants passing the two watchsites may breed. Therefore, only approximate correspondence should be expected between migration monitoring and BBS. We evaluated this correspondence for a region containing the most likely breeding areas of migrants detected at the watchsites, based on telemetry and banding studies (Clark 1985, Struve 1992, Brodeur et al. 1996, Fuller et al. 1998, Martell et al. 2001, Laing et al. 2005, Dunn et al. 2006, N. Bolgiano pers. comm.). This "northeastern region" consisted of CT, MA, ME, NH, NJ, NY, PA, RI, and VT in the U.S., and NB, NS, ON, and QC (east of 79° W) in Canada. Although BBS provides trend estimates for 11 raptor species in this region, we compared only the nine non-irruptive migrants for which BBS trends were estimated from ≥ 20 routes (Francis and Hussell 1998).

It is unlikely that BBS trends for most raptor species would be identical to migration trends, but some correspondence between the two datasets is expected if BBS and migration monitoring both measure changes in bird populations. Therefore, the degree of correspondence between migration indexes and the BBS offers one means of evaluating different index methods. For any two trend estimation methods to produce corresponding trends, (1) slope of the reduced major axis regression should equal one, (2) intercept of the reduced major axis regression should equal zero, and (3) there should be a high positive correlation between the trends. Satisfaction of criteria (1) and (2) indicates a 1:1 correspondence between the sets of trend estimates.

RESULTS

Migration Count Index. - Annual indexes derived from the six estimation methods were highly correlated for each species at each watchsite, averaging 0.91 (SD = 0.07, n = 12 species) at Hawk Mountain Sanctuary and 0.94 (SD = 0.04, n = 12 species) at Cape May Point (Appendix B). The lowest correlations were between AM and the GM(date, wind), and GM(date, wind, date by year) indexes. All within-site correlations among indexes were highly significant ($P \leq 0.01$). For the five regression-based indexes, the addition of wind variables and interaction terms generally increased the variation incorporated by the regression (Appendix B).

Trend Analysis. - For most species at both sites, the indexes differed in their estimate of the magnitude of population trend, but not its significance or direction (Table 1). Migration counts for 5 of 12 species increased or remained stable at both watchsites. Decreasing trends were found for 6 of 12 species at both watchsites. Trends at the two watchsites were in opposite directions only for Golden Eagles. Trends at the two watchsites were significantly correlated (r = 0.85-0.94, $P \leq 0.01$) and showed 1:1 correspondence (reduced major axis regression, b = 1.08-1.14, $P > 0.05$) for all six indexes.

Index Performance. - At both watchsites, average root mean squared error of the trend regression for the complete dataset was lower for all geometric-mean indexes than for AM (Table 2), indicating that the latter provided a poorer fit to trend regressions. The GM and GM(date) indexes had the lowest root mean squared error, suggesting that fit of the trend regression was not improved by the addition of wind variables or date by year interactions. Two-way ANOVA on root mean squared errors indicated significant main effects of watchsite ($F_{1,132} = 117.08$, $P \leq 0.001$) and index method ($F_{5,132} = 3.30$, $P = 0.008$) on the fit of the trend regressions, but no site by method interaction ($F_{5,132} = 0.17$, $P = 0.97$).

Tukey's HSD test (α = 0.05) indicated that all geometric-mean indexes had significantly lower root mean squared error than AM.

In 5-day-per-week simulations, average root mean squared error was lowest for GM and GM(date) indexes (Table 3). Two-way ANOVA indicated significant main effects of watchsite ($F_{1,132}$ = 134.12, $P \leq 0.001$) and index method ($F_{5,132}$ = 4.40, $P = 0.001$), but no site by method interaction ($F_{5,132}$ = 0.56, $P = 0.73$). Tukey's HSD test for multiple comparisons (α = 0.05) indicated that GM and GM(date) indexes had significantly lower root mean squared errors than AM, and that GM was significantly lower than GM(date, wind, date by year).

In 2-day-per-week simulations, average root mean squared error was lowest for GM and GM(date, wind) indexes (Table 3). Two-way ANOVA indicated significant main effects of watchsite ($F_{1,132}$ = 51.90, $P \leq 0.001$) and index method ($F_{5,132}$ = 4.56, $P \leq 0.001$), but no site by method interaction ($F_{5,132}$ = 0.49, $P = 0.78$). Tukey's HSD test (α = 0.05) indicated that GM and GM(date, wind) indexes had significantly lower root mean squared errors than GM(date, date by year), and that GM(date, wind) was significantly lower than AM.

In simulations of intermittent sampling (missing blocks of days), average root mean squared error was lowest for GM(date) and GM(date, wind) indexes (Table 3). Two-way ANOVA indicated significant main effects of watchsite ($F_{1,132}$ = 55.10, $P \leq 0.001$) and index method ($F_{5,132}$ = 4.28, $P = 0.001$), but no site by method interaction ($F_{5,132}$ = 0.09, $P = 0.99$). Tukey's HSD test (α = 0.05) indicated that GM, GM(date), and GM(date, wind) indexes had significantly lower root mean squared errors than AM.

Hawk Mountain Sanctuary trend estimates averaged 1.4-2.5% per year lower and Cape May Point estimates averaged 1.7-2.5% per year lower than BBS trends (Table 3). Correlations between Hawk Mountain Sanctuary and BBS trends were positive for all indexes (range 0.59-0.66), but were only significant (α=0.05) for date-adjusted indexes. Correlations between Cape May Point and BBS trends were lower than those for Hawk Mountain Sanctuary (range 0.32-0.39), and were not significant (Table 3). Reduced major axis regression of BBS trends on migration trends indicated an approximate 1:1

correspondence (Table 3). Precision of migration monitoring trend estimates was greater than that of BBS for most species (Fig. 1).

DISCUSSION

Index Performance. - The high correlations among indexes suggest that trends in migration counts are robust and can be detected with even relatively crude (i.e., arithmetic-mean) analytical methods. Even so, the analysis of root mean squared error of trend regressions shows that geometric-mean indexes perform better than arithmetic-mean indexes. Our analysis further shows that the ANCOVA method with date adjustment is superior to a simple geometric-mean passage rate for datasets missing substantial days of observations. This is an important finding because many migration watchsites rely on volunteer labor, and days of active migration are sometimes missed when observers are not available. Additionally, some days are missed due to inclement weather, and it is not known whether migratory flights cease on those days. The date-adjusted index assigns expected numbers of hawks to these missing days based on the seasonal pattern, which can reduce inter-annual variation stemming from missed days. We recommend that precision of trend estimates should be evaluated for migration watchsites sampling fewer than 5 days per week before they are used as a monitoring tool.

Birds of prey are difficult to monitor with BBS methods (Kirk and Hyslop 1998) resulting in high CVs (28 - 468% for northeastern region) for BBS raptor indexes. With the exception of the American Kestrel and Red-tailed Hawk, species monitored at migration watchsites are difficult to detect during the breeding season and unlikely to nest in close proximity to roads, giving them a low probability of detection on a road-based survey. Furthermore, BBS monitors primarily breeding and non-breeding adults, while autumn migration counts additionally monitor young of the year. This could weaken correlations between BBS and migration watchsites that count primarily young of the year (e.g. Cape May Point; Clark 1985). Still, BBS is the best independent source of trend estimates for most raptors, and the correspondence of migration monitoring trends with BBS trends indicates that both measure real changes in monitored populations. The weight of evidence concerning correspondence with BBS trends suggests the date-adjusted index (GM[date]) is the most suitable for migration monitoring. The lack of perfect correspondence between migration monitoring trends and those from BBS suggests that both programs can make important and complimentary contributions to long-term monitoring of raptor populations in North America (see Dunn et al. 2005). The greater precision of migration monitoring trends for many species (Fig. 1) further suggests that their use will improve monitoring efforts.

Importance of Weather Adjustment. - Weather, particularly wind speed and direction, is often cited as a factor that may potentially confound migration counts as means of estimating population trends (Mueller and Berger 1961, Broun 1963, Alerstam 1978, Titus and Mosher 1982, Kerlinger 1989). We found that adjusting for the effects of wind increases the amount of variation that is explained by the index regression (Appendix B), but does not generally improve the fit of trend regressions over that achieved with date adjustment (Table 3). Accounting for date appears more important than adjusting for the effects of wind in the derivation of annual indexes for raptors, a finding in agreement with previous research in the Appalachians (Titus and Mosher 1982). We suggest that weather variables such as wind direction and speed affect daily raptor passage within a year, but not inter-annual variation in counts (see Allen et al. 1996). This conclusion is based on the assumption that no trend occurs in weather patterns over the study period, however, and should be treated with caution if such a trend is detected. Weather variables are generally correlated, and the failure of wind variables to explain inter-annual variation in hawk counts leads us to believe that additional weather covariates are unlikely to prove important to the accurate estimation of trends. Even so, we recommend they be examined during future index development (see Hussell and Brown 1992).

Our analysis of simulated 2-day-per-week sampling suggests that adjustment for weather can become important when there are very few observation days in a season. However, this level of sampling falls far below the minimum coverage of 75% of a species' seasonal migration window recommended by Hussell and Ralph (2005) for effective migration monitoring. It also greatly reduces statistical power to detect trends (Thomas et al. 2004). We therefore do not believe a 2-day-per-week sampling frequency is adequate for population monitoring using migration counts.

Migration Counts as Indicators of Population Trends. - Titus and Fuller (1990) noted that migration counts were an efficient means of monitoring some raptor populations, and Bednarz et al. (1990) established that migration count trends agree qualitatively with independent predictions for species undergoing strong, sustained population changes. Several authors have demonstrated correspondence of migration trends with independent trend estimates for passerines (Hussell et al. 1992, Dunn and Hussell 1995, Dunn et al. 1997, Francis and Hussell 1998), and raptors (Hussell and Brown 1992).

Hawk Mountain Sanctuary is an inland site that concentrates migrants taking advantage of favorable conditions (leading line, sensu Geyer von Schweppenburg 1963), whereas Cape May Point concentrates migrants avoiding conditions on one side of a diversion line (Atlantic coast), often after having been drifted there by prevailing winds. For some species, juveniles are more prone to wind drift (Thorup et al. 2003), and constitute a larger proportion of the count at coastal watchsites like Cape May Point (Clark 1985) than adults. We believe the greater variability of indexes and larger confidence intervals of trends at Cape May Point compared with Hawk Mountain Sanctuary (Fig.1) reflect fluctuations in annual productivity for some species as well as the possibility of greater variation in the rate of multiple counting at Cape May. These two factors are likely the causes of lower correlations with BBS at Cape May Point. Our analysis of trend root mean squared error suggests indexes from coastal diversion-line watchsites are more variable, but the high inter-site correlations, 1:1 correspondence between trends, and lack of site by index interactions at these watchsites show that migration indexes are robust to variations in migration geography and suitable for the estimation of population trends. Correspondence with BBS trends for the breeding areas of our source populations further supports this interpretation.

The potential for relatively high rates of multiple counting is sometimes raised as a fatal flaw in migration monitoring. However, unless there is a trend across years in the rate of multiple counting, it will not adversely affect estimates of trend. The lack of site by index interactions in our analysis suggests that a trend in the rate of multiple counting is not present at these watchsites. Future studies of the level and year-to-year variability of multiple counting at a variety of watchsites would be helpful in addressing this potential concern.

The Partners in Flight North American Landbird Conservation Plan recommends "… improvement of migration monitoring to meet information needs of many raptors …" (Rich et al. 2004: 29). A recent Partners in Flight update of monitoring needs indicates that only 6 of 19 species of diurnal raptors that breed in Canada and Alaska are adequately monitored at a range-wide scale and recommends migration monitoring to improve knowledge of population trends of 18 of these species (Dunn et al. 2005). The analysis method we recommend makes it possible to use counts of visible migrants to help fill this gap. The benefits of large-scale citizen science as a source of population monitoring data are clear in programs such as BBS and CBC. More than 50 active raptor watchsites in North America have collected migration count data for at least 10 years (Zalles and Bildstein 2000), often using volunteer citizen scientists to collect the data (Bildstein 1998). With recent efforts at networking (MacLeod 2004) and the development of powerful methods of trend estimation (Hussell 1981, Hussell 1985, Hussell and Brown 1992, Francis and Hussell 1998), the ingredients are now available to incorporate migration monitoring into an integrated system for monitoring raptor populations.

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Table 1. Trends in six indexes of migration counts (1976-78 to 2001-03) at Hawk Mountain Sanctuary, PA (HMS) and Cape May Point, NJ (CMP), and in Breeding Bird Surveys (BBS; 1976 to 2003) for northeastern North America. Trends for BBS are derived from estimating equations route regression for regions with ≥ 20 routes reporting the species. Significance of trend is shown by: + $P \leq 0.10$, *$P \leq 0.05$, **$P \leq 0.01$.

Species	Site	AM[a]	GM[b]	DA[c]	DAW[d]	DY[e]	DYW[f]	BBS[g]
Osprey	HMS	0.4	1.2**	1.6**	2.1**	1.4**	1.6**	4.6**
(*Pandion haliaetus*)	CMP	2.5*	2.7*	2.8*	2.6*	3.0*	2.6*	
Bald Eagle	HMS	7.1**	5.1**	5.2**	6.4**	5.2**	6.4**	5.9
(*Haliaeetus leucocephalus*)	CMP	11.5**	7.6**	8.5**	8.3**	8.8**	8.8**	
Northern Harrier	HMS	-2.5**	-2.2**	-2.1**	-2.0**	-2.0**	-2.0**	-2.1
(*Circus cyaneus*)	CMP	0.0	-0.2	-0.2	-0.2	-0.1	-0.2	
Cooper's Hawk	HMS	3.8**	3.7*	4.2**	4.9**	4.5**	5.2**	3.6
(*Accipiter cooperii*)	CMP	4.2**	4.2**	4.2**	3.5**	4.6**	3.8**	
Sharp-shinned Hawk	HMS	-2.8**	-1.3**	-1.4**	-1.2*	-2.1**	-1.5**	6.2
(*A. striatus*)	CMP	-3.6**	-4.1**	-4.1**	-4.4**	-4.5**	-5.2**	
Broad-winged Hawk	HMS	-3.2**	-4.0**	-3.0**	-3.1**	-3.2**	-3.3**	0.4
(*Buteo platypterus*)	CMP	-2.2	-1.1	-1.1	-1.6	-0.6	-1.7	
Red-shouldered Hawk	HMS	-0.3	-0.5	-0.6	-0.3	-0.5	-0.3	-6.0
(*B. lineatus*)	CMP	-1.1	-0.1	-0.2	-0.9	-0.1	-1.6	
Red-tailed Hawk	HMS	-1.7**	-1.8**	-1.8**	-0.5	-1.8**	-0.6	2.8**
(*B. jamaicensis*)	CMP	-0.2	-1.9	-2.2 +	-2.8*	-1.9	-2.5	
Golden Eagle	HMS	2.8**	2.0**	2.2**	3.7**	2.4**	3.9**	na[h]
(*Aquila chrysaetos*)	CMP	-1.5	-1.1	-1.2	-0.5	-1.5	-0.9	
American Kestrel	HMS	-1.7**	-1.3**	-1.1*	0.5	-1.2*	0.0	-1.4**

(*Falco sparverius*)	CMP	-3.2**	-4.0**	-3.9**	-3.5**	-4.0**	-3.5**	
Merlin	HMS	5.6**	4.1**	5.6**	6.4**	5.9**	6.8**	13.6*
(*F. columbarius*)	CMP	2.3*	2.0 +	2.0 +	2.7*	2.0 +	2.2*	
Peregrine Falcon	HMS	4.9**	3.5**	5.1**	5.4**	5.7**	5.9**	na
(*F. peregrinus*)	CMP	7.7**	5.6**	6.0**	6.0**	7.0**	7.0**	

[a]AM - effort-weighted mean passage rate

[b]GM - effort-weighted geometric-mean passage rate

[c]DA - estimated birds/day index, date and year terms

[d]DAW - estimated birds/day index, date and year terms, wind terms

[e]DY - estimated birds/day index, date and year terms, date by year interactions

[f]DYW - estimated birds/day index, date and year terms, date by year interactions, wind terms

[g]BBS northeastern region - CT, MA, ME, NH, NJ, NY, PA, RI, VT, NB, NS, ON, QC (east of 79° W)

[h]na - BBS trend not available

Table 2. Average root mean squared error (SD) among trend regressions for six migration indexes calculated from counts of visible, non-irruptive migrants at Hawk Mountain Sanctuary, PA (HMS) and Cape May Point, NJ (CMP). Results are shown for (1) full data set, and three reduced data sets that simulate sampling (2) 5 days per week (3) 2 days per week, and (4) intermittently, in which blocks of 55 contiguous days were removed from early-, mid-, or late-season observations in 50% of the years.

