Migratory Bird Program at the U.S. Geological Survey Patuxent Wildlife Research Center/U.S. Fish and Wildlife Service Patuxent Research Refuge: Transformations in Management and Research

By R. Michael Erwin and Robert J. Blohm

Introduction

The Patuxent Wildlife Research Center (Patuxent), first known as the Patuxent Research Refuge, has a long and rich history of participation in the Department of Interior's (DOI) cooperative efforts to protect and conserve migratory birds in North America. This chapter describes many of the events and the people involved that constitute this important timeline for international conservation of a shared wildlife resource.

The Patuxent Research Refuge, renowned worldwide, is part of the National Wildlife Refuge System of the U.S. Fish and Wildlife Service (USFWS) that has, at different times and under a variety of organizational iterations, provided the physical location of Patuxent, the Migratory Bird Population Station (MBPS), the Migratory Bird and Habitat Research Laboratory (MBHRL), and the Laurel Branch of the Office of Migratory Bird Management (MBMO, now Division of Migratory Bird Management [DMBM]). This chapter also emphasizes the interrelations between the management objectives of the USFWS and the research program at Patuxent. Following incorporation of the research program into the National Biological Survey (NBS) and subsequently into the U.S. Geological Survey (USGS), the Migratory Bird program took on new identities, while the management functions continued to evolve within the USFWS despite these changes. Nevertheless, the USFWS and other agencies such as the National Park Service (NPS) were longstanding "clients" of the research community within DOI, and many of the former linkages between management and research were maintained.

Origins of the Migratory Bird Program

The Federal Migratory Bird Treaty Act of 1918, following earlier bird protection laws such as the Lacey Act (1900) and the Migratory Bird Act (1913), was one of the earliest and arguably one of the most important environmental laws enacted in the United States. These laws followed early efforts of protection initiated by the National Audubon Society and other organizations that recognized the devastating effect of unregulated sport and plume hunting on many species of migratory birds. As a result, more than 800 species of birds now receive protection under the act, which remains a landmark of wildlife conservation legislation, protecting our continent's migratory bird resource.

Most of the management and research on birds that occurred in the United States after the Federal Migratory Bird Treaty Act was passed, however, was directed at the agricultural impacts of birds. In fact, at the time of enactment, Federal responsibilities for migratory birds were assigned to the U.S. Department of Agriculture (USDA), Bureau of Biological Survey. Depredations on crops by blackbirds, starlings (*Sturnus vulgaris*), sparrows, crows (*Corvus brachyrhychos*), and other species dictated much of the focus of bird research in the USDA. Ironically, rather than concentrating on conservation, the early decades were devoted mainly to controlling bird populations! During the 1930s, the Dust Bowl drought period in the interior of the country, combined with excessive hunting, severely depleted waterfowl populations, forcing some changes in Federal responsibilities. In 1940, bird research, along with the Bureau of Biological Survey, was transferred from the USDA to the DOI, under the USFWS. A major division within the new agency was the Federal Wildlife Refuge System. Several Federal refuges had already been designated (beginning with Pelican Island in Florida, designated by President Theodore Roosevelt in 1903), focusing primarily on providing quality habitat along waterfowl migration routes and at wintering areas. The Patuxent Research Refuge (the original name of Patuxent as established in 1936) was unique in being the only refuge created with the term "research" in its enabling legislation. As part of its research mission, the Federal banding program, begun in 1920 in Washington, D.C., was transferred to the Patuxent Research Refuge in 1942, where it evolved into the Bird Banding Laboratory. For more information about the early history of Patuxent, visit the Web site http://www.pwrc.usgs.gov/75th/pwrc_timeline_20110830/ and other chapters in this report.

The Early Years at Patuxent: 1936–70

Much of the work conducted at Patuxent from the 1930s through the 1960s was centered on basic waterfowl biology and a variety of agricultural questions. Experimental work on various seeds of aquatic plants collected across North America was started by research biologist Francis Uhler on the Patuxent impoundments. His primary motivation was to determine which species were best propagated in impounded fresh and brackish water to enhance overwintering waterfowl populations. Whereas today's ecologists consider invasive species to be a recent phenomenon in the United States, Patuxent biologists were working on the problem in the early 1950s; invasive plants and their effects on habitat conditions became focal areas of research on freshwater wetlands and in Chesapeake Bay. Water chestnut (*Trapa natans)* (Uhler, 1954) and Eurasian watermilfoil (*Myriophyllum spicatum)* (Steenis and Stotts, 1965) were two of the important invaders that prompted efforts to develop effective control measures. Much of this early natural history work at the refuge was based on individual knowledge of aquatic plant life histories, and many experiments were conducted both in greenhouses and in impoundments, albeit not in a rigorous hypothesis-testing framework. Mr. Uhler, John Steenis, and Neil Hotchkiss were some of the early Patuxent biologists who brought years of field experience to the refuge programs.

Art Hawkins nest searching, Minnedosa, Manitoba, Canada, 1978. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

Studies of the population dynamics of waterfowl began very early at Patuxent under the auspices of the USFWS, Division of Wildlife Research, with coordinated banding programs begun in earnest in the 1950s (Hawkins and others, 1984). As mentioned earlier, national concerns for waterfowl population declines were voiced following the Dust Bowl-era droughts of the 1930s in much of the continent's interior, and later following periods of little precipitation and reduced duck numbers in the late 1940s. Banding crews were assigned to Montana, the Dakotas, and three western Canadian provinces to band flightless mallards (*Anas platyrhynchos*), as well as other ducks captured coincidentally with mallards, while adults were molting. The emphasis at this time was to determine the distribution of the mallard harvest. Other early efforts included diving duck banding in Alaska and black duck *(Anas rubripes)* banding in the Maritimes of Canada.

Biologists at Patuxent also figured prominently in early cooperative efforts to establish better ways of monitoring the status of waterfowl. Following World War II, the lack of breeding ground information on declining waterfowl populations prompted biologists and administrators in Canada and the U.S. to explore ways of developing improved methods of counting these birds and evaluating their breeding habitats across large areas of the continent in the spring. Fortunately, after the war, small aircraft were available as surplus and soon became part of the fleet used in experimental survey work of wildlife populations, namely waterfowl. Work in the air and on the ground revealed that birds could be counted by species from low-flying aircraft, and soon a statistically reliable method for determining breeding population size and distribution of waterfowl and assessing habitat conditions was in place. This annual survey, first operational in 1955, was then expanded beyond its origins in the prairie-parkland region of western Canada and the north-central U.S. to northern "bush" areas, including parts of Alaska. In the early 1960s, a second annual (July) survey was established to obtain a measure of waterfowl productivity by counting broods.