	AM[a]	GM[b]	DA[c]	DAW[d]	DY[e]	DYW[f]
(1) HMS	2.12	1.70	1.71	1.74	1.88	1.96
	(0.44)	(0.33)	(0.31)	(0.36)	(0.39)	(0.41)
CMP	3.23	2.64	2.65	2.72	2.73	3.01
	(0.87)	(0.60)	(0.60)	(0.58)	(0.62)	(0.69)
(2) HMS	1.81	1.46	1.46	1.54	1.60	1.78
	(0.40)	(0.27)	(0.26)	(0.30)	(0.26)	(0.42)
CMP	3.00	2.32	2.36	2.41	2.78	2.92
	(0.90)	(0.43)	(0.39)	(0.38)	(0.91)	(0.79)
(3) HMS	1.71	1.39	1.38	1.38	1.74	1.75
	(0.37)	(0.24)	(0.32)	(0.38)	(0.43)	(0.70)
CMP	2.30	1.90	2.08	1.83	2.43	2.13
	(0.43)	(0.31)	(0.60)	(0.36)	(0.62)	(0.51)
(4) HMS	2.39	1.90	1.69	1.73	1.91	1.93
	(0.70)	(0.36)	(0.28)	(0.32)	(0.38)	(0.37)
CMP	3.18	2.59	2.43	2.44	2.73	2.83
	(0.93)	(0.79)	(0.65)	(0.57)	(0.85)	(0.82)

[a]AM - effort-weighted mean passage rate

[b]GM - effort-weighted geometric-mean passage rate

[c]DA - estimated birds/day index, date and year terms

[d]DAW - estimated birds/day index, date and year terms, wind terms

[e]DY - estimated birds/day index, date and year terms, date by year interactions

[f]DYW - estimated birds/day index, date and year terms, date by year interactions, wind terms

Table 3. Pearson's correlation coefficients (*n* = 9 species) between trends for Breeding Bird Surveys (BBS) and those for six migration indexes at Hawk Mountain Sanctuary, PA (HMS) and Cape May Point, NJ (CMP), mean differences between trends, and intercepts (95% C.I.) and slopes (95% C.I.) of reduced major axis regression between migration indexes and BBS[g] (Sokal and Rohlf 1981). Significance of correlation is indicated by: + $P \leq 0.10$, *$P \leq 0.05$, **$P \leq 0.01$.

Index	r	Difference	Intercept	b[h]
			<u>HMS</u>	
AM[a]	0.59+	-2.27	-1.39 (-4.45, 0.69)	0.68 (-0.28, 1.38)
GM[b]	0.61+	-2.47	-1.27 (-3.60, 0.40)	0.56 (0.33, 1.15)
DA[c]	0.66*	-2.08	-0.97 (-3.36, 0.66)	0.59 (0.38, 1.15)
DAW[d]	0.65*	-1.43	-0.44 (-3.08, 1.42)	0.64 (0.40, 1.26)
DY[e]	0.63*	-2.14	-1.10 (-3.68, 0.72)	0.62 (0.37, 1.17)
DYW[f]	0.65*	-1.51	-0.60 (-3.33, 1.32)	0.67 (-4.99, 1.02)
			<u>CMP</u>	
AM[c]	0.39	-1.73	-1.23 (-4.79, 1.55)	0.82 (-0.46, 1.86)
GM[d]	0.34	-2.23	-1.33 (-4.67, 1.50)	0.67 (-0.68, 1.48)
DA[e]	0.34	-2.16	-1.38 (-4.94, 1.53)	0.72 (-0.72, 1.53)
DAW[f]	0.39	-2.37	-1.60 (-5.05, 0.99)	0.72 (-0.65, 1.55)
DY[g]	0.32	-2.04	-1.33 (-4.99, 1.75)	0.74 (-0.80, 1.62)
DYW[h]	0.37	-2.47	-1.81 (-5.66, 1.00)	0.76 (-0.73, 1.67)

[a]AM - effort-weighted mean passage rate

[b]GM - effort-weighted geometric-mean passage rate

[c]DA - estimated birds/day index, date and year terms

[d]DAW - estimated birds/day index, date and year terms, wind terms

[e]DY - estimated birds/day index, date and year terms, date by year interactions

[f]DYW - estimated birds/day index, date and year terms, date by year interactions, wind terms

[g]BBS northeastern region - CT, MA, ME, NH, NJ, NY, PA, RI, VT, NB, NS, ON, QC (east of 79° W)

[h]b - slope of major axis (model II regression; Sokal and Rohlf 1981)

FIGURE LEGEND

Fig. 1. Population trend estimates and 95% confidence intervals for raptors monitored by (a) Breeding Bird Surveys and migration watchsites at (b) Hawk Mountain Sanctuary, and (c) Cape May Point. Breeding Bird Survey trends are for a northeastern region comprised of the states of CT, MA, ME, NH, NJ, NY, PA, RI, and VT in the U.S., and the provinces of NB, NS, ON, and QC (east of 79° W) in Canada. Migration monitoring trends are for date-adjusted geometric-mean indexes.

APPENDIX A

MIGRATION COUNT INDEX REGRESSION

Annual arithmetic-mean passage rate $(AM)_j$ in year j was calculated by summing counts for each species across their seasonal passage windows in year j, dividing these sums by the total number of count hours and multiplying by the number of hours in the standard count day (H). The result was an arithmetic-mean daily passage rate for each species corrected for hours of effort at each site, i.e., for one site,

$$(AM)_j = \left(\sum_{i=1}^{I} C_{ij} \Big/ \sum_{i=1}^{I} h_{ij} \right) \times H \qquad (1)$$

where C_{ij} and h_{ij} are the count and the number of hours of observation on day i in year j, respectively, and i varies from 1 to I (the number of days in the species' seasonal migration window).

The geometric-mean passage rate in year j, $(GM)_j$, was determined from the weighted regression [equation (1) in Methods], including only the year terms, Y_j (which is equivalent to a one-way ANOVA with year as the factor). The estimate of the "transformed" geometric mean [i.e., of $\ln(N_{ij}+1)$] for year j was

$$(TGM)_j = a_0 + a_j \qquad (2a)$$

which was identical to the weighted mean of the transformed counts calculated directly as:

$$\left(\sum_{i=1}^{I} [h_{ij}\{\ln(N_{ij}+1)\}] \Big/ \sum_{i=1}^{I} h_{ij} \right) \times H \qquad (2b)$$

This estimate was then back-transformed to the original scale to obtain:

$$(GM)_j = e^{[(TGM)_j + V/2]} - 1 \qquad (2c)$$

where V is the error variance of the regression (equal to the weighted variance of the raw transformed counts pooled over all years). On the assumption that $(N_{ij}+1)$ conforms to a lognormal distribution, adding $V/2$ to $(TGM)_j$ prior to back transformation provides an estimate of the average number of hawks per day for the selected migration window for the species. Although this index is calculated from the geometric mean of $\ln(N_{ij}+1)$, it is reported as an estimate of the arithmetic mean. This makes no difference to the relationships of the annual indexes to each other or to estimates of trends or their significance, but seasonal sums of the counts will conform more closely to the numbers recorded in the raw data than if we reported geometric-mean rates of passage. This applies also to the remaining four indexes.

To improve the distribution of residuals in the subsequent analysis, we performed an identical preliminary regression in all of the four remaining analyses (Hussell 1981, Hussell et al. 1992). Independent variables in the preliminary analysis were 1st and 2nd order date terms and 1st to 4th order year terms (i.e., year was treated as a continuous variable, not as categorical dummy variables). Cases (days) with predicted values less than zero in the preliminary regression were deleted from the data for the main analysis. This could have the effect of deleting days at the start and/or end of the migration window of some species in some or all years.

The midpoint of the passage window was set as the zero date, so that deviations were both positive and negative, limiting the correlation among higher order terms. Likewise, in the preliminary regression, the midpoint year in the series of years analyzed was set as the zero year.

Date-adjusted estimated geometric-mean daily count $(GM[date])_j$ was estimated from the regression model including year and date terms only, i.e.,

$$\ln(N_{ij}+1) = a_0 + \sum_{j=1}^{J} a_j Y_j + \sum_{k=1}^{4} b_k i^k + e_{ij} \qquad (3a)$$

This index was designed to eliminate bias introduced by days when no data were collected. The estimated geometric-mean count (back-transformed) for each day in each year was then calculated, summed each year over the migration period, and divided by the number of days in the season and re-transformed to obtain $(TDA)_j$. Then:

$$(GM[date])_j = e^{[(TDA)_j + V/2]} - 1 \qquad (3b)$$

Date-adjusted estimated geometric-mean daily count with wind covariates index *(GM[date, wind])*$_j$ was derived in the same manner as the *(GM [date])*$_j$ index, with the addition of 12 variables incorporating wind speed and direction (*E, SE, S, SW,* $E^2 \ldots SW^3$, represented by $\sum_{l=1}^{L} d_l W_{lij}$ in the regression model). For this index, however, the estimated geometric-mean count (back-transformed) for each day in each year was calculated assuming that the value of each wind variable on all days in all years was equal to the mean value of that variable in the data.

Date-adjusted, estimated geometric-mean daily count with date by year interactions *(GM[date, date by year])*$_j$ index was derived in the same manner as the *(GM [date])*$_j$ index, with the addition of 1st-4th order interaction terms between date and year (represented by $\sum_{j=0}^{J} \sum_{k=1}^{4} c_{jk} (Y_j i^k)$ in the model). These terms were included to allow for inter-annual variations in the timing and pattern of migration. We used stepwise regression analysis (*P* to enter = 0.01, *P* to exit = 0.01001) to select interaction terms only for years in which they strongly affected the regression model. Interaction terms were evaluated in blocks (1st -4th order) for each year, and could only enter the model if they were significant as a block for any given year.

Date-adjusted, estimated geometric-mean daily count with date by year interactions and wind covariates *(GM[date, wind, date by year])*$_j$ index was derived in the same manner as *(GM[date, date by year])*$_j$, with the addition of 12 variables representing wind speed and direction *(E, SE, S, SW,* $E^2 \ldots SW^3$*)*. This method used all terms in the full regression model described above, except that the date by year interactions were included only if they met the criteria for entry in the stepwise procedure. The effect of wind variables on the estimated geometric-mean count was treated in the same way as for the *(GM [date, wind])*$_j$ index (see above).

APPENDIX B

Annual count totals (count), sample sizes (days), average inter-index correlation (*r*), and adjusted R^2 values for annual hawk migration indexes derived from five regression models (n = 12 species) at Hawk Mountain Sanctuary, PA (HMS), and Cape May Point, NJ (CMP).

					Adjusted R^2				
Species	Site	Count	Days	*r*	GM[a]	DA[b]	DAW[c]	DY[d]	DYW[e]
Osprey	HMS	500	1916	0.88	0.02	0.30	0.36	0.36	0.42
	CMP	2,346	1448	0.97	0.12	0.29	0.41	0.41	0.53
Bald Eagle	HMS	77	3645	0.96	0.09	0.15	0.22	0.18	0.24
	CMP	87	1681	0.99	0.23	0.25	0.33	0.30	0.37
Northern Harrier	HMS	268	2257	0.99	0.07	0.20	0.20	0.22	0.22
	CMP	1,657	2155	0.98	0.10	0.17	0.36	0.25	0.43
Cooper's Hawk	HMS	520	2231	0.97	0.09	0.41	0.52	0.48	0.55
	CMP	2,497	1762	0.95	0.12	0.38	0.50	0.43	0.56
Sharp-shinned Hawk	HMS	6,079	1623	0.87	0.04	0.39	0.51	0.48	0.59
	CMP	27,224	1712	0.96	0.10	0.25	0.40	0.34	0.49
Broad-winged Hawk	HMS	8,653	1075	0.90	0.07	0.45	0.46	0.52	0.54
	CMP	2,344	1044	0.87	0.05	0.11	0.27	0.20	0.35
Red-shouldered Hawk	HMS	268	1871	0.94	0.01	0.20	0.27	0.24	0.33
	CMP	444	1412	0.90	0.02	0.11	0.26	0.11	0.29
Red-tailed Hawk	HMS	3,730	2176	0.79	0.03	0.38	0.50	0.44	0.55
	CMP	1,943	1726	0.90	0.06	0.27	0.42	0.29	0.45
Golden Eagle	HMS	72	1897	0.93	0.04	0.11	0.22	0.16	0.27
	CMP	12	1306	0.97	0.01	0.05	0.11	0.08	0.15
American Kestrel	HMS	533	2102	0.79	0.03	0.12	0.32	0.15	0.36
	CMP	9,106	1531	0.90	0.05	0.11	0.42	0.14	0.45

Merlin	HMS	75	1875	0.97	0.11	0.30	0.35	0.34	0.38
	CMP	1463	1393	0.96	0.08	0.28	0.44	0.30	0.48
Peregrine Falcon	HMS	28	1623	0.98	0.04	0.25	0.26	0.29	0.30
	CMP	632	1180	0.98	0.19	0.50	0.52	0.58	0.58

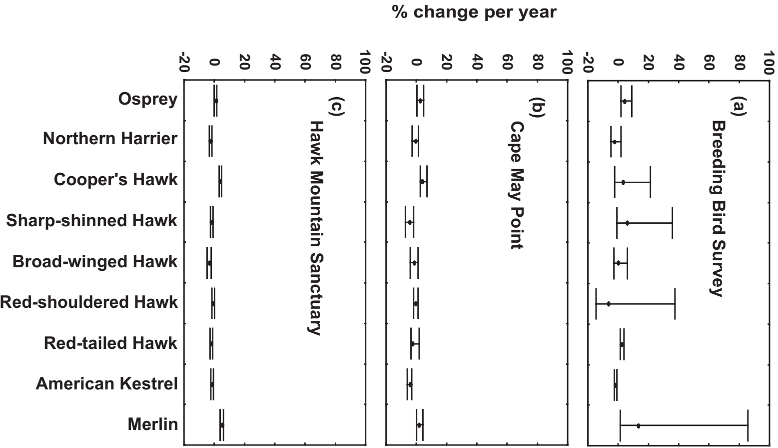
[a]GM - effort-weighted geometric-mean passage rate

[b]DA - estimated birds/day index, date and year terms

[c]DAW - estimated birds/day index, date and year terms, wind terms

[d]DY - estimated birds/day index, date and year terms, date by year interactions

[e]DYW - estimated birds/day index, date and year terms, date by year interactions, wind term


% change per year
-20
0
20
40
60
80
100
(a) Breeding Bird Survey
(b) Cape May Point
(c) Hawk Mountain Sanctuary
Osprey
Northern Harrier
Cooper's Hawk
Sharp-shinned Hawk
Broad-winged Hawk
Red-shouldered Hawk
Red-tailed Hawk
American Kestrel
Merlin

Hawk Mountain Sanctuary Conservation Status Report

American Kestrel

Scientific Name:	*Falco sparverius*
French Name:	*Crécerelle d'Amérique*
Spanish Name:	*Cernícalo Americano*
Body length[a]:	Female: 23-31 cm Male: 22-27 cm
Wingspan:	Female: 57-61 cm Male: 51-56 cm
Mass:	Female: 86-165 g Male: 80-143 g

Breeding Range in the New World (italicized terms are defined in the glossary):

Throughout North America north to the tree line, except southern parts of Texas, Louisiana, Florida, and the Olympic Peninsula of Washington. Also breeds throughout most of Central and South America except for the Amazon Basin.

Winter Range in the New World:

Southern British Columbia, Idaho, Utah, Colorado, Nebraska, Iowa, Illinois, Indiana, Ohio, New York, Vermont, New Hampshire south throughout the United States and Mexico. Some individuals from North America migrate south into Central America.

Type of Migrant: Partial Migrant

Nest Type: Cavity (secondary)

Food Habits: Insects, small rodents and less frequently, small birds.

Primary Flight Mode: Flapping interspersed with gliding; deep wingbeats; buoyant flight; frequently hovers over fields.

ECOLOGY AND POPULATION STATUS

The American Kestrel, North America's smallest *falcon*, is commonly seen hunting over or perched near open fields in both rural and suburban areas. Although hover-hunting is a conspicuous behavior, the kestrel catches most of its prey by pouncing from a perch. Kestrels prey primarily upon insects and small rodents, typically in open areas. Commonly taken insects include grasshoppers, cicadas, beetles, dragonflies, butterflies and moths. Spiders and scorpions are eaten as well. American Kestrels also take small rodents including voles, mice, and shrews, as well as small birds, reptiles, and amphibians. The species rarely feeds on carrion except for prey that it has previously killed and cached.

One of the continent's most widespread raptors, kestrels breed in eastern and western North America, north to the tree line and south into most of Central and South America. American Kestrels are obligate secondary cavity nesters, which means they do not excavate their own cavities, but nest in existing natural and man-made cavities, including tree cavities, abandoned buildings, and nest boxes. Kestrels are common in both farmlands and low-density suburban areas as well as in open and semi-open natural habitats, and sometimes nest in urban areas, too.

The American Kestrel is a *partial migrant*, and a large proportion of the population of the northeastern United States migrates south in autumn. American Kestrels breeding in northern portions of their range are more migratory than those breeding farther south, and birds in northern areas migrate farther than those in southern areas. Many southern populations are sedentary, and this combination of factors produces a *leap-frog migration* pattern. In comparison to Merlins and Peregrine Falcons, which often fly to the tropics to overwinter, most kestrels breeding in North America overwinter in the United States. This diminutive raptor is not a particularly strong flyer, and larger numbers are counted at coastal *raptor migration counts* either because they are pushed there by prevailing winds, or because prey are more abundant there. As a result, annual population indexes at Cape May Point in southern New Jersey are typically 10-20 times higher than those at Hawk Mountain Sanctuary in the central Appalachian Mountains of eastern Pennsylvania.

Data from *raptor migration counts*, *Christmas Bird Counts (CBCs)*, and annual *Breeding Bird Surveys (BBSs)* indicate that populations of the American Kestrel have declined substantially in parts of the northeastern United States since the mid-1970s. The decrease was particularly large and *statistically significant* at Cape May (-4.1% per year from 1976-2003, *P* ≤ 0.001). The index for Hawk Mountain during the same period showed a smaller, but still statistically significant, decrease (-1.1% per year, *P* = 0.03).

*BBS*s, conducted for the U.S. Geological Survey, show a significant decline in the kestrel population in northeastern North America (Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, New Brunswick, Nova Scotia, Ontario, and Quebec east of 79° W), which includes the areas from which Cape May and Hawk Mountain receive migrants. The *BBS* estimates a kestrel population trend of -1.4 % per year (*P* ≤ 0.05) for 1976-2003 (Sauer et al. 2004) in this region.

CBC data for 1959-1988, which includes the end of the *DDT* era (1959-1972), indicate a slight increase of 0.8% per year across the United States (Sauer et al 1996). Among states in the *Atlantic Flyway*, seven had negative trends in *CBC* data and seven showed positive trends during this period. An analysis of *CBC* data (National Audubon Society 2002) for the northeastern United States and eastern Canada for 1976-2003 by Hawk Mountain scientists, however, reveals a statistically significant decline of 4.6% per year (*P* <0.01) during this post-DDT era time frame. The trend in kestrel numbers in the *CBC* for the southeastern United States also is negative (-1.4 % per year, *P* <0.01) for 1976-2003.

HISTORIC AND CURRENT CONSERVATION CONCERN

Overall, the data suggest substantial decreases in populations of American Kestrels across much of northeastern North America. The greater decline at Cape May versus Hawk Mountain indicates that these two eastern *raptor migration counts* monitor different portions of the regional population or different age or sex groups within the same portion of the regional population. We know that when migrating, juvenile raptors are more likely to be drifted off course by wind than are adult raptors. Prevailing northwesterly winds in the northeastern United States during autumn push birds towards the Atlantic coast, and Cape May counts most likely reflect decreases in numbers of juveniles in the population. The lower rate of decline in migration counts at Hawk Mountain may indicate that most kestrels migrating over Hawk Mountain each season are adults. If this interpretation is correct, then counts at Hawk Mountain will likely decline further in the future as older birds die.

Nest productivity in Hawk Mountain's kestrel nestbox program declined 57% between 2000 and 2004, stemming primarily from a 40% decline in nesting attempts.

Declines in kestrel populations migrating through Hawk Mountain and Cape May watch sites may be due to several factors. Researchers found that kestrels continued to be exposed to high levels of *DDT* well into the late 1970s, even after the pesticide was banned in the United States in 1972. Laboratory experiments have shown that *DDT* interferes with successful reproduction in the American Kestrel. Populations of the larger Cooper's Hawk increased throughout the region from 1976-2003, and studies at Hawk Mountain and elsewhere have demonstrated that this species regularly preys upon American Kestrels. At the same time, much of the region has been re-forested, replacing food-gathering habitat for kestrels with forests that provide fewer feeding opportunities. Since the mid-1990s, *West Nile Virus* also has impacted numerous bird populations in the region. Although the impact of the virus on kestrel populations is unknown, researchers working with Hawk Mountain in 2004 found that 95% of the adults using nest boxes in the vicinity of the sanctuary had been exposed to the virus.

[a] Principal source of information for the physical and ecological summary: Smallwood, J.A. and D.M. Bird. 2002. American Kestrel (*Falco sparverius*). *In* The Birds of North America, No. 602 (A. Poole and F. Gill, eds). The Birds of North America, Inc., Philadelphia, PA.

RAPTOR MIGRATION COUNT DESCRIPTIONS

Cape May Point

LOCATION: 39°14'N, 74°49'W; within Cape May Point, 110 km s-se of Camden, 140 km s of Trenton, se New Jersey, ne United States.

ALTITUDE: Sea level.

BIOGEOGRAPHICAL PROVINCE: Nearctic Realm (1), Eastern Forest (1.5.5) (Udvardy 1975); Humid Temperate Domain (200), Hot Continental Division (220), Permanently Humid Eastern Oceanic Broadleaf Forests (221) (Bailey 1989).

SITE DESCRIPTION: A peninsula watchsite at the s tip of New Jersey. The 25-km long, 12 km-wide, ne-sw peninsula is between Delaware Bay (w) and the Atlantic Ocean (e). Cape May is 18 km ne of Cape Henlopen across the mouth of Delaware Bay. Dune scrub, salt marsh, tidal creek, and mixed forest dominate the site. Counts are conducted at Cape May Point State Park. The area surrounding the site includes private residences and businesses, intermingled with city parks and natural areas, including Higbee Beach Wildlife Management Area and the Nature Conservancy's Cape May Migratory Bird Refuge. Facilities at the site include a hawk-watch platform, nature center, walking trails, and parking lot. Counts are conducted from the hawk-watch platform at the edge the Cape May State Park parking lot. The platform, which has a 360° view, is handicap accessible.

Southbound migrants following the Atlantic Coastline are funneled to the tip of Cape May Point and concentrated in a small area due to surrounding waters. Migrants have been observed directly crossing the Delaware Bay, and also circling out of sight. Wind is a major factor, which affects direction and altitude of migrating raptors at the site. West winds seem to produce the most pronounced flight of Sharp-shinned Hawks (Kerlinger and Gauthreaux 1984).

A second watchsite, East Point, at the mouth of the Maurice River on Delaware Bay, 32 km to the northwest, records migrants that are reluctant to cross the mouth of Delaware Bay at Cape May and that are following the bayshore northwest to a narrower crossing point.

LAND TENURE: State.

PROTECTION: The site includes Cape May New Jersey State Park, Higbee Beach Wildlife Management Area, and the Nature Conservancy's Cape May Migratory Bird Refuge.

LAND USE: Beaches, fishing, hiking, natural areas, parking lots.

THREATS: None.

MONITORING ACTIVITY: Sporadic monitoring (30-83 days, annually) in 1931-1937, 1965, and 1970. Regular monitoring since 1976. In most years 1-3 individuals conduct counts on 100-120 8-hr days, each autumn. Not regularly monitored in spring. Results are compiled by New Jersey Audubon's Cape May Bird Observatory.

MIGRATION PERIOD(S): Boreal autumn (Aug.-Dec.), also spring (Mar.-May).
RAPTOR SPECIES: Sixteen species are recorded as regular migrants at the site, 3 species as irregular migrants, and 2 species as vagrants. Information below, except for max.1-day counts, is based on 10 years (1976-1985) of counts. An average 68,400 raptors is observed each autumn. Species observed include Black Vulture (ave. ann. count: 2; max. 1-day count: 5, 24 Nov. 1984; max. ann. count: 5), Turkey Vulture (642; 200, 26 Oct. 1979; 959), Osprey (1540; 308, 6 Oct. 1985; 2940), Mississippi Kite (1; 3, 14 Aug. 1982; 4), Bald Eagle (18; 7, 16 Sep. 1985; 32), Northern Harrier (1640; 278, 12 Nov. 1980; 3120), Sharp-shinned Hawk (42,700; 11,096, 4 Oct. 1977; 52,300), Cooper's Hawk (1440; 421, 11 Oct. 1985; 2670), Northern Goshawk (33; 50, 7 Nov. 1973; 86), Red-shouldered Hawk (472; 162, 13 Nov. 1980; 749), Broad-winged Hawk (3840; 9400, 4 Oct. 1977; 13,900), Swainson's Hawk (2; 3, 25 Sep. 1981; 7), Red-tailed Hawk (1700; 494, 11 Nov. 1973; 2280), Rough-legged Hawk (6; 4, 13 Nov. 1983; 12), American Kestrel (12,300; 24,875, 16 Oct. 1970; 21,800), Merlin (1330; 273, 11 Oct. 1985; 2880), and Peregrine Falcon (249; 72, 8 Oct. 1983; 518) (Dunne and Sutton 1986).

Hawk Mountain Sanctuary
LOCATION: 40°38'N, 75°59'W; 11 km w of Kempton, 40 km west northwest of Allentown, and 40 km north of Reading, Pennsylvania, northeastern United States.
ALTITUDE: 190-465 m.
BIOGEOGRAPHICAL PROVINCE: Nearctic Realm (1), Eastern Forest (1.5.5); Humid Temperate Domain (200), Hot Continental Regime Mountains (M220), Forest-alpine Meadows (M221) (Bailey 1989).
SITE DESCRIPTION: A mountaintop watchsite on the Kittatinny Ridge, the 300-km long, se-most ridge in the central Appalachian Mountains of eastern Pennsylvania. The site includes more than a dozen ridgetop outcrops overlooking the Kempton valley to the east and Little Schuylkill River valley to the west. Forest cover is primarily second-growth mixed deciduous forest, including oak-maple (*Quercus-Acer*) associations and Eastern Hemlock (*Tsuga canadensis*). Valleys surrounding the site are characterized by rolling, partly wooded farmland and Christmas-tree plantations (Brett 1991).

The Appalachian Trail abuts the Sanctuary on the east. Visitor facilities include a raptor museum, visitor center, bookstore, and living quarters for visiting researchers. The Sanctuary, which is open year-round, attracts > 80,000 visitors, annually, with <3000 visitors on some weekend days in Oct. Visitors have access to 10 lookouts and 15 km of trails. Admission is charged for access to the lookouts. Sanctuary-associated visitation contributes >1.5 million $US to the local economy.

The site's principal lookout, North Lookout, is a 465m rocky outcrop with a 240° view to the northeast. The lookout, which is accessible only by foot, is 1 km from the Visitor Center parking lot. Raptors slope soar along the Kittatinny Ridge at the site. Migration is most pronounced on northwest winds, especially on the several days following the passage of cold fronts (Allen et al 1996).

LAND TENURE: Private.

PROTECTION: The site is in a 900ha private wildlife sanctuary, and adjacent to 9000 ha of State Gamelands and National Park Service's Appalachian Trail.

LAND USE: Outdoor recreation, ecological research, environmental education.

THREATS: None.

MONITORING ACTIVITY: Monitoring has occurred since 1934 (excluding 1943-1945). 1-3 individuals conduct counts on the North Lookout on an average 110 days (15 Aug.-15 Dec.), annually. A spring count (15 April-15 May) was reinitiated in 1998. Counts also have been made from other lookouts at the site.

MIGRATION PERIOD(S): Boreal autumn (Aug.- Dec.), also spring (late Mar.-May).

RAPTOR SPECIES: Sixteen species are recorded as regular migrants; 2 species as irregular migrants. Information below is based on 59 years of data (1934-1995). An average 18,000 raptors is seen each year. Species observed include Black Vulture (ave. ann. count: 36), Turkey Vulture (103), Osprey (686; period of peak passage: late Sep.; max. 1-day count: 175, 23 Sep. 1989), Bald Eagle (61; Sep. and Dec.; 48, 4 Sep. 1950), Northern Harrier (312; no peak; 49, 16 Sep. 1980), Sharp-shinned Hawk (7640; early Oct.; 2620, 8 Oct. 1979), Cooper's Hawk (589; early Oct.; 204, 8 Oct. 1981), Northern Goshawk (59; mid-Nov.; 64, 10 Nov. 1973), Red-shouldered Hawk (263; late Oct.; 173, 23 Oct. 1977), Broad-winged Hawk (8340; mid-Sep.; 21,448, 14 Sep. 1978), B. swainsoni (13 in 59 years), Red-tailed Hawk (3780; early Nov.; 1144, 24 Oct. 1990;

Rough-legged Hawk (14), Golden Eagle (62; early Nov.; 14, 12 Nov. 1987), American Kestrel (625; early Oct.; 168, 3 Sep. 1977), Merlin (85; early Oct.; 34, 3 Oct. 1989); Gyrfalcon (6 in 59 years) and Peregrine Falcon (33; early Oct.; 11, 7 Oct. 1937).