This cooperative effort to count waterfowl each year on the breeding grounds is widely recognized as one of the most reliable wildlife surveys in the world. Moreover, it remains a primary source of information used in the annual development of hunting regulations in Canada and the U.S. Biologists from Patuxent, who played key roles in this survey achievement, included Walter Crissey (see Crissey's autobiography [Crissey, 2006]), E.B. (Jake) Chamberlain, Fred Glover (see Glover, 2010), Chuck Evans, and John (Johnny) Lynch. During this period, many biologists, including flyway biologists (pilots), were associated with migratory game-bird management investigations and assigned to management offices within the USFWS (for example, Branch of Game Management, later Branch/Division of Management and Enforcement).

Because of their field responsibilities, biologists were typically often stationed around the country, including at Patuxent (Chamberlain, Glover, and Evans). Crissey, a biologist for migratory game birds in the Section of Waterfowl Management Investigations, Division of Wildlife Research, and stationed at Patuxent, was also a pilot (and later became the first director of MBPS; see below). Lynch, who was stationed in coastal Louisiana for virtually his entire career, operated a field office for Patuxent and was actively involved with surveys of snow geese (*Anser caerulescens*) and other Gulf Coast waterfowl. Chamberlain, Glover, and Evans were instrumental in evaluating the feasibility (later deemed impractical until renewed efforts in the 1980s) of establishing systematic waterfowl surveys in eastern Canada to complement efforts in the West. Over the years, Dr. Glover also participated extensively in the Canadian waterfowl banding program, as well as winter surveys in Mexico and Central and South America. Dr. Joe Linduska, editor of "Waterfowl Tomorrow" (Linduska, 1964), which chronicled at the time more than three decades of work on waterfowl in North America, including the aforementioned survey and banding efforts, was also a colleague of Crissey, Glover, and others at Patuxent in the early 1950s; he later became Chief of the Branch of Game Management in the USFWS.

Crissey also worked with Patuxent biologist Earl Atwood in the early 1950s to design and implement a national mail survey that would provide annual estimates of the number of waterfowl hunters and their harvest of ducks and geese. This approach far surpassed earlier efforts to estimate waterfowl harvest that relied on hunter bag checks, which were of little meaningful use in managing the annual kill. A few years later, Dr. Aelred Geis and Mr. Samuel Carney, both stationed at Patuxent, developed the Waterfowl Parts Collection Survey that is still conducted annually to estimate the species, sex, and age composition of the duck and goose harvest in the U.S. Among others working in the harvest surveys group at the time were Glen Smart, Ed Rosasco, and Woody Martin.

More locally, with the proximity of Chesapeake Bay to Patuxent, a good deal of waterfowl research took place in the bay, with interest in both native tundra swans (*Cygnus columbianus*) (formerly whistling swans) and non-native mute swans (*Cygnus olor),* as well as the large wintering populations of canvasbacks (*Aythya valisineria)*. These nearby wildlife resources fostered a long line of research and management work by staff centered at Patuxent that continues in various forms today.

It soon became apparent that with the successful development and implementation of several large-scale data-gathering efforts for migratory birds, and with other monitoring efforts

Leaders in Migratory Birds at Patuxent Wildlife Research Center meeting, Laurel, MD, 1969. (Left to right: 1st row, Frank Bellrose, Ian Nisbet, Ira Gabrielson, Walter Crissey, Roland Clement; 2nd row, Oliver Austin, William Drury, Robert Carrick, Eugene Dustman; 3rd row, Howard Wight, John Aldrich, Charles Henny, Kenneth Williamson, Hugh Boyd; 4th row, Lars von Haartman, Laurence Jahn, Joseph Hickey, Harvey Nelson; 5th row, Lee Eberhardt, Aelred Geis, John Gottschalk, Alexander Dzubin.) (From U.S. Fish and Wildlife Service, 1972) under consideration, the ever-growing base of information that resulted was quickly outstripping annual efforts for analysis and interpretation. Consequently, in 1961, the USFWS reorganized within the Division of Research by creating the Migratory Bird Populations Station located at Patuxent. This new but separate office was given specific responsibilities that combined both research and management functions, whereas other ongoing research activities, such as environmental contaminants, animal damage control, and wetland ecology, remained with the research facility. Special emphasis was given to the analysis and interpretation of the aforementioned large stores of information on migratory birds that were becoming available each year, in addition to other biological investigations that were assigned to the station. The internationally recognized Bird Banding Laboratory (BBL) became part of this new organization as well, and many band-recovery data, critical in the development of annual hunting regulations, added to the workload.

Walt Crissey was appointed the first director of MBPS. Other migratory bird biologists in this office included Al Geis, John P. Rogers (assistant director, following Al Geis); Chan Robbins (Non-Game Birds); Howard Wight, Bill Kiel, Jim Teer, Fant Martin, Roy Tomlinson, Jim Ruos, Bill Goudy, and Milt Reeves (Migratory Shore and Upland Game Birds); Al Duvall and Earl Baysinger (Bird Banding Laboratory); and Robert I. Smith, Kahler Martinson, Chuck Kaczynski (Kimball), Cal Lensick, Chuck Henny, Dave Anderson, Ken Burnham, and Dick Pospahala (Waterfowl).

Whereas ducks, geese, and swans were the primary focus at the outset, other migratory game-bird species, including woodcock (*Scolopax minor*), mourning doves (*Zenaida macroura*), white-winged doves (*Zenaida asiatica*), and rails, soon received much-needed attention from staff at the station. Work focused on many aspects of the annual cycle of these webless game-bird species, with particular emphasis on population status, productivity, habitat requirements, and mortality factors, including hunting (see Sanderson, 1977). Important advances were soon forthcoming. Ongoing analyses of band-recovery information helped inform the creation of two management units for woodcock in the eastern and central U.S. Biologists, including Fant Martin, Bill Goudy, and later Bill Krohn, Tom Dwyer, and others, helped establish and refine the woodcock singing ground survey, contributed to the development of valid sex and age identification criteria for harvested woodcock (using their wings [F. Martin]), and improved understanding of woodcock biology and management. Mourning dove work also benefited from staff work at Patuxent. For example, the three management units that guide the activities of dove managers today are based on an analysis of mourning dove band recoveries by Bill Kiel in the late 1950s, and Patuxent and MBPS staff helped improve the long-running call-count survey, using a stratified random sampling approach for the selection of survey routes around the country, during 1957–66. An outgrowth of Roy Tomlinson's work while at the station in the mid-1960s was the development of a comprehensive, long-range research and management program for mourning doves in the U.S. (R.E. Tomlinson, 1966, unpub. report available at the U.S. Fish and Wildlife Service, Division of Migratory Bird Management).