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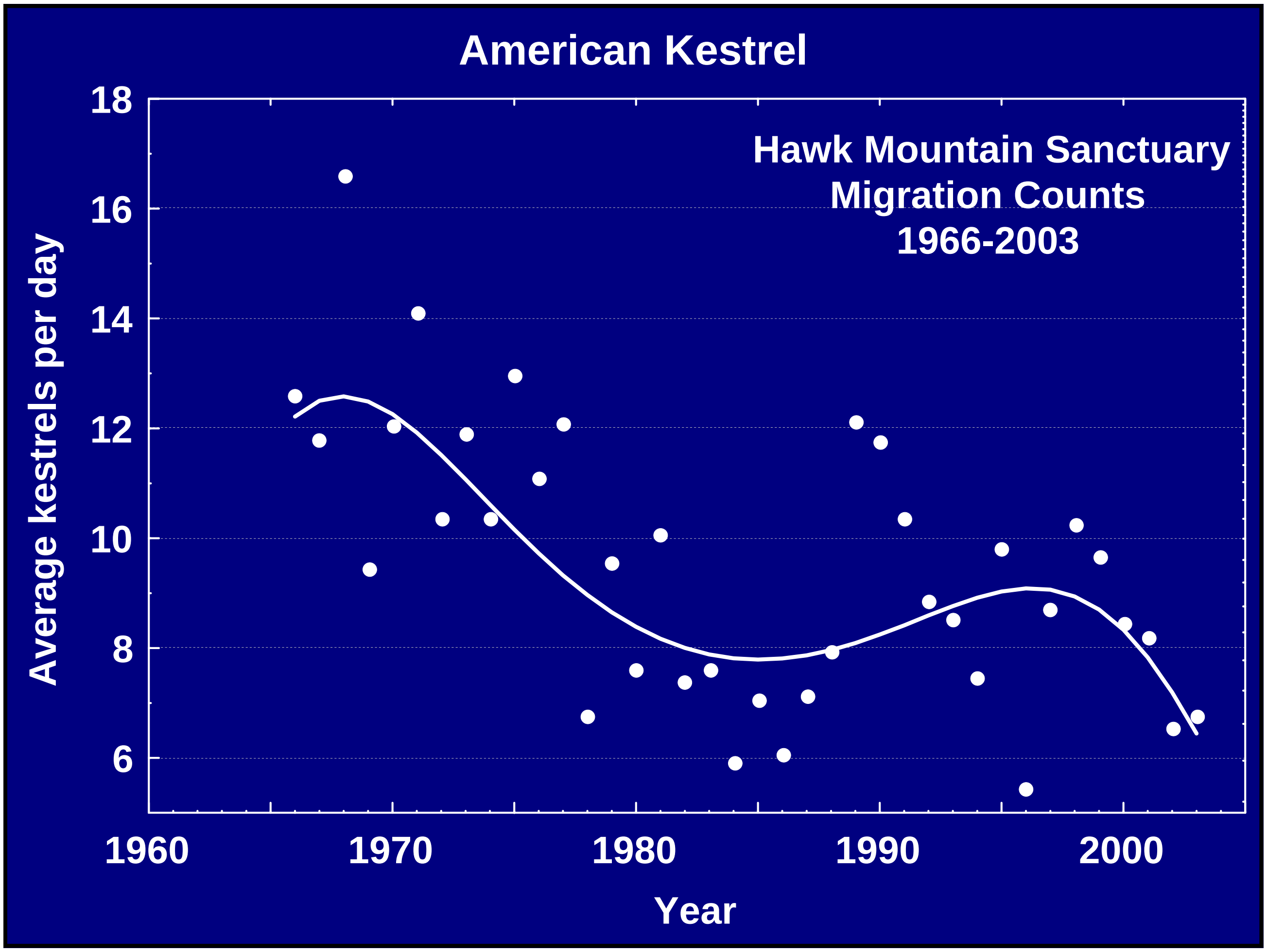
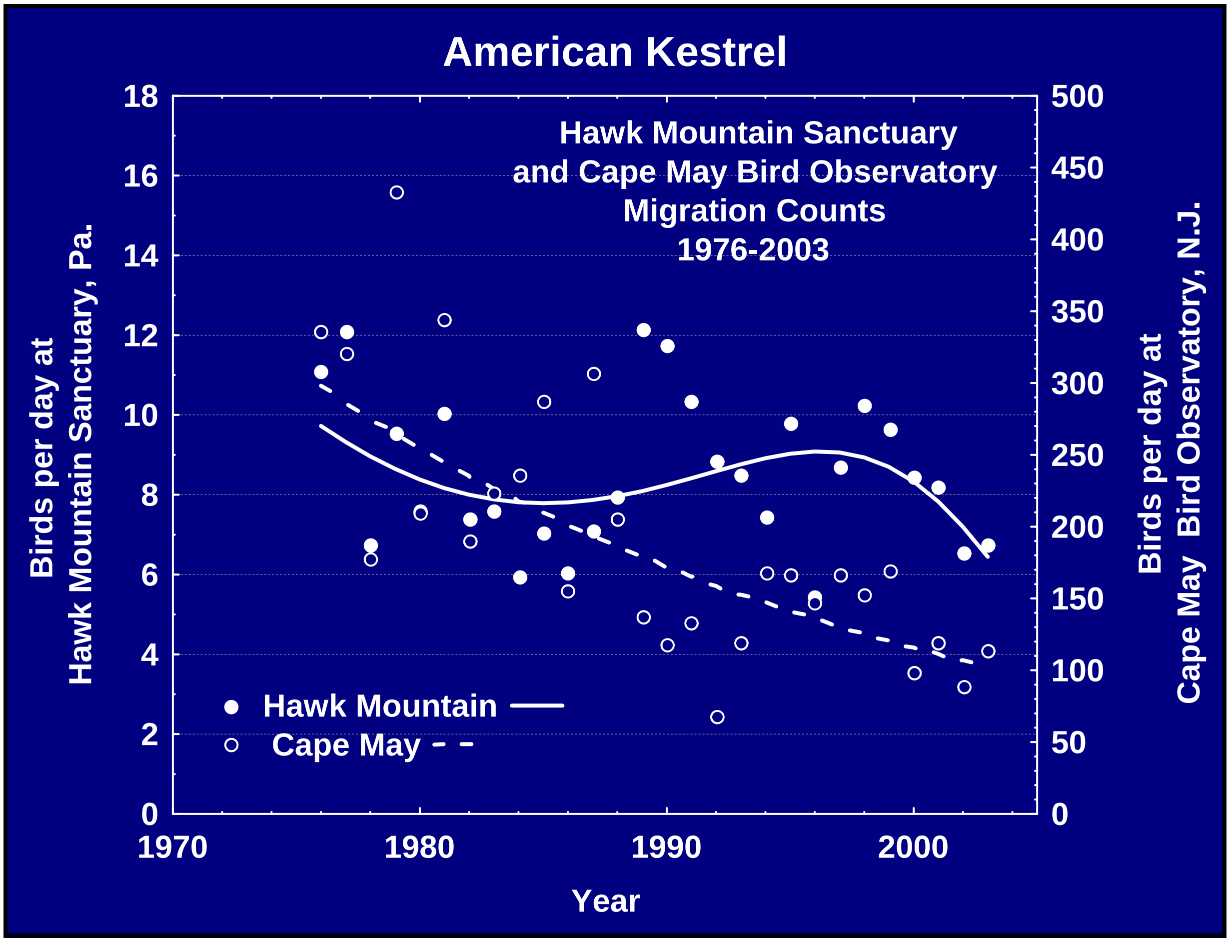
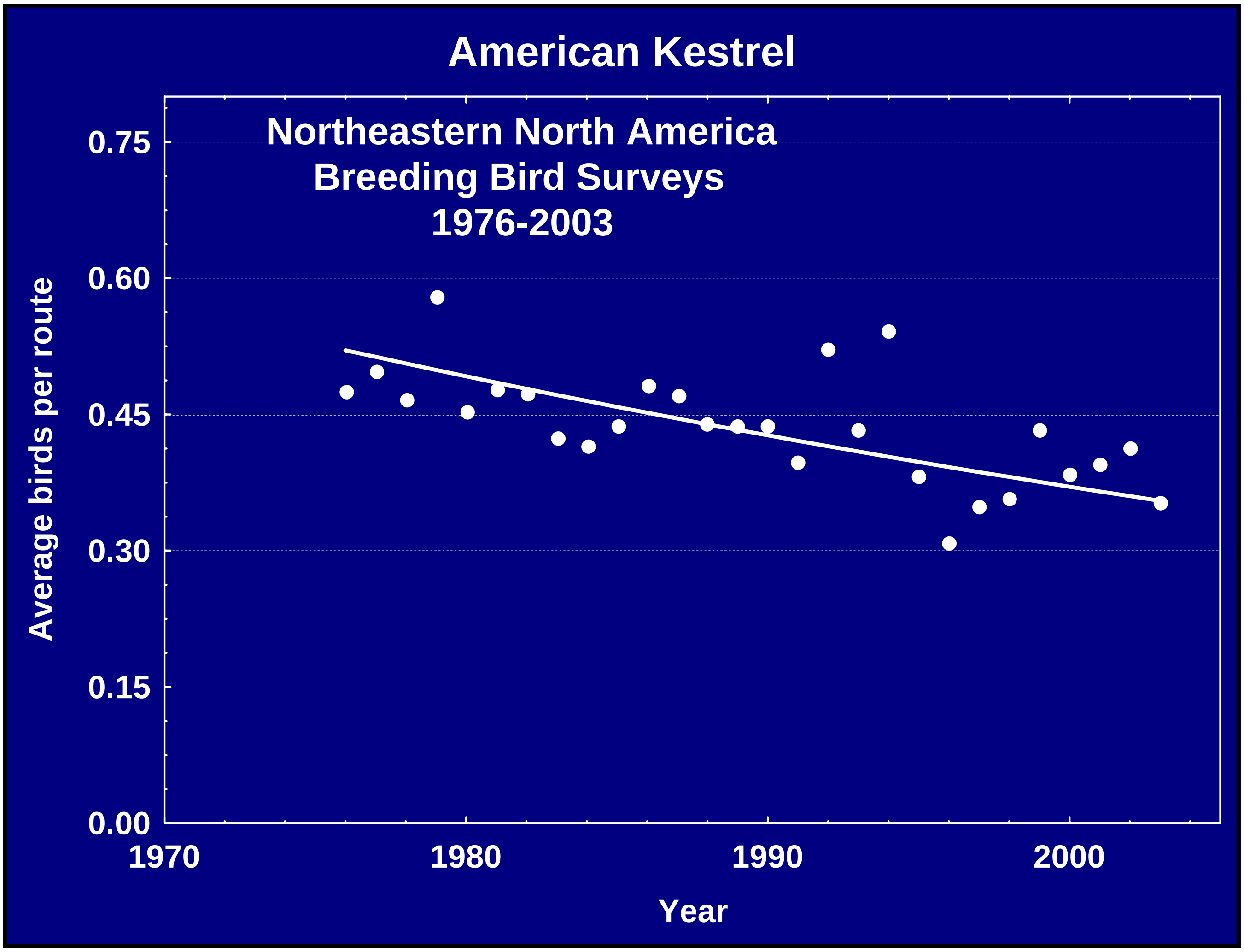


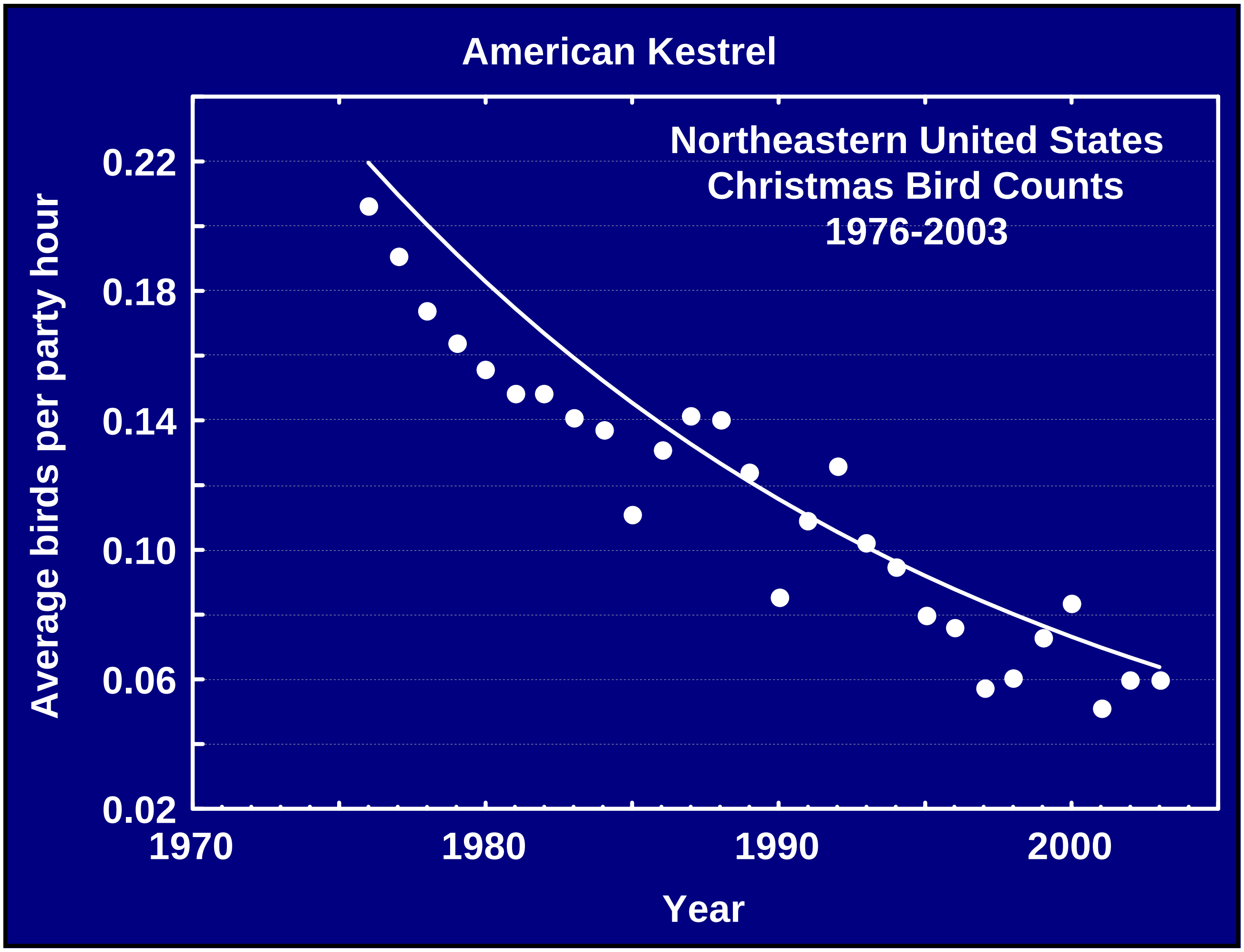
American Kestrel annual population indexes for Hawk Mountain Sanctuary, Pennsylvania. From 1966-2003, the population decreased 1.6 % per year. The line indicates the statistically significant long-term trend.



American Kestrel annual population indexes for Hawk Mountain Sanctuary, Pennsylvania and Cape May Bird Observatory, New Jersey. From 1976-2003, the index decreased 1.1 % per year at Hawk Mountain and 4.1 % per year at Cape May. Lines indicate statistically-significant long-term trends.



American Kestrel population indexes (average birds per route) for Breeding Bird Surveys in Northeastern North America (U.S. states and Canadian provinces north of the southern borders of PA and NJ). From 1976-2003, counts of kestrels on survey routes in this region decreased 1.4% per year. The line indicates this statistically significant trend. (source: J. R. Sauer, USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA)



American Kestrel population indexes (average birds per party hour) for Christmas Bird Counts in the northeastern United States and eastern Canada. From 1976-2003, Christmas Bird Counts of kestrels decreased 4.6% per year. The line indicates the statistically significant long-term trend. (Data source: National Audubon Society. 2002. The Christmas Bird Count Historical Results [Online]. Available http://www.audubon.org/bird/cbc [November 2004].)

Hawk Mountain Sanctuary Conservation Status Report

Bald Eagle

Scientific Name: *Haliaeetus leucocephalus*

French Name: *Pygargue à Tête Blanche*

Spanish Name: *Aguila Cabeza Blanca, Aguila Calva*

Body length[a,b]: Range: 70-96 cm (female ave: 91.1 cm, male ave: 84.3 cm)

Wingspan: Range: 180-244 cm (female ave: 221.13 cm, male ave: 207.3 cm)

Mass: Range: 2.0-6.3 kg (female ave: 5.3 kg, male ave: 4.3 kg)

(Physical measurements for the northern subspecies average approximately 10% larger than the southern subspecies.)

Breeding Range in the New World (italicized terms are found in the glossary):

Alaska south of the Brooks Range, Canada south of the northern Yukon and British Columbia and south of a line from the MacKenzie River to the mouth of the Churchill River on Hudson Bay. Breeding attempts recorded in all 48 contiguous United States. Extensive breeding populations in the Great Lakes region, Pacific Northwest, and along the southern Atlantic Coast from Florida to South Carolina. Limited number of breeding pairs in Baja California, Sonora, and Chihuahua, Mexico.

Winter Range in the New World:

Winters primarily in coastal Canada and Alaska, and contiguous 48 states. Limited reports of birds wintering in Mexico, along the Gulf of Mexico, Gulf of California, Baja California, and rivers in Sonora and Chihuahua. Florida population breeds in winter.

Type of Migrant: Partial

Nest Type: Large stick nest near crown of an emergent tree

Food Habits: Opportunistic feeder. Eats primarily fish, but takes various other animals including small mammals, reptiles and amphibians, crustaceans, and various birds (including waterfowl). Scavenges

	from carcasses of birds and mammals, and frequents garbage dumps in some areas. Also pirates prey from other species such as Osprey.
Primary Flight Mode:	Slow, powerful flapping flight interspersed with soaring on flat wings.

ECOLOGY AND POPULATION STATUS[c]

One of ten species of "fish" or "sea" eagles worldwide, the Bald Eagle is North America's second largest bird of prey (exceeded only by the California Condor). It is generally seen near aquatic habitats (coastlines, lakes, rivers), where it often hunts from a perch in a tall tree. Whether perched or flying with its characteristic slow, methodical, deep wingbeats, an adult Bald Eagle is visually distinctive because of its size and the contrast between its dark brown body and white head and tail. Juvenile eagles bear plumage with varying combinations of brown and white for the first 4 years of life, and are often confused with Golden Eagles.

Bald Eagles breed across much of North America, always in close proximity to water. Their breeding range in North America includes most of Alaska and Canada south of the tree line, and coastal and other aquatic areas of most of the lower 48 states. Large breeding populations are found in the coastal Pacific Northwest, the Great Lakes states, the Atlantic coastal states, and the Maritime Provinces of Canada. There are smaller numbers of breeding eagles in the Rocky Mountain region, the southwestern United States, states along the Gulf of Mexico, and in parts of Mexico. Nests typically are found near the top of large, dominant trees in forested areas within 2 km of water bodies, although ground nests have been documented in treeless regions. The diet is composed primarily of fish. For example, a study in Maine (Todd et al. 1982) reported that although 64 species of vertebrates were found in prey remains, about 75% of the remains were from fish. Diet studies from a variety of locations, however, have demonstrated that the Bald Eagle's diet is quite variable, and can include high proportions of birds and mammals.

The Bald Eagle is a *partial migrant*. Migration patterns of Bald Eagles are complex, and migratory tendency varies with age and with factors related to location of breeding site (climate, food availability, etc.). Most immature eagles migrate and are nomadic until they are mature. Adults are typically sedentary, but migrate if food availability decreases in breeding locations. Southbound autumn migrations occur from August through January in most locations, but some individuals move short distances to winter food resources rather than making large migratory movements. Bald Eagles begin nesting in Florida in November and December, and their young sometimes fledge as early as late March. In spring and summer, young-of-the-year fly north to over-summer in the northern United States and southern Canada. They return to their birthplace in late summer - early autumn. As a result of this unusual migration pattern, Hawk Mountain Sanctuary experiences two peaks in eagle migration each autumn. In late August-September, individuals from southern populations are counted as they return to their Florida breeding grounds. In November-December, a second peak occurs as individuals from breeding grounds north of Hawk Mountain pass the Sanctuary on their way to southern wintering grounds.