Parallel to the migratory game-bird work, the Animal Damage Control unit was formed at Patuxent, following the transfer of the "economic pests" programs from the USDA to DOI in 1940. The early emphasis at Patuxent was on research to evaluate how hedgerow and field border management for wildlife might minimize effects on agricultural production. One of the more productive researchers, Brooke Meanley, conducted many studies of red-winged blackbirds (*Agelaius phoeniceus*) in grain-belt areas, where the emphasis was on finding control solutions at the huge wintering roosts. His interests included rails and other marsh species in addition to blackbirds (Meanley and Webb, 1963; Meanley, 1975).

A major change in wildlife and avian science occurred after the 1962 publication of Rachel Carson's "Silent Spring" (Carson, 1962). This award-winning book has been widely recognized by environmental scientists across North America as the most influential book on the environment published in the 20th century. It spurred national concerns for both wildlife and human health. As a result, a major new research thrust was undertaken at Patuxent with the formation of a Contaminants Research program—first under Dr. Eugene Dustman, followed by Dr. Lucille Stickel—that was separate from the Migratory Bird program. This new focus provided a major impetus to the "nongame-bird" research field that had been quietly progressing under Robert Stewart and Chandler Robbins since the late 1940s. In spite of very limited funding, these two biologists produced a much-cited book on bird distribution throughout the Washington, D.C., and Chesapeake Bay area (Stewart and Robbins, 1958).

Robbins, concerned with songbird declines reported by many citizens, teamed up with Canadian Wildlife Service

Brooke Meanley banding blackbirds at night in Arkansas, 1951. Photo by Garner Allen, U.S. Fish and Wildlife Service volunteer.

Bob Stewart raking submerged aquatic vegetation in the Susquehanna Flats, Chesapeake Bay, 1950s. Photo by Paul F. Springer, U.S. Fish and Wildlife Service.

biologist Anthony Erskine to create the North American Breeding Bird Survey (BBS), using volunteers across the U.S. and southern Canada. The first full year of the BBS was 1965, when Robbins reported that about 50,000 birds had been counted (Robbins, 1965)—a truly impressive beginning of what would later become the longest running systematic terrestrial wildlife survey in North America. Today (2016), the BBS remains the monitoring standard for assessing land-bird population trends and helps inform and guide decision making within the avian research and management communities (see the Web page developed by Dr. John R. Sauer and others at the Patuxent Wildlife Research Center [http://www.pwrc.usgs.gov/bbs/bbs.html] and Sauer [2016]).

Finally, in 1965, under Dr. Dustman's leadership, the Endangered Species Research program was founded and headed by Dr. Ray Erickson. Captive propagation at Patuxent soon gained national and international prominence, with efforts focused on bald eagles (*Haliaeetus leucocephalus*) and whooping cranes (*Grus americana*) as part of broader restoration efforts to enhance their numbers in the wild.

The Environmental Era: 1970s

With the advent of Earth Day in 1970 and the support generated during the Nixon Administration for several environmental initiatives, including most prominently the passage of the National Environmental Policy Act (1972) and the Endangered Species Act (1973), funding levels in the DOI increased dramatically. The awakening of the public with the publication of "Silent Spring" (Carson, 1962) and improved media coverage of environmental incidents converged to encourage greater Federal attention to scientific research. Patuxent benefited greatly from this momentum, hiring many new scientists in the areas of environmental contaminants, endangered species, and migratory birds. These areas later became separate programs within the USFWS.

In 1972, the USFWS underwent a major reorganization with respect to migratory birds. This move was prompted first by migratory bird management responsibilities within the USFWS that were expanding quickly and needed to be addressed. Secondly, personnel involved in many management-related field activities (for example, surveys and banding) often came from many different offices spread throughout the organization, such as the Division of Research/MBPS and Division of Management and Enforcement, among others, that complicated staffing assignments. Finally, field studies on key migratory bird research topics and ongoing efforts to analyze the wealth of banding and population data, previously assigned to MBPS, needed to be maintained, at a minimum, and expanded if possible. As a result, two new offices were formed with personnel primarily from the aforementioned divisions. The Office of Migratory Bird Management (MBMO) was created to function solely on the management side of migratory bird work, whereas the other new office, the Migratory Bird and Habitat Research Lab (MBHRL), retained migratory bird research as its primary responsibility.

In effect, the dissolution of MBPS completed the separation of research and management activities related to migratory birds within the USFWS. (Later, each regional office in the USFWS began to enhance in-house capacity for migratory bird management with the addition of a Migratory Bird Coordinator and support staff to their organizational structure.) Dr. John P. Rogers was selected as the first chief of MBMO, with George Brakhage as his assistant chief; Dr. Robert I. Smith became the first director of MBHRL. Bob Smith was soon transferred to MBMO headquarters in Washington, D.C., to begin work on the lead poisoning issue in waterfowl, at which time Dr. Fant Martin replaced him as director.

Most staff members in the new management office were located at Patuxent in the Branch of Surveys, although the chief's office was headquartered in Washington, D.C., and many flyway biologists (pilots) in the Branch were assigned to field stations around the country. Mort Smith became chief of the Branch of Surveys, with Dick Pospahala as his assistant chief. Housed within this group were the Bird Banding Lab (George Jonkel, Chief); Waterfowl Population Surveys (Duane Norman, Chief, but located in Portland, OR); Harvest Surveys (Sam Carney, Chief); computer support and Electronic Data Processing (Bill Bauer, Chief); and staff specialist support (doves, woodcock, waterfowl), along with other administrative and support personnel. Similarly, most MBHRL personnel were also located at Patuxent, although some staff members were assigned to field stations around the country. Scientists involved in disciplines, such as environmental contaminants research and endangered species propagation, remained assigned to Patuxent. The office of the Atlantic Flyway Representative, located at Patuxent, was now attached to MBMO. Ed Addy had occupied this important position, first as a flyway biologist and then as the flyway representative, since the late 1940s and served as the liaison between the USFWS and the Atlantic Flyway Council until he retired in 1972; he was replaced by Warren Blandin. Both MBMO and MBHRL operated independently of Patuxent's director, although all offices shared some administrative and maintenance support and contributed to overhead costs associated with the amount of space occupied.