Data from hawk *raptor migration counts*, *Christmas Bird Counts (CBCs)*, and annual *Breeding Bird Surveys (BBSs)* indicate that populations of the Bald Eagle have increased steadily in northeastern North America since 1976. From 1976 to 2003, migration counts at Hawk Mountain Sanctuary in Pennsylvania increased at a *statistically significant* 5.2% per year ($P \leq 0.001$); those at Cape May Bird Observatory in New Jersey increased at a *statistically significant* 8.5% per year ($P \leq 0.001$).

BBSs, conducted for the U.S. Geological Survey, show significant increases in Bald Eagle populations in northeastern North America (Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, New Brunswick, Nova Scotia, Ontario, and Quebec east of 79° W), which includes the areas from which Cape May and Hawk Mountain receive migrants. The BBS estimates a non-significant increasing trend in the Bald Eagle population of 5.9 % per year for 1976-2003 in northeastern North America (Sauer et al. 2004).

CBC data for 1959-1988, which includes the end of the *DDT era*, indicate an increase of 1.0 % per year across the United States, with increasing trends reported mainly in the West (Sauer et al 1996). Among states along the Atlantic coast, 2 had negative trends in CBC data and 7 showed positive trends during this period. An analysis of recent CBC data (National Audubon Society 2002) for the northeastern United States from 1976 to 2003 by Hawk Mountain scientists reveals a *statistically significant* increase of 7.2 % per year ($P \leq 0.001$).

HISTORIC AND CURRENT CONSERVATION CONCERN

The Bald Eagle, which was selected as the national symbol of the United States in 1782, was endangered and nearly extinct in the lower 48 states by the middle of the 20th century. The population was pushed to this condition largely by its sensitivity to the organochlorine pesticide *DDT*, which was widely used from the mid 1950s until 1972, when widespread use was banned in the United States. Hawk Mountain Sanctuary was the only place on the continent where migrating eagles were systematically counted before, during, and after the widespread use of *DDT*. These early migration counts showed a marked decline from 1946-1972. Ecologist and author Rachel Carson used eagle count data from Hawk Mountain to help make her case against *DDT* in *Silent Spring*.

The recovery of the eagle population of the northeastern United States after *DDT* was banned can be seen in the accompanying graphs. The differences in trend estimates from the two locations highlight the importance of using several *raptor migration counts* within a geographic region when attempting to identify population trends. In the case of the Bald Eagle, numbers have increased more rapidly at Cape May than at Hawk Mountain. The difference between Cape May and Hawk Mountain may reflect heavier historical use of DDT in coastal areas from which Cape May's migrants may be drawn. Increases in migration counts also reflect re-introduction efforts in many eastern states, in which hundreds of fledglings were released into the wild.

The graph of juvenile and adult Bald Eagle trends at Hawk Mountain Sanctuary reveals a pattern characteristic of recovery in *age-structured populations.* Numbers of juveniles counted at Hawk Mountain began to increase steadily in the early 1970s, corresponding closely with the banning of *DDT* in the United States. Counts of adults, however, continued to decline and did not begin consistent increases until approximately a decade later. This pattern is associated with the time it takes juveniles to acquire the adult plumage indicative of reproductive maturity (5 years for Bald Eagles) combined with low recruitment rates of young into the adult segment of the population. Just as the ratio of juveniles- to- adults can indicate that increased reproduction is the cause of population growth, a decrease in this ratio at Hawk Mountain was interpreted by Rachel Carson as indicative of failing reproductive success during the *DDT* era.

Bald Eagles passing Hawk Mountain Sanctuary and Cape May Bird Observatory comprise two distinct geographic populations. One is exceptional in that it breeds in Florida in winter and that juveniles spend the summer on nonbreeding areas in the Northeast. These nonbreeding areas overlap the breeding areas used by the other northeastern population, which breeds in Canada and the northeastern U.S. during summer, and moves south to nonbreeding areas in the southeast during autumn. Despite differences in the rates of increase in numbers of eagles seen at Hawk Mountain Sanctuary and Cape May Bird Observatory, trends in the counts indicate a strong comeback by our national symbol since the end of the *DDT* era, and the trends in BBS and CBC indexes further support this conclusion.

Despite bans on the widespread use of *DDT* and similar pesticides in the United States, humans remain the greatest single threat to eagles, both directly through shooting, trapping, and poisoning, and indirectly through effects of developments (electrocutions, collisions with buildings, land-use change). Of individuals examined by the USGS from 1963 to 1984, 23% died of trauma (mostly collisions), 22% from gunshots, 11% from poisoning, 9% from electrocution, 5% from trapping, and 30% from malnutrition, disease, or unknown causes. Like many scavengers, Bald Eagles also have been found to be at risk from lead pellets found in carcasses of waterfowl and game animals.

The Bald Eagle is protected in the United States under the Bald Eagle Protection Act and the Endangered Species Act. Its current status is listed as threatened, but the U.S. Fish and Wildlife Service filed intent in 1999 to remove the Bald Eagle from the list and declare it recovered. Known nest sites in the United States are typically protected by buffer zones in which human activities are restricted, but the size of these buffers varies by region. It remains to be seen how accelerating land development and the accompanying removal of forests in the northeastern United States will affect future population trends.

[a,b]Principal sources of information for the physical description:

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[c]Principal source of information for ecological summary:

Buehler, D.A. 2000. Bald Eagle (*Haliaeetus leucocephalus*). *In* The Birds of North America, No. 506 (A. Poole and F. Gill, eds). The Birds of North America, Inc., Philadelphia, PA.

RAPTOR MIGRATION COUNT DESCRIPTIONS

Cape May Point

LOCATION: 39°14'N, 74°49'W; within Cape May Point, 110 km s-se of Camden, 140 km s of Trenton, se New Jersey, ne United States.

ALTITUDE: Sea level.

BIOGEOGRAPHICAL PROVINCE: Nearctic Realm (1), Eastern Forest (1.5.5); Humid Temperate Domain (200), Hot Continental Division (220), Permanently Humid Eastern Oceanic Broadleaf Forests (221) (Bailey 1989).

SITE DESCRIPTION: A peninsula watchsite at the s tip of New Jersey. The 25-km long, 12 km-wide, ne-sw peninsula is between Delaware Bay (w) and the Atlantic Ocean (e). Cape May is 18 km ne of Cape Henlopen across the mouth of Delaware Bay. Dune scrub, salt marsh, tidal creek, and mixed forest dominate the site. Counts are conducted at Cape May Point State Park. The area surrounding the site includes private residences and businesses, intermingled with city parks and natural areas, including Higbee Beach Wildlife Management Area and the Nature Conservancy's Cape May Migratory Bird Refuge. Facilities at the site include a hawk-watch platform, nature center, walking trails, and parking lot. Counts are conducted from the hawk-watch platform at the edge the Cape May State Park parking lot. The platform, which has a 360° view, is handicap accessible.

Southbound migrants following the Atlantic Coastline are funneled to the tip of Cape May Point and concentrated in a small area due to surrounding waters. Migrants have been observed directly crossing the Delaware Bay, and also circling out of sight. Wind is a major factor, which affects direction and altitude of migrating raptors at the site. West winds seem to produce the most pronounced flight of Sharp-shinned Hawks.

A second watchsite, East Point, at the mouth of the Maurice River on Delaware Bay, 32 km to the northwest, records migrants that are reluctant to cross the mouth of Delaware Bay at Cape May and that are following the bayshore northwest to a narrower crossing point.

LAND TENURE: State.

PROTECTION: The site includes Cape May New Jersey State Park, Higbee Beach Wildlife Management Area, and the Nature Conservancy's Cape May Migratory Bird Refuge.

LAND USE: Beaches, fishing, hiking, natural areas, parking lots.

THREATS: None.

MONITORING ACTIVITY: Sporadic monitoring (30-83 days, annually) in 1931-1937, 1965, and 1970. Regular monitoring since 1976. In most years 1-3 individuals conduct counts on 100-120 8-hr days, each autumn. Not regularly monitored in spring. Results are compiled by New Jersey Audubon's Cape May Bird Observatory.

MIGRATION PERIOD(S): Boreal autumn (Aug.-Dec.), also spring (Mar.-May).

RAPTOR SPECIES: Sixteen species are recorded as regular migrants at the site, 3 species as irregular migrants, and 2 species as vagrants. Information below, except for max.1-day counts, is based on 10 years (1976-1985) of counts. An average 68,400 raptors is observed each autumn. Species observed include Black Vulture (ave. ann. count: 2; max. 1-day count: 5, 24 Nov. 1984; max. ann. count: 5), Turkey Vulture (642; 200, 26 Oct. 1979; 959), Osprey (1540; 308, 6 Oct. 1985; 2940), Mississippi Kite (1; 3, 14 Aug. 1982; 4), Bald Eagle (18; 7, 16 Sep. 1985; 32), Northern Harrier (1640; 278, 12 Nov. 1980; 3120), Sharp-shinned Hawk (42,700; 11,096, 4 Oct. 1977; 52,300), Cooper's Hawk (1440; 421, 11 Oct. 1985; 2670), Northern Goshawk (33; 50, 7 Nov. 1973; 86), Red-shouldered Hawk (472; 162, 13 Nov. 1980; 749), Broad-winged Hawk (3840; 9400, 4 Oct. 1977; 13,900), Swainson's Hawk (2; 3, 25 Sep. 1981; 7), Red-tailed Hawk (1700; 494, 11 Nov. 1973; 2280), Rough-legged Hawk (6; 4, 13 Nov. 1983; 12), American Kestrel (12,300; 24,875, 16 Oct. 1970; 21,800), Merlin (1330; 273, 11 Oct. 1985; 2880), and Peregrine Falcon (249; 72, 8 Oct. 1983; 518) (Dunne and Sutton 1986).

Hawk Mountain Sanctuary

LOCATION: 40°38'N, 75°59'W; 11 km w of Kempton, 40 km west northwest of Allentown, and 40 km north of Reading, Pennsylvania, northeastern United States.

ALTITUDE: 190-465 m.

BIOGEOGRAPHICAL PROVINCE: Nearctic Realm (1), Eastern Forest (1.5.5); Humid Temperate Domain (200), Hot Continental Regime Mountains (M220), Forest-alpine Meadows (M221) (Bailey 1989).

SITE DESCRIPTION: A mountaintop watchsite on the Kittatinny Ridge, the 300-km long, se-most ridge in the central Appalachian Mountains of eastern Pennsylvania. The site includes more than a dozen ridgetop outcrops overlooking the Kempton valley to the east and Little Schuylkill River valley to the west. Forest cover is primarily second-growth mixed deciduous forest, including oak-maple (*Quercus-Acer*) associations and Eastern Hemlock (*Tsuga canadensis*). Valleys surrounding the site are characterized by rolling, partly wooded farmland and Christmas-tree plantations (Brett 1991).

The Appalachian Trail abuts the Sanctuary on the east. Visitor facilities include a raptor museum, visitor center, bookstore, and living quarters for visiting researchers. The Sanctuary, which is open year-round, attracts > 80,000 visitors, annually, with <3000 visitors on some weekend days in Oct. Visitors have access to 10 lookouts and 15 km of trails. Admission is charged for access to the lookouts. Sanctuary-associated visitation contributes >1.5 million $US to the local economy.

The site's principal lookout, North Lookout, is a 465m rocky outcrop with a 240° view to the northeast. The lookout, which is accessible only by foot, is 1 km from the Visitor Center parking lot. Raptors slope soar along the Kittatinny Ridge at the site. Migration is most pronounced on northwest winds, especially on the several days following the passage of cold fronts.

LAND TENURE: Private.

PROTECTION: The site is in a 900ha private wildlife sanctuary, and adjacent to 9000 ha of State Gamelands and National Park Service's Appalachian Trail.

LAND USE: Outdoor recreation, ecological research, environmental education.

THREATS: None.

MONITORING ACTIVITY: Monitoring has occurred since 1934 (excluding 1943-1945). 1-3 individuals conduct counts on the North Lookout on an average 110 days (15 Aug.-15 Dec.), annually. A spring count (15 April-15 May) was reinitiated in 1998. Counts also have been made from other lookouts at the site.

MIGRATION PERIOD(S): Boreal autumn (Aug.- Dec.), also spring (late Mar.-May).

RAPTOR SPECIES: Sixteen species are recorded as regular migrants; 2 species as irregular migrants. Information below is based on 59 years of data (1934-1995). An average 18,000 raptors is seen each year. Species observed include Black Vulture (ave.

ann. count: 36), Turkey Vulture (103), Osprey (686; period of peak passage: late Sep.; max. 1-day count: 175, 23 Sep. 1989), Bald Eagle (61; Sep. and Dec.; 48, 4 Sep. 1950), Northern Harrier (312; no peak; 49, 16 Sep. 1980), Sharp-shinned Hawk (7640; early Oct.; 2620, 8 Oct. 1979), Cooper's Hawk (589; early Oct.; 204, 8 Oct. 1981), Northern Goshawk (59; mid-Nov.; 64, 10 Nov. 1973), Red-shouldered Hawk (263; late Oct.; 173, 23 Oct. 1977), Broad-winged Hawk (8340; mid-Sep.; 21,448, 14 Sep. 1978), B. swainsoni (13 in 59 years), Red-tailed Hawk (3780; early Nov.; 1144, 24 Oct. 1990; Rough-legged Hawk (14), Golden Eagle (62; early Nov.; 14, 12 Nov. 1987), American Kestrel (625; early Oct.; 168, 3 Sep. 1977), Merlin (85; early Oct.; 34, 3 Oct. 1989); Gyrfalcon (6 in 59 years) and Peregrine Falcon (33; early Oct.; 11, 7 Oct. 1937).

DATA SOURCES:

Cape May Bird Observatory. 2005. Hourly hawk migration count data 1976-2003. New Jersey Audubon Society, Cape May Bird Observatory, Cape May Court House, New Jersey, USA. Available online at http://www.njaudubon.org/research/index.html#capemay.