In spite of the organizational separation, strong connections were sustained between the MBMO and the researchers at Patuxent. Work in the late 1960s and early 1970s was devoted primarily to analyzing bird-band recoveries. This effort was led by Drs. Charles Henny and David Anderson, who established a strong statistical basis for population assessment using banding data. Beginning in 1969, an in-depth study of the mallard was begun by biologists in both offices, focusing on data that had been gathered from 20 years of field investigations in North America. Results of this work became known as the "Mallard Report Series," an eight-volume set of reports that ultimately improved understanding of mallard numbers and their relation to habitat availability and hunting mortality. This series, authored by many MBHRL/MBMO biologists, is one of the most comprehensive studies of a single waterfowl species available today.

Dr. Anderson, who left Patuxent in the mid-1970s for a USFWS Cooperative Research Unit position in Utah (then later moved to the Colorado Unit), set the bar high for quantitative wildlife population ecology research (see Burnham and Anderson, 2002). Some of his major career accomplishments that had their origins at Patuxent were in the areas of (1) distance sampling for density estimation, using line-transect methodology; (2) early computer models to facilitate band-recovery analyses; (3) early applications of capture-recapture models, using Cormack-Jolly-Seber models (see reviews by Nichols, 1992; Williams and others, 2002) that incorporated information-theoretic approaches and model comparisons as an alternative to traditional hypothesis testing; and (4) concepts borrowed from economics and engineering, particularly applications of decision theory and dynamic optimization, to solve complex natural-resource problems. Anderson has been recognized both nationally and internationally as one of the most influential researchers in the area of wildlife science and biometrics in the past 50 years.

Following the departure of Dave Anderson, Dr. Jim Nichols was hired in 1976. Although the "shoes" of Dr. Anderson would prove difficult to fill, Jim Nichols continued the outstanding quantitative modeling work that has come to define modern wildlife ecology and management. Also in the 1970s (and later in the 1980s), additional staff members were hired in MBHRL and at Patuxent who would continue to promote strong linkages between management needs for game species and population ecology. These new biologists included biometricians and computer programmers Paul Geissler, Jim Hines, John R. Sauer (transferred from MBMO), B.K. ("Ken") Williams, and Michael Conroy. A strong contingent of waterfowl field researchers was added as well, including Matthew Perry, Jerry Longcore, Michael Haramis, Ronald Kirby, Kenneth Reinecke, and David Krementz. Investigations such as the major collaboration between MBHRL scientist Matt Perry and research scientists at the Northern Prairie Wildlife Research Center in Jamestown, ND, David Trauger and Jerry Serie, focused on the canvasback (*Aythya valisineria*) and attempted to clarify key linkages among the breeding grounds in southern Canada, stopover areas along the Mississippi River, and the wintering grounds of Chesapeake Bay. Other game-bird work soon followed after the addition of new hires to MBHRL, including woodcock investigations in Maine (Bill Krohn and Tom Dwyer) and mourning dove research studies in South Carolina and Georgia (George Haas). Dick Coon was added to MBHRL staff and provided oversight to the Accelerated Research Program (ARP) in the latter half of the decade. Dr. Franklin Percival was selected as the first supervisor of the Game Bird Section.

At the same time that the Game Bird Section was gaining strength, the Non-Game Section in MBHRL was also adding research personnel, especially after the selection of Stanley

Mike Conroy conducting survey of black ducks in New Jersey, 1981. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

Anderson as the section chief. Soon, Chandler Robbins would no longer be the "lone voice in the wilderness" regarding non-game issues and needs. Deanna Dawson (songbirds) joined the group, followed by Mark Fuller (raptors), Marshall Howe (shorebirds), Michael Erwin (colonial waterbirds), and Barry Noon (forest birds). Although game birds continued to be a major focus of the USFWS, administrators now recognized that major gaps existed in our knowledge of many groups of birds that were "off the radar screen" of management. Moreover, many species in fact seemed to be showing signs of severe population declines in some areas of the continent, and the aforementioned positions and others were filled to help respond to their needs. Later, during the next decade, tension grew within the agency over the traditional emphasis on game-bird studies as opposed to the relatively "upstart" non-game program. Ultimately, the passage of the Fish and Wildlife Conservation Act of 1980 and the 1988 amendment helped broaden the focus on other migratory birds and provided an important impetus for expanding and supporting the non-game program. To mitigate some of the divisiveness at Patuxent, a reorganization occurred that created groups without the labels "game" and "non-game."

The 1970s also were busy years in MBMO, on the management side at Patuxent, and the Branch of Surveys in particular began to complete its staffing and undertake a number of key initiatives in addition to routine activities. New flyway biologists (pilots) were hired and stationed at Patuxent to begin training for pilot-in-command positions. During the 1970s, these new members included Mike Cox, Jim Goldsberry, Bruce Conant, Bill Larned, and Al Novara. Staff biologist positions were also filled—Ron Reynolds (Bird Banding Lab), John Tautin (woodcock, following Joe Artmann), Dave Dolton (mourning doves), and Bob Blohm (waterfowl)—and key support personnel, including Judy Bladen, Phil Koscheka, and Fred Fiehrer, among others, were added.

One of the important assignments for the management office at Patuxent was the first comprehensive review of the spring waterfowl breeding ground survey that had been in place operationally since 1955. Dr. Dave Bowden of Colorado State University was contracted to review the statistical underpinnings of the survey and provide guidance to the office on such issues as representativeness of the sampling units (transect segments), stratification boundaries, and variance estimation, among other aspects (D.C. Bowden, 1973, unpub. report available at the U.S. Fish and Wildlife Service, Division of Migratory Bird Management). Much of the decade was spent implementing many of the recommendations of this review. Additionally, Branch of Surveys staff members, along with assistance from MBHRL biologists, helped prepare the "FES 75," the "Final Environmental Statement for the Issuance of Annual Regulations Permitting the Sport Hunting of Migratory Birds" (U.S. Department of the Interior, 1975). This seminal document firmly established the biological, legal, and administrative foundation for the annual development of hunting regulations for migratory game birds.

Jim Goldsberry and Al Novara, U.S. Fish and Wildlife Service, with aerial survey plane, Chesapeake Bay waterfowl survey, fall 1979. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

The 1980s Computer Revolution: A PC in Every Office

Although MBHRL was discontinued as a research office in 1981, its staff and function continued under Patuxent's organizational umbrella. Overall, despite this change, research personnel were nearly at full strength, and a great deal of energy and activity had developed on many fronts. Some of the key projects that involved close collaboration between MBMO staff and Patuxent's research personnel are listed in table 1. The management needs of the USFWS provided the primary focus for most of the researchers, although some research addressed the needs of other interest groups, including the NPS, U.S. Forest Service, State agencies, and other organizations. The geographic scope was by no means limited to the U.S. and Canada, however. Because migratory bird issues do not recognize international boundaries, research activities expanded to a global reach. Research staff conducted cooperative research and conservation in Mexico, Belize, Jamaica, Dominican Republic, Trinidad, Suriname, Russia, Greenland, and France, among others.

In the early 1980s, a monumental change was evident in the BBL, where the staff was transitioning from manually processing banding and recovery information to using desktop computers. The benefits of the transition, initiated by Dick Pospahala with data-processing support from Phil Koscheka and Fred Fiehrer, in terms of time, accuracy, and responsiveness to the public were soon apparent. In the mid-1980s, another major change occurred in the manner in which the government operated. Personal computers (PCs) quickly became available for every management, research, and administrative office, greatly facilitating the processing of information and accelerating the pace of data analysis and global

Table 1. Examples of joint projects between migratory bird management and research personnel at the Patuxent Wildlife Research Center from the 1960s through the 1990s.

Title of project	Period of study	Major issue or question
Annual hunting regulations	1960s and ongoing	Improve annual estimates of waterfowl breeding populations and levels of productivity
Shooting hours study	1979–80	Determine effects on waterfowl populations of potential changes in shooting times for hunting
Stabilized regulations	1980–85	Provide accurate assessments of vital rates of mallards during breeding and nonbreeding periods while hunting regulations are stabilized; continue development of mallard model
September dove hunting	Late 1970s to early 1980s	Determine effects of previous September season openings on mourning dove populations
Reward band study	1960s–90s	Update previous estimates of reporting rates of bands recovered by waterfowl hunters, with initial focus on mallards
Woodcock Singing Ground Survey	1970s–80s	Improve survey route selection and detection of breeding birds in the Northeast and Midwest
Mourning dove surveys	1980s	Same issues as woodcock
May waterfowl surveys	1970s–90s	Improve stratification needed for aerial surveys, especially in Canadian provinces; review design and other statistical aspects
Mid-Winter Waterfowl Inventory	1985–90	Review key design and operational aspects of mid-winter inventory; structure and collate aerial survey data to make flyway population estimation feasible, with focus on Atlantic Flyway
Colonial waterbird surveys	1979–80s	Improve protocols for estimating breeding populations along Atlantic Coast
Raptor surveys	1978–90s	Develop methods for estimating raptor breeding population trends in the United States.
Shorebird surveys	1978–90s	Improve protocols for the International Shorebird Survey, especially the spatial sampling frame
North American Waterfowl Management Plan	Mid-1980s—ongoing (original plan and updates)	Integrate population and habitat information, along with research questions, to achieve sustainable waterfowl populations across North America
Adaptive Harvest Management (AHM)	1990s	Incorporate Adaptive Resource Management (ARM) principles and approaches to the annual development of hunting regulations, focusing on the mallard

information dissemination. Over the next 5 years, scientists became trained in a wide variety of new software for statistical analysis in addition to manuscript development. Gone were the days of decks of computer cards, carbon copies, and multilith offset printing, among other vestiges of the precomputer era. The new "e-mail" was catching on in the 1980s as well, vastly reducing the time scientists needed to spend on letter preparation and telephone conversations.

The advent of PCs greatly reduced the amount of time required for statistical analysis and modeling, as "down time" spent waiting for mainframe computer runs became a thing of the past. Major statistical programs, such as SAS, SPSS, and others, were adapted to perform on PCs, greatly enhancing the individual scientist's capacities. One example of an area in which sophisticated analysis and modeling were facilitated by PC use was the development of the "mallard model," a comprehensive effort initiated in the early 1970s by Dave Anderson and elaborated upon by Jim Nichols and Jim Hines at Patuxent, among others, to better understand the demography of the North American mallard population. Key MBMO scientists at Patuxent teamed with researchers at the center and its Vicksburg, MS, field station (Dr. Ken Reinecke) and the Northern Prairie Wildlife Research Center (Dr. Doug Johnson, Dr. Lew Cowardin, and others) to use PCs to greatly improve our understanding of mallard demographic parameters and consolidate numerical estimates of key vital rates.

One MBMO initiative in the 1980s stands out in terms of its purpose, scope, and involvement by research and management staff, not only at Patuxent but at many other agencies and organizations—an evaluation of the effect of stabilized hunting regulations on ducks in the U.S. and Canada. This program, known as the "Stabilized Regulations Study," was a massive undertaking of resources and staff in both countries, beginning in Canada in 1979 and in the U.S. in 1980, and terminating in 1985. Focused on the mallard, this investigation attempted to answer a series of questions related to mallard biology and management during a period when hunting regulations (season lengths and bag limits) were held constant. The study culminated in many reports and peer-reviewed publications, which reflected well on the MBHRL and MBMO staff at Patuxent who helped design and carry out this cooperative undertaking (see McCabe, 1987).