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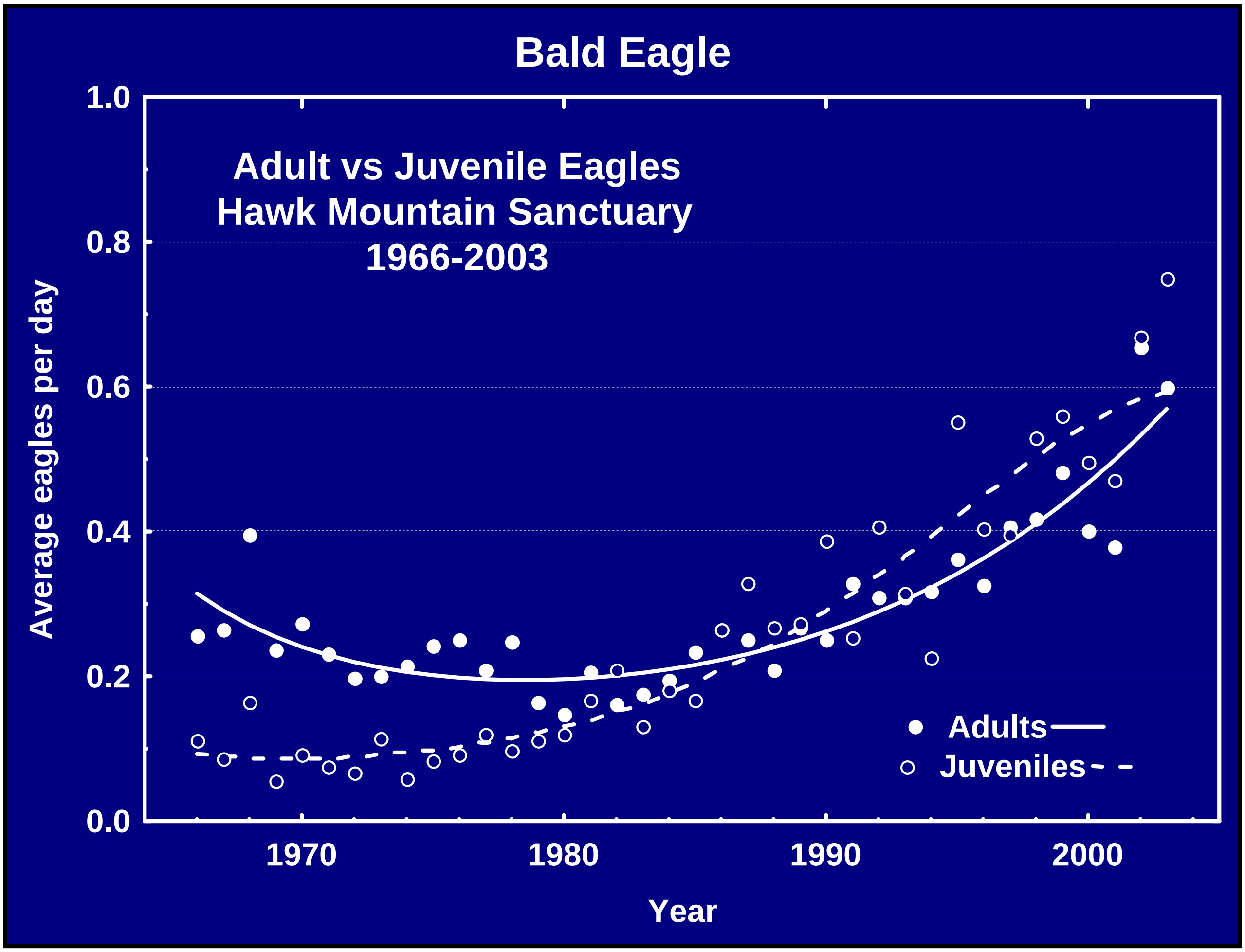
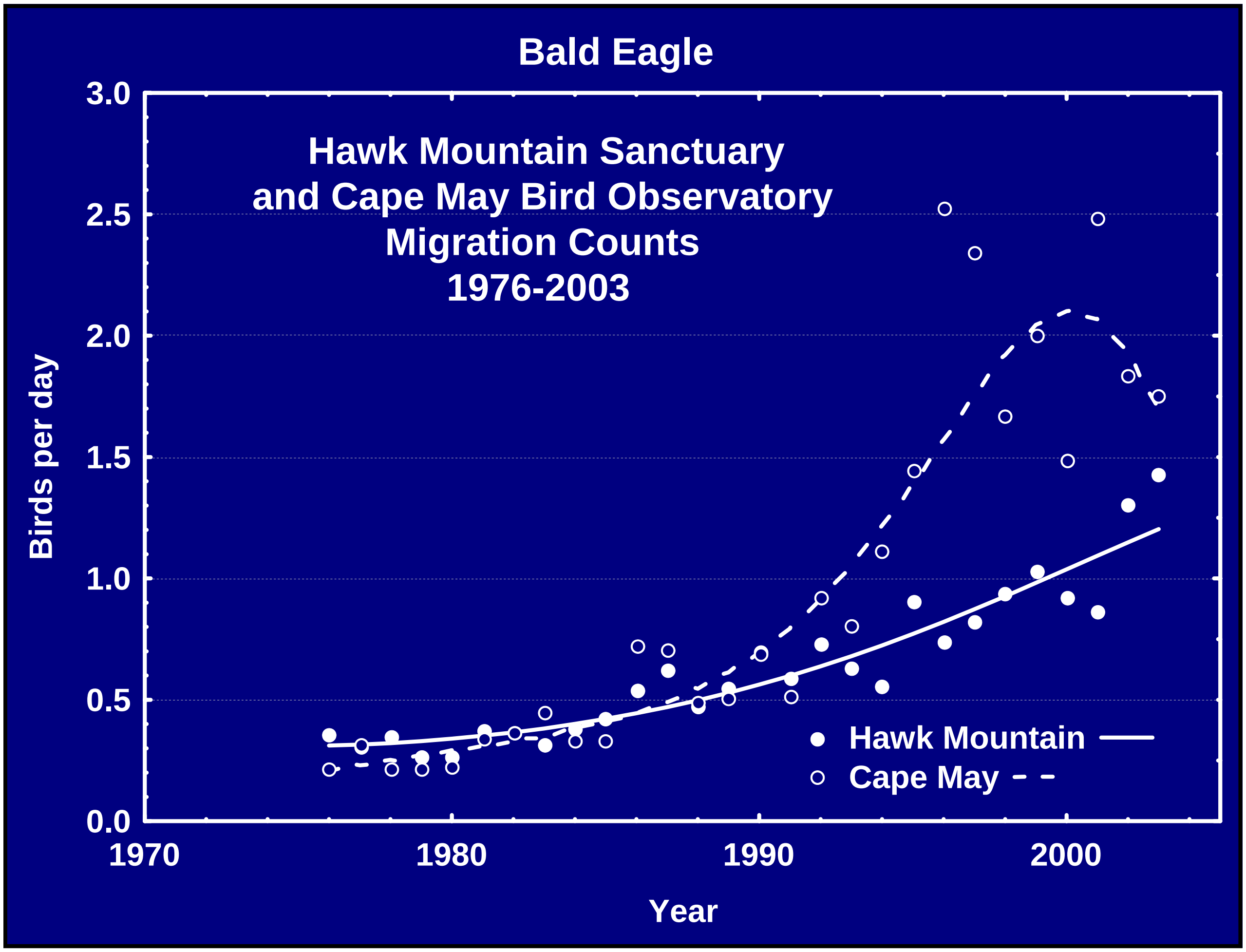
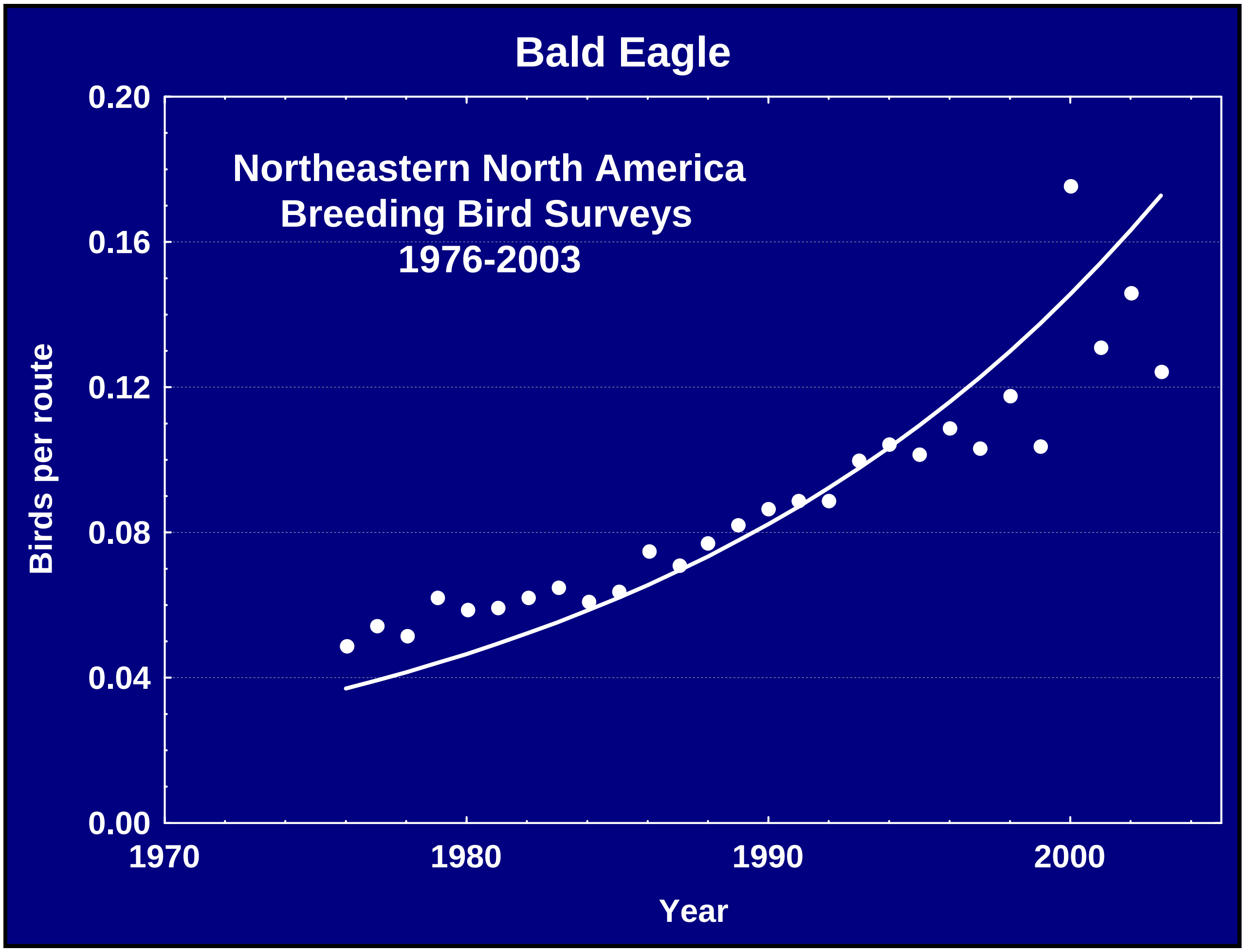
Wiemeyer, S.N., B.M. Mulhern, F.J. Ligas, R.J. Hensel, J.E. Mathisen, F.C. Robards, and S. Postupalsky. 1972. Residues of organochlorine pesticides, polychlorinated biphenyls, and mercury in bald eagle eggs and changes in shell thickness, 1969 and 1970. Pesticides Monitoring Journal 6: 50-55.



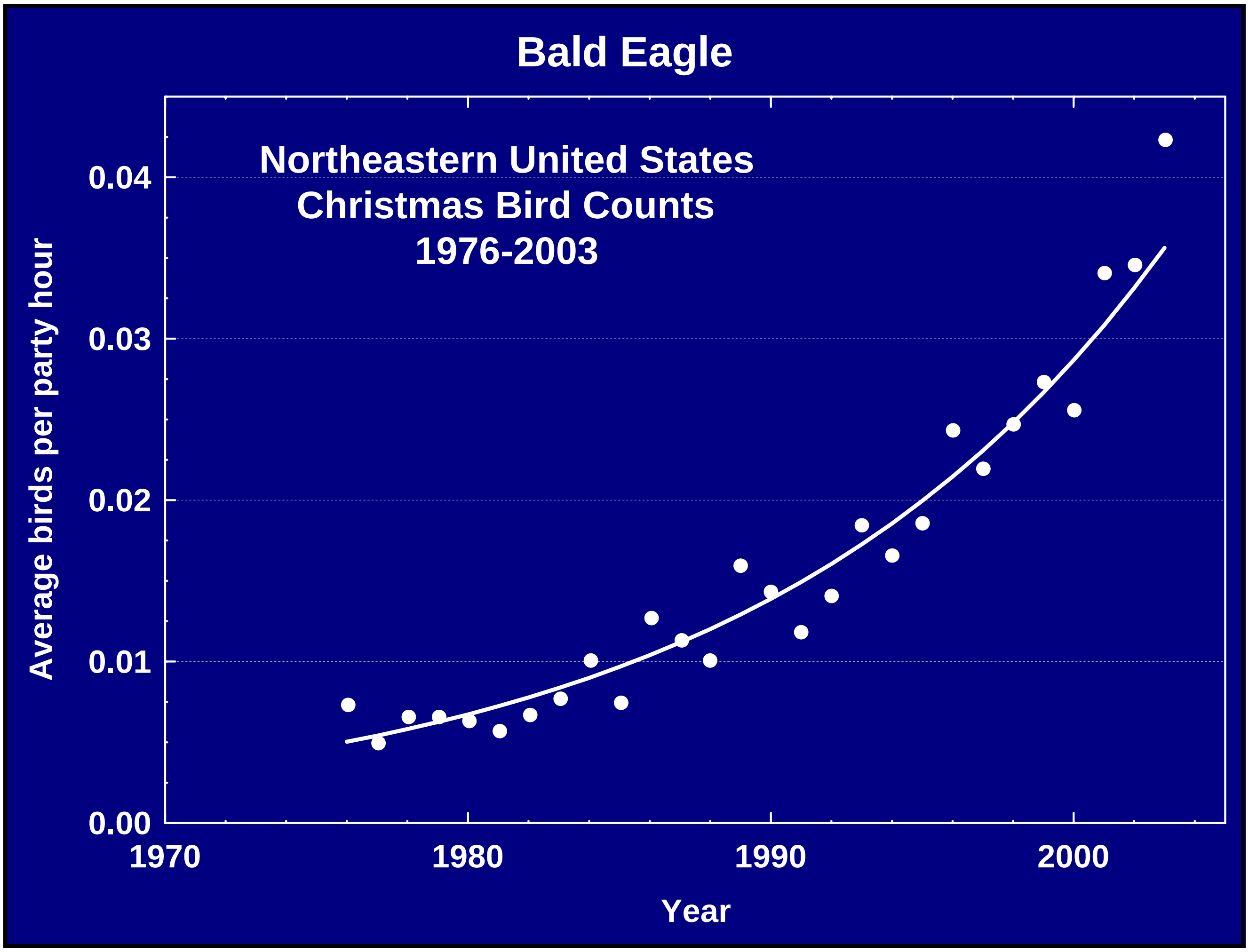
Adult and juvenile Bald Eagle annual population indexes (birds counted per day) for Hawk Mountain Sanctuary, Pennsylvania. From 1966-2003, the total population increased 3.1 % per year. Adults increased in the count 1.7% per year. Juveniles began increasing in the count about a decade before adults and increased at 5.3% per year. The lines indicate these statistically significant long-term trends.



Annual Bald Eagle population indexes (birds counted per day) for Hawk Mountain Sanctuary and Cape May Bird Observatory. From 1976-2003, the index increased by 5.2 % per year at Hawk Mountain and 8.5 % per year at Cape May. The lines indicate these statistically significant long-term trends.



Bald Eagle population indexes (average birds per route) for Breeding Bird Surveys in northeastern North America (U.S. states and Canadian provinces north of the southern borders of PA and NJ). From 1976-2003, counts of eagles on survey routes in this region increased 5.9 % per year. The line represents this trend, but due to high variability the trend was not statistically significant. (source: J. R. Sauer, USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.)



Bald Eagle population indexes (average birds per party hour) for Christmas Bird Counts in the northeastern United States. From 1976-2003, Christmas Bird Counts of eagles increased 7.2% per year. The line indicates the statistically significant long-term trend. (Data source: National Audubon Society. 2002. The Christmas Bird Count Historical Results [Online]. Available http://www.audubon.org/bird/cbc [November 2004].)

Hawk Mountain Sanctuary Conservation Status Report

Peregrine Falcon

Scientific Name: *Falco peregrinus*

French Name: *Faucon pélerin*

Spanish Name: *Halcón peregrino*

Body length[a]: Range: 36-58 cm (female ave: 51.5, male ave: 42.5)

Wingspan: Range: 90-117 cm (female ave: 111.0, male ave: 92.1)

Mass: Range: 530-1,595 g (female ave: 1,000, male ave: 660)

(There are three native subspecies in North America, and 19 subspecies worldwide. Four additional subspecies in North America owe their origins to introduction efforts in the late 20th century. Some variation in measurements may be due to the use of these introduced subspecies.)

Breeding Range in the New World (italicized terms are in the glossary):

Breeding range is discontinuous with known breeding in Alaska, including the Aleutian Islands, Alaska Peninsula, the northwest coast and north slope of the Brooks Range; Canada, including Yukon, Northwest Territories, Nunavat, British Columbia, Ontario along the Great Lakes, Quebec along the St. Lawrence river; Contiguous 48 United States, including northern and eastern states as well as Arizona, western Colorado, northern California, coastal Pacific Northwest, Montana, northwestern New Mexico, Utah, and northern Wyoming; Mexico, including Baja California and islands of the Gulf of California, Sonora, Chihuahua, Coahuila, Durango; Latin America, including much of South America, but not Central America.

Winter Range in the New World:

Winters primarily in coastal western Canada and Alaska, and in the contiguous 48 states; often in major urban areas. Neotropical distribution concentrated along coasts, in cities, and in wetlands

	throughout Caribbean, Mexico, Central and South America to approximately 40° S.
Type of Migrant:	Partial, "leap-frog".
Nest Type:	Small "scrape" or depression on a ledge, sometimes in old stick nests of other birds, also on building ledges in cities. Some nest sites are used across many decades, even after years of absence.
Food Habits:	Preys primarily on birds of between 50 and 500 grams, including passerines, waterfowl and other, smaller raptors. Also takes mammals (primarily bats), amphibians, fish, and insects. Avian prey are generally taken in flight.
Primary Flight Mode:	Powerful, moderately deep flapping with an irregular cadence. Infrequent gliding, sequences of alternate flapping and gliding.

ECOLOGY AND POPULATION STATUS

One of six falcons in North America, the Peregrine Falcon is long-winged, and second in mass to the Gyrfalcon. Adult peregrines have bluish-gray upperparts and a blackish head. The species has a dark malar, or "moustache" mark on each side of its face, whitish cheeks, whitish or buffy underparts with black spotting or bars, and gray or black barring on the undersides of its wings and tail. Females are 15-20% larger and 40-60% heavier than males. Although peregrines occasionally soar and glide, they are most often seen in flapping flight.

North America's best-known falcon, the peregrine is a truly cosmopolitan species. Found on every continent except Antarctica, some individuals from northern populations annually migrate up to 25,000 km. These characteristics make the species name, which is derived from Latin for "wanderer", quite fitting. Despite its near global range, the Peregrine Falcon is sparsely distributed in all but a few locations. This pattern of distribution makes it vulnerable to local extirpation, and is one of the reasons that a great deal of effort has been expended toward its conservation.

Peregrine Falcons, which have been prized for falconry for centuries, are often described as the perfect flying machine. The species is a powerful hunter, well suited for capturing avian prey. Peregrines are known for fast and maneuverable flight when chasing prey and when performing aerial courtship and territorial displays. Hunting peregrines typically strike their prey in the air and then grasp it with the talons. Sometimes they deliver a stunning strike or blow at the end of a high-speed "stoop", or dive and retrieve their prey on the ground.

The species prefers to nest on cliffs, and the presence of suitable nest sites often determines its distribution and density. Nest sites often overlook rivers and lakes, coasts, and mountain valleys. The species also nests on rocky islands. A nest site must afford protection from the weather and potential predators, and it must be in or near areas with adequate prey. Successful breeders rarely change nest sites, and preferred nest sites are used for generations. It is not uncommon for nest sites to be occupied for decades and, sometimes, for centuries.

The species also nests in tree cavities and in the stick nests of other species, as well as on the ground, and on manmade structures. Historically, peregrines were known to nest on old buildings in small towns. With the Peregrine Falcon's reintroduction in eastern North America, many individuals now nest in cities, where they prey on pigeons and rats. In 2000, 14 pairs of Peregrine Falcons were breeding in New York City.

Peregrine nests, or "eyries", typically consist of a shallow nest scrape, or depression. Nesting material is not added to the scrape. Males usually initiate construction of the scrape, but females often are involved as well. In some cases males prepare several scrapes at the nest cliff.

Although best known as aerial hunters, peregrines also hunt from perches. In North America, known prey includes more than 420 species of birds, and 23 mammals, including 10 bats. Peregrines kill birds as large as Sandhill Cranes, but their typical prey consists of smaller birds, including Mourning Doves, Rock Pigeons, American Robins, and Starlings. In coastal areas, shore birds and ducks are commonly taken. When migrating in concentrated flyways, Peregrine Falcons sometimes feed on other raptors, including Sharp-shinned Hawks, American Kestrels, and Merlins.

The Peregrine Falcon is a *partial migrant*. Migration begins across a broad front, but clearly defined routes become evident as the species concentrates along *leading* and *diversion lines*. Unlike many other raptors, peregrines often cross large bodies of water and are seen along coastlines not so much to avoid water, but rather because coastlines are prime hunting areas. Peregrine Falcons regularly cross the Gulf of Mexico and the Caribbean Sea. In eastern North America, coastal watchsites report many more migrating peregrines than inland watchsites.

Some peregrines migrate distances of up to 13,000 km one way. Northern breeders in Greenland and Canada, for example, overwinter as far south as central Argentina and Chile. Peregrines exhibit a "leap-frog" migration pattern in which breeders from northern areas overwinter south more southerly breeders.

Data from *raptor migration counts*, and *Christmas Bird Counts (CBCs)*, indicate that populations of Peregrine Falcons have increased in northeastern North America since 1976 (two years after the initiation of reintroduction efforts). From 1976 to 2003, migration counts at Hawk Mountain Sanctuary in Pennsylvania increased a *statistically significant* 5.1% per year ($P \leq 0.001$) whereas those at Cape May Bird Observatory in New Jersey increased a *statistically significant* 6.0% per year ($P \leq 0.001$). A lower overall rate of increase at Hawk Mountain Sanctuary of 1.2% annually between 1966 and 2003 is due to declines between the late 1960s and mid 1970s.

An analysis of recent *CBCs* (National Audubon Society 2002) south of Pennsylvania and New Jersey from 1976 to 2003 indicates a *statistically significant* increase of 5.5 % per year ($P \leq 0.001$). *CBCs* for the northeastern United States increased a *statistically significant* 9.2 % annually ($P \leq 0.001$) at the same time.

The annual *Breeding Bird Surveys (BBSs)*, conducted for the U.S. Geological Survey, do not include the Peregrine Falcon, so no population trend data are available from this source. However, other studies of breeding populations in North America indicate rates of increase between 5 and 10 % annually.

HISTORIC AND CURRENT CONSERVATION CONCERN

Historically, peregrines have been subject to several types of direct persecution including shooting, trapping, and egg-collecting. They also have been captured for use in falconry. Peregrines were shot at well-known migration spots, including Hawk Mountain and Cape May Point, in the early 20th century. During the *DDT era* of 1945-1972, numbers of peregrines in North America declined significantly. Counts of migrating peregrines declined precipitously at Hawk Mountain from the 1950s through the 1970s, and the species was considered *extirpated* in the eastern United States by 1965. In 1963 the desertion of nest sites in Great Britain was linked to the widespread use of organochlorine insecticides like *DDT*. In 1965, attention was drawn to the status of Peregrine Falcon populations in North America at a conference of raptor scientists held in Madison, Wisconsin, where significant declines caused by reproductive failure were described throughout the continenet. Subsequent research identified eggshell thinning as the cause of reproductive failure, and *DDT* residues (primarily the contaminant, DDE) as the cause of eggshell thinning. The widespread use of *DDT* was banned in the U.S. in 1972.

The Peregrine Falcon was listed as endangered under the Endangered Species Conservation Act in 1970, and it received protection under amendments to the Migratory Bird Treaty Act in 1972, and under the new Endangered Species Act in 1973. Regional recovery plans for the species were established under the Endangered Species Act, all of which sought to reduce the environmental contamination caused by pesticides, and most of which also called for extensive captive propagation and release programs. The release and reintroduction of peregrines propagated in captivity began in 1974. By 1998, almost 7,000 individuals had been released and breeding pairs had reclaimed over 700 territories vacated during the *DDT* era. The combined effects of strict legal protection, restoration efforts and the ban on the widespread use of *DDT* led Peregrine Falcon numbers to begin to increase in the late 1970s. Populations continued to increase in the 1980s and 1990s and by the late 1990s most populations had almost fully recovered.

Counts of migrating raptors began to reflect this increase in the late 1970s. For example, whereas an average autumn count for Hawk Mountain between 1934 and 2002 was 26 peregrines, an average of 44 were seen between 1993 and 2002. Migration counts at Cape May Bird Observatory have decreased a non-significant 9% per year since 1998. This may indicate either that the source population has recently stabilized, or is declining. Either way these North American counts suggest that populations of the Peregrine Falcons need to be monitored continually. Monitoring of migrants at watchsites is particularly important for this species because it is not monitored by *BBS*s on the breeding grounds.

[a]Principal source of information for physical and ecological summary:

White, C. M., N. J. Clum, T. J. Cade, and W. G. Hunt. 2002. Peregrine Falcon (*Falco peregrinus*). *In* The Birds of North America, No. 660 (A. Poole and F. Gill, eds). The Birds of North America, Inc., Philadelphia, PA.

RAPTOR MIGRATION COUNT DESCRIPTIONS

Cape May Point

LOCATION: 39°14'N, 74°49'W; within Cape May Point, 110 km s-se of Camden, 140 km s of Trenton, se New Jersey, ne United States.

ALTITUDE: Sea level.

BIOGEOGRAPHICAL PROVINCE: Nearctic Realm (1), Eastern Forest (1.5.5); Humid Temperate Domain (200), Hot Continental Division (220), Permanently Humid Eastern Oceanic Broadleaf Forests (221) (Bailey 1989).

SITE DESCRIPTION: A peninsula watchsite at the s tip of New Jersey. The 25-km long, 12 km-wide, ne-sw peninsula is between Delaware Bay (w) and the Atlantic Ocean (e). Cape May is 18 km ne of Cape Henlopen across the mouth of Delaware Bay. Dune scrub, salt marsh, tidal creek, and mixed forest dominate the site. Counts are conducted at Cape May Point State Park. The area surrounding the site includes private residences and businesses, intermingled with city parks and natural areas, including Higbee Beach Wildlife Management Area and the Nature Conservancy's Cape May Migratory Bird Refuge. Facilities at the site include a hawk-watch platform, nature center, walking trails, and parking lot. Counts are conducted from the hawk-watch platform at the edge the Cape May State Park parking lot. The platform, which has a 360° view, is handicap accessible.

Southbound migrants following the Atlantic Coastline are funneled to the tip of Cape May Point and concentrated in a small area due to surrounding waters. Migrants have been observed directly crossing the Delaware Bay, and also circling out of sight. Wind is a major factor, which affects direction and altitude of migrating raptors at the site. West winds seem to produce the most pronounced flight of Sharp-shinned Hawks.

A second watchsite, East Point, at the mouth of the Maurice River on Delaware Bay, 32 km to the northwest, records migrants that are reluctant to cross the mouth of

Delaware Bay at Cape May and that are following the bayshore northwest to a narrower crossing point.

LAND TENURE: State.

PROTECTION: The site includes Cape May New Jersey State Park, Higbee Beach Wildlife Management Area, and the Nature Conservancy's Cape May Migratory Bird Refuge.

LAND USE: Beaches, fishing, hiking, natural areas, parking lots.

THREATS: None.

MONITORING ACTIVITY: Sporadic monitoring (30-83 days, annually) in 1931-1937, 1965, and 1970. Regular monitoring since 1976. In most years 1-3 individuals conduct counts on 100-120 8-hr days, each autumn. Not regularly monitored in spring. Results are compiled by New Jersey Audubon's Cape May Bird Observatory.

MIGRATION PERIOD(S): Boreal autumn (Aug.-Dec.), also spring (Mar.-May).

RAPTOR SPECIES: Sixteen species are recorded as regular migrants at the site, 3 species as irregular migrants, and 2 species as vagrants. Information below, except for max.1-day counts, is based on 10 years (1976-1985) of counts. An average 68,400 raptors is observed each autumn. Species observed include Black Vulture (ave. ann. count: 2; max. 1-day count: 5, 24 Nov. 1984; max. ann. count: 5), Turkey Vulture (642; 200, 26 Oct. 1979; 959), Osprey (1540; 308, 6 Oct. 1985; 2940), Mississippi Kite (1; 3, 14 Aug. 1982; 4), Bald Eagle (18; 7, 16 Sep. 1985; 32), Northern Harrier (1640; 278, 12 Nov. 1980; 3120), Sharp-shinned Hawk (42,700; 11,096, 4 Oct. 1977; 52,300), Cooper's Hawk (1440; 421, 11 Oct. 1985; 2670), Northern Goshawk (33; 50, 7 Nov. 1973; 86), Red-shouldered Hawk (472; 162, 13 Nov. 1980; 749), Broad-winged Hawk (3840; 9400, 4 Oct. 1977; 13,900), Swainson's Hawk (2; 3, 25 Sep. 1981; 7), Red-tailed Hawk (1700; 494, 11 Nov. 1973; 2280), Rough-legged Hawk (6; 4, 13 Nov. 1983; 12), American Kestrel (12,300; 24,875, 16 Oct. 1970; 21,800), Merlin (1330; 273, 11 Oct. 1985; 2880), and Peregrine Falcon (249; 72, 8 Oct. 1983; 518) (Dunne and Sutton 1986).

Hawk Mountain Sanctuary

LOCATION: 40°38'N, 75°59'W; 11 km w of Kempton, 40 km west northwest of Allentown, and 40 km north of Reading, Pennsylvania, northeastern United States.

ALTITUDE: 190-465 m.

BIOGEOGRAPHICAL PROVINCE: Nearctic Realm (1), Eastern Forest (1.5.5); Humid Temperate Domain (200), Hot Continental Regime Mountains (M220), Forest-alpine Meadows (M221) (Bailey 1989).

SITE DESCRIPTION: A mountaintop watchsite on the Kittatinny Ridge, the 300-km long, se-most ridge in the central Appalachian Mountains of eastern Pennsylvania. The site includes more than a dozen ridgetop outcrops overlooking the Kempton valley to the east and Little Schuylkill River valley to the west. Forest cover is primarily second-growth mixed deciduous forest, including oak-maple (*Quercus-Acer*) associations and Eastern Hemlock (*Tsuga canadensis*). Valleys surrounding the site are characterized by rolling, partly wooded farmland and Christmas-tree plantations (Brett 1991).

The Appalachian Trail abuts the Sanctuary on the east. Visitor facilities include a raptor museum, visitor center, bookstore, and living quarters for visiting researchers. The Sanctuary, which is open year-round, attracts > 80,000 visitors, annually, with <3000 visitors on some weekend days in Oct. Visitors have access to 10 lookouts and 15 km of trails. Admission is charged for access to the lookouts. Sanctuary-associated visitation contributes >1.5 million $US to the local economy.

The site's principal lookout, North Lookout, is a 465m rocky outcrop with a 240° view to the northeast. The lookout, which is accessible only by foot, is 1 km from the Visitor Center parking lot. Raptors slope soar along the Kittatinny Ridge at the site. Migration is most pronounced on northwest winds, especially on the several days following the passage of cold fronts.

LAND TENURE: Private.

PROTECTION: The site is in a 900ha private wildlife sanctuary, and adjacent to 9000 ha of State Gamelands and National Park Service's Appalachian Trail.

LAND USE: Outdoor recreation, ecological research, environmental education.

THREATS: None.

MONITORING ACTIVITY: Monitoring has occurred since 1934 (excluding 1943-1945). 1-3 individuals conduct counts on the North Lookout on an average 110 days (15 Aug.-15 Dec.), annually. A spring count (15 April-15 May) was reinitiated in 1998. Counts also have been made from other lookouts at the site.

MIGRATION PERIOD(S): Boreal autumn (Aug.- Dec.), also spring (late Mar.-May).

RAPTOR SPECIES: Sixteen species are recorded as regular migrants; 2 species as irregular migrants. Information below is based on 59 years of data (1934-1995). An average 18,000 raptors is seen each year. Species observed include Black Vulture (ave. ann. count: 36), Turkey Vulture (103), Osprey (686; period of peak passage: late Sep.; max. 1-day count: 175, 23 Sep. 1989), Bald Eagle (61; Sep. and Dec.; 48, 4 Sep. 1950), Northern Harrier (312; no peak; 49, 16 Sep. 1980), Sharp-shinned Hawk (7640; early Oct.; 2620, 8 Oct. 1979), Cooper's Hawk (589; early Oct.; 204, 8 Oct. 1981), Northern Goshawk (59; mid-Nov.; 64, 10 Nov. 1973), Red-shouldered Hawk (263; late Oct.; 173, 23 Oct. 1977), Broad-winged Hawk (8340; mid-Sep.; 21,448, 14 Sep. 1978), B. swainsoni (13 in 59 years), Red-tailed Hawk (3780; early Nov.; 1144, 24 Oct. 1990; Rough-legged Hawk (14), Golden Eagle (62; early Nov.; 14, 12 Nov. 1987), American Kestrel (625; early Oct.; 168, 3 Sep. 1977), Merlin (85; early Oct.; 34, 3 Oct. 1989); Gyrfalcon (6 in 59 years) and Peregrine Falcon (33; early Oct.; 11, 7 Oct. 1937).