Following the conclusion of this initiative, MBMO/Branch of Surveys staff members, along with support from MBHRL scientists, assisted in the preparation of "SEIS 88," the "Final Supplemental Environmental Impact Statement: Issuance of Annual Regulations Permitting the Sport Hunting of Migratory Birds" (U.S. Department of the Interior, 1988). This important document was a follow-up to the original environmental impact statement published in 1975. In 1984, Dave Bowden was again asked to review the May aerial survey for breeding waterfowl and the Branch of Surveys was tasked with evaluating Bowden's recommendations, culminating in a major report by Graham Smith (Smith, 1995). Finally, a collaborative effort of research and management scientists at Laurel produced an important study of reporting rates of banded waterfowl conducted by using reward bands. These studies followed an earlier investigation by Drs. Chuck Henny and Ken Burnham at Patuxent in the 1970s that had provided the most recent baseline of reporting rates of recovered bands available at the time. Information from the 1980s study and subsequent investigations ultimately helped optimize continental banding efforts of waterfowl and had a profound effect on BBL operations.

The 1980s also saw many staff and organizational changes within MBMO that affected the migratory bird management program at Patuxent. Following the untimely death of Warren Blandin in 1982, Jerry Serie left a research scientist position at the Northern Prairie Wildlife Research Center to become Atlantic Flyway Representative. Sam Droege came to the Branch of Surveys as coordinator of the BBS when it was part of the migratory bird management program, and Alan Davenport transferred from Northern Prairie as well, bringing his computer expertise to the branch. Drs. Bob Trost and John Sauer were hired to provide biometric support to the Branch of Surveys, while Brad Bortner, Dave Sharp, Sean Kelly, and Fred Johnson added migratory game-bird expertise, joining other biological and administrative staff in the newly formed Population Assessment Section, headed by Dr. Bob Blohm. New pilot-biologists included John Solberg, Fred Roetker, Jim Bredy, Carl Ferguson, and Jim Walter, all of whom spent time training at Patuxent before being assigned to respective field stations around the country. After the departure of John Rogers as chief of MBMO and the retirement of George Brakhage, key openings in the office were soon filled by Dr. Rollin Sparrowe as chief, and Dr. Ken Williams as his deputy. The latter move further exemplified the ongoing close relationship between research and management programs and personnel at Patuxent, as Williams left his biometrician position in MBHRL to assume supervisory responsibilities in MBMO. At Patuxent, Dr. Robert I. Smith became Chief of the Branch of Surveys after Mort Smith was transferred to MBMO's Washington, D.C., office. George Jonkel and Sam Carney retired at the end of the decade and were replaced by John Tautin and Dr. Paul Geissler, respectively.

The "Identity Crises": 1990s

Because of major political shifts in Washington, D.C., in the early and mid-1990s, two monumental reorganizations occurred within DOI that affected Patuxent. Then-Secretary Bruce Babbitt formed a new Interior science agency, known as the National Biological Survey (which later became the National Biological Service, or NBS), by combining all research personnel within DOI, including those from USFWS, NPS, and Bureau of Land Management, into one Bureau. Biologists at major research centers, such as Patuxent, Northern Prairie, Denver, and others, along with staff at cooperative research units located at many universities across the country, soon found their organizational allegiance drastically changed. Even the BBL and BBS at Patuxent, whose missions were management oriented, were caught up in this restructuring. This move was in response to criticism about science, policy, and regulatory authorities being located within the same agencies. Not surprisingly, because of this unexpected reorganization, Patuxent scientists and administrators suffered through a great deal of confusion and program uncertainty. Still more changes were on the horizon. In the midst of all this restructuring, political battles were still being waged in the corridors of Washington, D.C. Only 2 years after the NBS had been formed, discussions were underway to make yet another change—and this time the future of all of DOI research was at stake.

To "save" the approximately 1,800 scientists in NBS, Secretary Babbitt merged the former NBS with the U.S. Geological Survey (USGS) in 1996, to become a fourth unit, the Biological Resources Discipline (BRD), within the USGS. Therefore, the disciplines of water resources, geology, and mapping now included wildlife research biologists, biometricians, and other staff under the same organizational "umbrella." Scientists at Patuxent, as well as their peers at former USFWS research units, faced a major redirection of their scientific mission, not once but twice. In migratory birds, instead of focusing on the trust species of the USFWS and issues important to national wildlife refuges and international treaty obligations, the former USFWS scientists now were obligated to deal with all the DOI land and resource issues. Similarly, scientists who had spent their entire careers at national parks conducting NPS research were asked to expand their scope considerably under the USGS flag, in some cases at a different location, such as Patuxent. Consequently, after merging with the USGS, Patuxent's science plan suddenly looked very different within an agency whose culture had historically been defined by the physical sciences. Gone was a "migratory birds" program, as well as separately funded programs for contaminants or endangered species. Instead, more generic scientific objectives were established that, in the biological discipline, focused on ecosystem research, with little emphasis on population-level science or species conservation concerns.

Following several changes in USGS directors since 1996, administrative alignments and objectives too have changed; moreover, after more than a decade, the former USFWS and NPS biologists have acclimated to the new research model. Another shift in the paradigm has been the fostering of researcher alignments with research universities. These cooperative arrangements have long been part of the culture of the USFWS (the Cooperative Fish and Wildlife Research Unit program) and NPS (Cooperative Parks Studies Unit program), but most researchers in the USGS traditionally had been based at a small number of centers independent of university campuses (for example, Menlo Park, CA; Woods Hole, MA; and Reston, VA [USGS headquarters]). Today, the presence of biologists at universities across the country has spawned the formation of many local and regional partnerships addressing a wide variety of fish and wildlife resource issues. In addition, these strong university ties have facilitated the training of many graduate and post-graduate students by Patuxent scientists.

In spite of this functional upheaval in the traditional pursuits of wildlife ecology, conservation, and management, many important projects and advancements occurred during the 1990s and early 2000s. Many of these involved extensive interactions among Patuxent researchers, visiting scientists and post-doctoral students, and migratory bird management personnel in the USFWS and other agencies. Again, one contributing factor was the increasing use of PCs, which improved the efficiency of model development and prompted other innovative statistical approaches, making them more accessible to the wider scientific community around the world. Jim Hines, a longtime associate of Jim Nichols, became one of the country's premier computer programmers in the area of wildlife demographic modeling. His development of user-friendly software has enabled wildlife researchers worldwide to access upgraded capture-recapture models for closed and open populations, occupancy models for metapopulation analyses, and other decision-support tools. The importance of this long-term, productive collaboration between Nichols and Hines cannot be overstated.

Within the Migratory Bird program of the USFWS, the decade of the 1990s was highlighted by major changes in a longstanding survey effort centered at Patuxent and by a major paradigm shift in the decision-making process with respect to establishing annual harvest regulations. Not unexpectedly, staffing and organizational changes occurred during this decade as well.

Although problems with response rates in the harvest survey program had been recognized previously, levels reached unacceptable lows in the 1980s, prompting the waterfowl management community, particularly the USFWS, to seek alternative approaches. Initiated at the request of the International Association (now Association) of Fish and Wildlife Agencies in 1991, the new Harvest Information Program (HIP) moved away from the previous sampling frame based on duck stamp purchases to one that required licensed hunters to identify themselves as migratory bird hunters and supply name, address, and other information necessary for subsequent sampling efforts. Following a pilot stage and staggered entrance of states into the new system, the HIP survey became fully operational in 1998 and today stands as a much more reliable method for assessing hunter activity and success, not only for waterfowl but for other species of migratory game birds as well. Dr. Paul Padding, newly hired to the Harvest Surveys staff at Patuxent, provided overall guidance that contributed to the program's successful development and implementation, with critical assistance from Dr. Paul Geissler (formerly of MBHRL), Mary Moore, Bob Jessen, and Larry Hindman (Maryland Department of Natural Resources).

Against the backdrop of declining duck populations in the 1980s, ongoing high demand for more hunting opportunities, and longstanding uncertainty about the effects of hunting on migratory bird populations that continued to generate high levels of controversy, the stage was set in the early 1990s for a dramatic change in the annual regulations-setting process for waterfowl hunting. Beginning in 1992, MBMO, along with research scientists at Patuxent and with the support of all four Flyway Councils, embarked on a long but successful collaboration to bring about needed changes in harvest management. The objectives of this cooperative effort were to help improve managers' understanding of the effects of hunting regulations on harvests and population levels, to maximize cumulative harvests over the long term, while maintaining waterfowl populations at or above objective levels, and at the same time to provide a more informed and objective decision-making process for addressing harvest management issues each year. This process, an outgrowth of Adaptive Resource Management (ARM), focused from the beginning on the population dynamics and harvest potential of mallards. It became known as Adaptive Harvest Management (AHM) and was fully implemented in 1995. Although many individuals contributed to AHM's development and implementation over the years, the hub of activity was at Patuxent, where Fred Johnson (MBMO) provided the theoretical framework, along with Jim Nichols, Ken Williams, Graham Smith, Bob Trost, Bill Kendall, Jim Dubovsky, Dave Caithamer, and later Scott Boomer and Mike Runge, and many others in the research and management offices. This highly successful program continues to this day, and its value to waterfowl management can be directly attributed to the involvement from the beginning of biologists from Federal, State, and nongovernmental agencies (NGOs) and organizations.

The New Millennium: Research into New Dimensions

Once the wildlife programs were merged with other USGS research priority areas, the momentum shifted away from traditional species and community approaches to consider topics such as ecosystem dynamics, global climate change, and environmental health. Although new allegiances and partnerships were being formed within and outside the USGS community, and despite changing scientific missions, the legacy of wildlife population dynamics at Patuxent managed to continue uninterrupted. As proof, a major manuscript was completed early in the 2000s and published in book form, marking the culmination of two decades of work on population demographic analysis and effective wildlife management (Williams and others, 2002). The authors —Ken Williams, Mike Conroy, and Jim Nichols—were all collaborating Patuxent researchers in the 1980s, although Williams and Conroy later left for other positions.

Increasing concern about climate change in the Federal science agencies resulted in major funding initiatives for Patuxent and other USGS research facilities. Patuxent scientists focused on studying possible effects of coastal sea-level rise on lands under management policies of the USFWS, NPS, States, and NGOs. Don Cahoon, Glenn Guntenspergen, and Mike Erwin all initiated studies at many Atlantic coastal (and international) sites in which surface elevation tables were used to compare marsh dynamics to relative sea-level rise.

On the management side, the 2000s marked an expansion of the biological staff at Patuxent. The Branch of Population and Habitat Assessment (formerly the Population Assessment Section), with Mark Koneff as chief, added many migratory bird specialists, including nongame biologists—many with advanced quantitative skills—who collectively provided a level of expertise in population ecology and modeling matched only by Patuxent's USGS scientists. In addition to carrying out traditional responsibilities related to operational surveys and the annual regulations development process, staff members provided continued support to AHM and HIP, and embarked on new initiatives. Some of these included waterfowl population survey improvements (Emily Silverman); development of more informed, model-based harvest strategies for woodcock (Guthrie Zimmerman) and mourning doves (Mark Seamans, Todd Sanders); additional reporting rate investigations (Pam Garrettson, Andy Royle); and adaptive harvest strategies for waterfowl other than mallards (for example, northern pintails [*Anas acuta*], Mike Runge [Patuxent]; American black ducks, Mike Conroy [USGS, retired], Pat Devers; and scaup [*Aythya affinis and A. marila*], Scott Boomer).

In the 2000s, the longstanding work and collaboration on AHM at Patuxent finally began to have far-reaching ramifications in the natural-resource community. Because of the ongoing success of AHM in helping biologists manage waterfowl harvests, and because of the willingness of key individuals in research and management to share their knowledge and understanding of this new management approach, a paradigm shift in the way natural-resource issues could be resolved was taking place outside the migratory bird management arena. Today, ARM has been accepted within DOI as a policy approach for resolving natural-resource management issues on Federal lands and for helping to fulfill Federal mandates for trust species. Some of the projects involving substantial management input to the research planning process during the past decade are listed in table 2. The first eight projects listed involve a continuation of the linkages between the management personnel (formerly MBMO, renamed Division of Migratory Bird Management in 2000) and researchers at Patuxent, including the BBL. The remaining projects involve substantial input from the refuge component of the USFWS and from the NPS. Additional shared research/management projects that have emerged include management activities within other State, Federal, and international agencies, such as:

1. **Avian disease ecology**—Since 2005, with the outbreak of avian influenza in bar-headed geese (*Anser indicus*) at Qinghai Lake in western China and its potential for global spread to humans, Patuxent and other USGS facilities have been engaged in research in east Asia (Jiao, 2010). The "management" agencies now include the United Nations Food and Agriculture Organization, USFWS, USGS, USDA, and many Chinese science and

Table 2. Recent (1990s to present [2016]) projects involving collaboration of Patuxent Wildlife Research Center migratory bird researchers with management personnel on studies of mutual interest, and related scientific advances.