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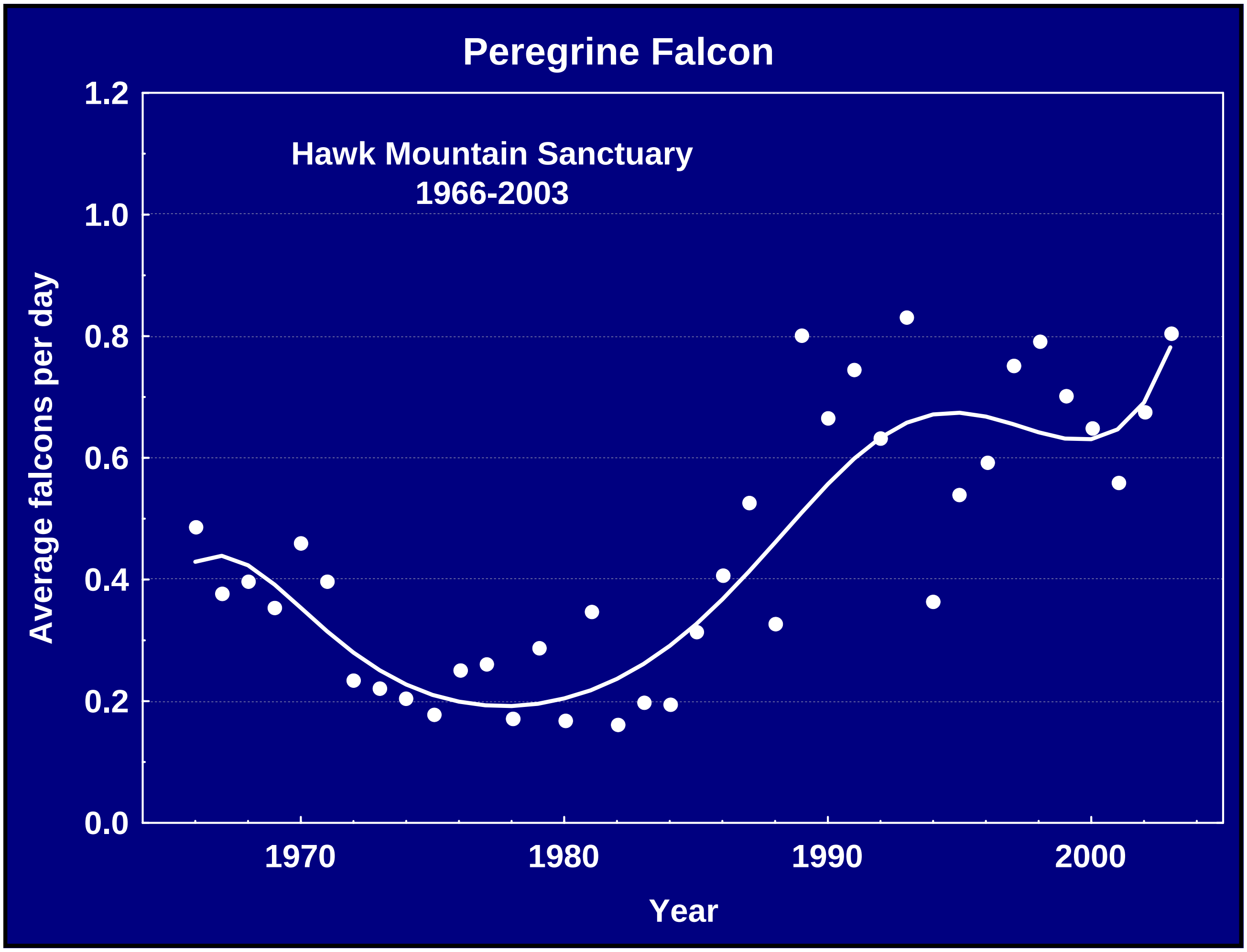
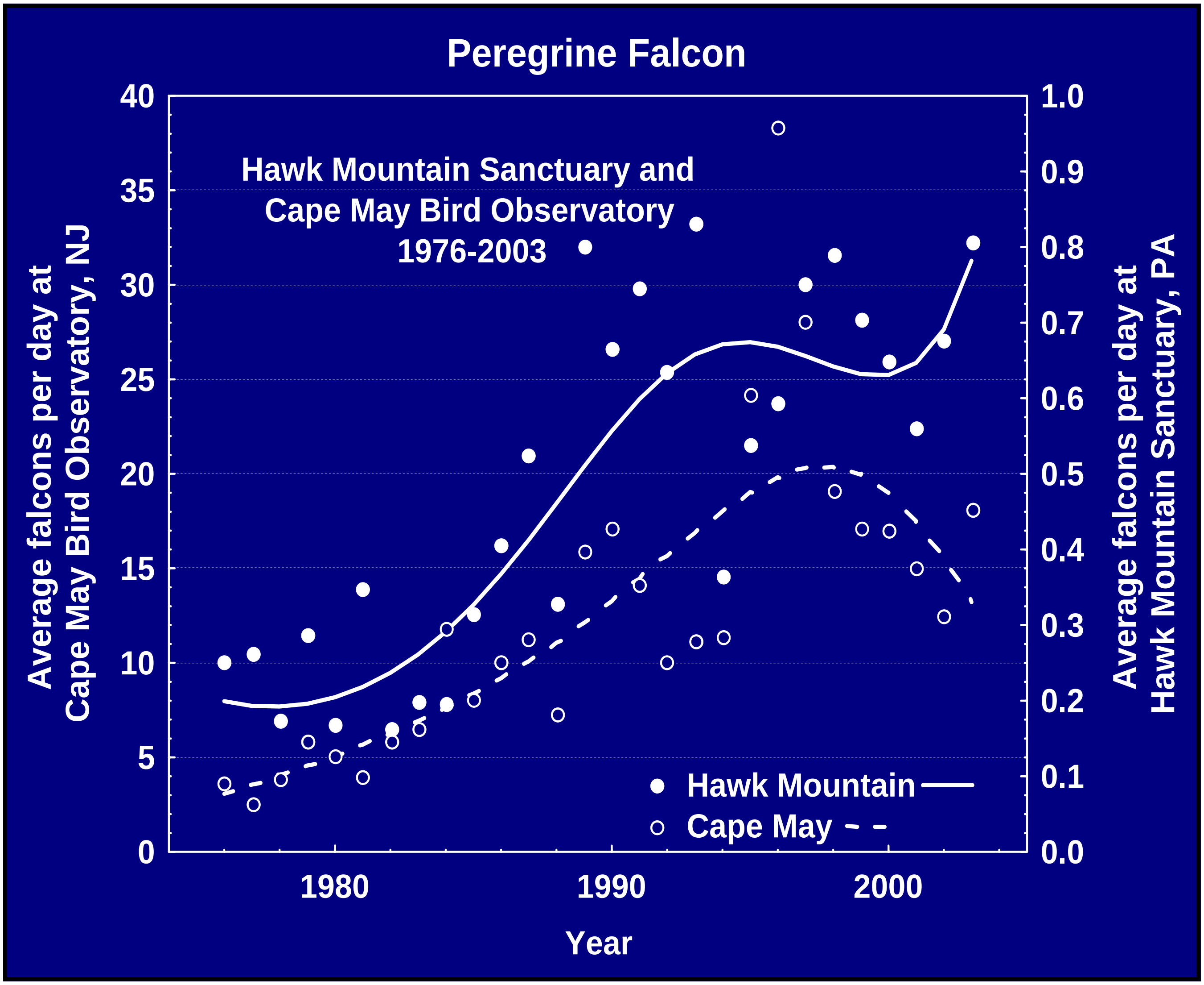
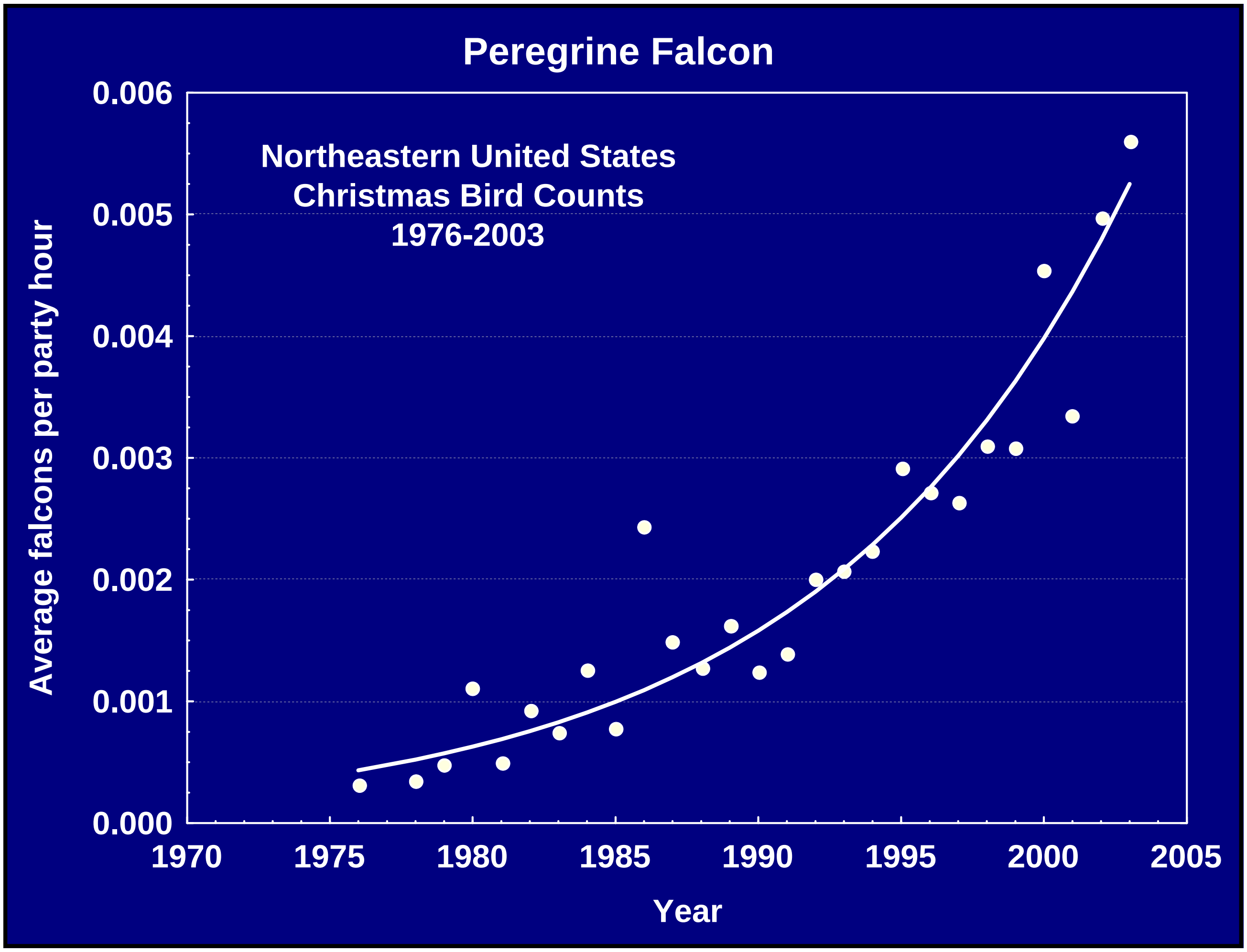


Peregrine Falcon population indexes (birds counted per day) for Hawk Mountain Sanctuary, Pennsylvania. From 1966-2003, the total population increased 1.2 % per year. The line indicates the statistically significant long-term trend.



Annual Peregrine Falcon population indexes (birds counted per day) for Hawk Mountain Sanctuary and Cape May Bird Observatory. From 1976-2003, the index increased by 5.1 % per year at Hawk Mountain and 6.0 % per year at Cape May. The lines indicate these statistically significant long-term trends.



Peregrine Falcon population indexes (average birds per party hour) for Christmas Bird Counts in the northeastern United States. From 1976-2003, Christmas Bird Counts of eagles increased 9.2 % per year. The line indicates the statistically significant long-term trend. (Data source: National Audubon Society. 2002. The Christmas Bird Count Historical Results [Online]. Available http://www.audubon.org/bird/cbc [November 2004].)

Glossary of Terms

Hawk Mountain Sanctuary Conservation Status Reports

Accipiter. A genus of approximately 50 largely forest-dwelling species of diurnal raptors, most of which have short, rounded wings and long tails.

Age Structured Population. A population in which birth and death rates vary as functions of the age of the individual.

Atlantic flyway. Migration flyway along the Atlantic coast of North America, consisting of Canadian provinces New Brunswick, Nova Scotia, Ontario, Quebec and U.S. states Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, and West Virginia.

Breeding Bird Survey (BBS). A monitoring program for bird populations on their breeding grounds developed at the USGS Patuxent Wildlife Research Center in Laurel, Maryland to monitor population trends on a continental scale. The North American Breeding Bird Survey (BBS) was formally launched in 1966 when approximately 600 surveys were conducted in the U.S. and Canada east of the Mississippi River. Today there are approximately 3700 active BBS routes across the continental U.S. and Canada, of which nearly 2900 are surveyed annually. A three-minute point count is conducted at each stop, during which the observer records all birds heard or seen within 0.25 mile of the stop. Routes are randomly located in order to sample habitats that are representative of the entire region. Other requirements such as consistent methodology and observer expertise, visiting the same stops each year, and conducting surveys under suitable weather conditions are necessary to produce comparable data over time. A large sample size (number of routes) is needed to average local variations and reduce the effects of sampling error. The density of BBS routes varies considerably across the continent, reflecting regional densities of skilled birders.

Breeding range. The geographic area where a species is known to reproduce.

Buteo. A genus of 28 species of largely open-habitat diurnal raptors with long, broad wings and short tails.

Chain migration. Occurs when migratory populations that breed at high latitudes migrate approximately the same distance as those that breed at lower latitudes, thereby maintaining their latitudinal relationship between seasons.

Christmas Bird Count (CBC). A winter monitoring program for birds in North America, administered by the National Audubon Society. It consists of a series of “count circles,” 15 miles (24 km) in diameter, which are surveyed on a single day between December 14th and January 5th each year. On the survey day, a team of birders counts every bird they encounter within the circle and records its species. The Christmas Bird Count began on Christmas Day 1900, when ornithologist Frank Chapman proposed a new holiday tradition - a "Christmas Bird Census" - that would count birds in the holidays rather than hunt them.

Complete migrant. A species or population in which at least 90% of all individuals regularly migrate.

Differential migration. Age-or sex-related differences in one or more aspects of migration behavior, including direction or speed of travel, distance traveled, timing of departure, etc.

Diurnal. Active primarily during daylight hours.

Diversion line. A geographic or topographic feature that has features that cause migrants to alter their course so as to avoid crossing the line, making them appear to follow it (see leading line).

DDT. DDT (dichlorodiphenyltrichloroethane) is a pesticide once widely used to control insects in agriculture and insects that carry diseases such as malaria. DDT is a white, crystalline solid with no odor or taste. A persistent, broad-spectrum compound often termed the "miracle" pesticide, DDT came into wide agricultural and commercial usage in the United States in the late 1940s. By 1972, approximately 675,000 tons had been applied in the U.S. The peak year for use in the United States was 1959, when nearly 80 million pounds were applied. After 1959, use declined steadily to about 13 million pounds in 1971, most of it applied to cotton. The decline was attributed to a number of factors including increased insect resistance, development of more effective alternative pesticides, growing public and user concern over adverse environmental side effects, and governmental restriction on DDT beginning in 1969. Its use in the United States was banned in 1972 because of damage to wildlife, but is still used in some countries. DDE (dichlorodiphenyldichloroethylene) and DDD (dichlorodiphenyldichloroethane) are chemicals similar to DDT that contaminate commercial DDT preparations. For additional information on these and other pesticides, visit the following internet website: http://www.atsdr.cdc.gov/tfacts35.html

Extirpated. Eliminated from an area.

Falcon (genus Falco). A genus of 37 diurnal raptors with long, pointed wings and long tails.

Irruptive migrant. Species or populations in which the extent of migratory movement varies annually, typically due to among-year shifts in prey abundance, and whose migrations are less regular than those of partial and complete migrants.

Leading line. Geographic or topographic features that intersect the principal axis of migration of a region and have properties that induce migrants to change their direction of travel so as to follow them.

Leap-frog migration. Occurs when migratory populations that breed at high latitudes migrate substantially farther and "leap over" non-migratory (and sometimes, migratory) populations that breed at lower latitudes. This effectively reverses their latitudinal relationship between seasons.

Long-distance migrant. A species in which at least 20% of all individuals regularly migrate more than 1,500 miles (2,400 km).

Migration. Directed movements from one location to another, recurring seasonally and alternating in direction.

Raptor migration count. A location at which visible migrants are regularly and systematically counted and recorded.

Migration Flyway. Pathway of travel along which raptors concentrate while migrating.

Partial migrant. Species or population in which fewer than 90% of all individuals regularly migrate, whereas others do not.

Short stopping. A phenomenon, first described in migratory waterfowl, that occurs when migrants shorten the lengths of their outbound movements to take advantage of newly available wintering areas that are closer to their breeding grounds than traditional wintering areas.

Statistically significant. A population trend is considered statistically significant if there is high confidence that it is actually different from zero. The *P*-values associated with the trend estimates report this probability that the trend is real (non-zero); the smaller the *P*-value, the greater the probability. For example, $P \leq 0.001$ for Cape May means the chance that the true trend equals 0% per year is less than 0.1%. Our confidence in the Cape May trend is therefore very high. Ecologists typically describe any result where $P \leq 0.05$ as statistically significant, but other levels (for example 0.10 or 0.01) are sometimes chosen, depending on the question being asked. In Hawk Mountains' raptor conservation status reports, any trend for which $P \leq 0.05$ is considered to be statistically significant.

Thermal. A pocket of warm, rising air created by the differential heating of the earth's surface.

Wind drift. Occurs when migrants encountering cross winds are pushed off their intended course even while maintaining the same heading.

Winter range. The geographic area where a species is known to "over-winter" during the non-breeding season.

West Nile Virus. West Nile Virus (WNV) has emerged in recent years in temperate regions of Europe and North America, presenting a threat to public and animal health. The most serious manifestation of WNV infection is fatal encephalitis (inflammation of the brain) in humans and horses, as well as mortality in certain domestic and wild birds. WNV has also been a significant cause of human illness in the United States in 2002 and 2003. West Nile virus has been detected in dead birds of at least 138 species in North America. Although birds, particularly crows and jays, infected with WN virus can die or become ill, most infected birds do survive. There is no evidence that a person can get WNV from handling live or dead infected birds. For information about West Nile Virus, try this webpage operated by the Centers for Disease Control (http://www.cdc.gov/ncidod/dvbid/westnile/index.htm).