Title of project or study	Time period	Related scientific advances
Capture-recapture modeling	1990s and ongoing	Expansion of applications to estimate species richness; development of methods for coping with detectability differences, multistate populations, and missing data; development of user-friendly software
Occupancy modeling	1990s and ongoing	Expanded use of models to consider larger metapopulation dynamics, colonization, dispersal, range shifts, and epidemiology; software development
Status of migratory bird populations across the United States and Canada	1990s and ongoing	Accessibility of summary results from Breeding Bird Survey to increase knowledge of status and trends of many North American landbirds and some game-bird species
Adaptive management of migratory game-bird species	1990s and ongoing	First application of Adaptive Resource Management (ARM) principles to harvest regulations for mallards, American black ducks, and other species and populations of waterfowl
Additional reward band studies	1990s and ongoing	Availability of reporting rate information available for other species besides mallards; optimization of banding needs
Updated Supplemental Environment Impact Statement 88	2006–11	Updated information that supports the biological, legal, and administrative aspects of promulgating annual hunting regulations for migratory game birds
Improved harvest strategies for migratory game birds	1990s and ongoing	Improved use of available information to make more informed harvest management decisions
Priority research and management needs for migratory shore and upland game birds	2006–11	Identification of top research and management activities to address needs; enhancement of funding request justifications
Wetland mitigation studies	1990–98	Improved approaches to water management on Patuxent Research Refuge property
Coastal sea-level rise on Federal lands	1998 and ongoing	Use of surface elevation tables on refuges and National Park Service lands to evaluate refuge and other Federal lands most vulnerable to sea-level rise
Open marsh water management on Federal lands	1999–2006	First large-scale experimental approach to studying effects of hydrologic manipulations on salt-marsh environments
Integrated Waterbird Monitoring and Management	2009 and ongoing	Application of principles of ARM and Structured Decision-Making (SDM) to wetland management in the eastern United States to optimize use by a diverse water-bird community
Wind turbine impacts in eastern mountain ridges	2005 and ongoing	Experimental application of acoustic receptors at proposed turbine locations in the Appalachian region; documentation of bird and bat impacts
Seaduck movements and trophic relations	2004 and ongoing	Discovery of new routes used during migration and staging in Canada; collection of new energetic information (captive flock)

forest agencies. The research activities have expanded from using satellite telemetry to monitor selected species of waterfowl in China and Mongolia to developing risk models based on poultry farm distributions and wildlife migration movements in eastern Asia (see http://www.usgs.gov/blogs/features/usgs_science_pick/understanding-global-avian-influenza-transmission-pathways-through-ecology/). Other USGS researchers have added study sites in Africa and parts of the Middle East to the East Asian locations. Close coordination with the USFWS was facilitated by the 2008 hiring of an Avian Disease Coordinator, Dr. Samantha Gibbs, in the DMBM.

2. **Structured Decision-Making (SDM)**—The increased complexity of natural resource issues, many of which have competing demands, has led to the emergence of a new paradigm to formulate effective management planning. The popularity of SDM, an outgrowth of ARM, has increased among Federal agencies over the past several years (Martin and others, 2009). One demonstration of it has been on a multirefuge study across the Northeast and Midwest to assess impoundment management for waterbirds (Lyons and others, 2008). The approach, many of whose elements are borrowed from systems theory, has broad appeal to a wide audience of managers. Challenges in determining the timing and spatial scale of management implementation can be addressed using SDM. Also, the SDM approach can be useful in seeking optimal solutions where many management objective functions have been identified. Patuxent and DMBM scientists have offered training classes in SDM applications.

3. **Offshore energy infrastructure**—The need for exploration to discover additional energy sources, including wind generation and new oil/natural gas fields, demands that environmental impacts be evaluated. In the past 5 to 6 years, Patuxent has been engaged with the Bureau of Ocean Energy Management (formerly Minerals Management Service), the USFWS, and several State agencies and NGOs in evaluating the potential for impacts of turbine or rig installations on migratory birds. Some of the research has focused on marked individual seaducks in Nantucket Sound, MA, including the identification of their foraging and roosting locations during winter, in conjunction with a broader seaduck study in the U.S. and Canada. In addition, a large database has been developed to capture available information on seabird distributions along the entire Atlantic Coast.

4. **Island restoration**—The demands of shipping and maintenance of navigation channels along the coast require the U.S. Army Corps of Engineers and State management agencies to coordinate disposal plans for millions of cubic yards of dredged materials. One such large-scale project that has involved Patuxent since the mid-1990s is the Paul Sarbanes Ecosystem Restoration Project at Poplar Island in Talbot County, on Maryland's Eastern Shore (see http://www.nab.usace.army.mil/About/ProjectFactSheets.aspx). This "Beneficial Use" project requires that the restoration of the approximately 1,150-acre island provides equal areas of uplands (up to about 8.6 yards above North American Vertical Datum of 1988) and wetlands. The objective for the wetland area is to attract key species of nesting and migrating waterbirds, nesting diamondback terrapins (*Malaclemys terrapin*), fishes, and other species. Patuxent scientists have been major participants in habitat design for the project area and monitoring of use by waterbirds and breeding success since 2002 (Erwin and others, 2007).

Conclusions

Patuxent's program for migratory birds, like most Federal programs, has been altered dramatically over the past 80 years as bureaus reorganized, administrations forced a reexamination of priorities, funding levels fluctuated, and scientific personnel came and went. Nevertheless, the level of scientific activity has remained consistently high, with Chandler Robbins serving as the "guiding light" in his 60 years of dedicated research service. Scientists located at Patuxent and working in either wildlife research or wildlife management have taken active roles in forging new initiatives in a number of key areas over the years. Some examples are—

- Managing aquatic vegetation in impoundments to support waterfowl;
- Expanding the capabilities and efficiency of the BBL to allow sophisticated distribution and population analyses of both hunted and nonhunted species of birds;
- Developing rigorous national/international bird surveys for waterfowl, woodcock, mourning doves, and other webless migratory game-bird species to support the promulgation of annual hunting regulations;
- Improving or formulating more effective inventory and monitoring methods for songbirds, shorebirds, raptors, and colonial waterbirds, and extending the training to a number of underdeveloped countries in the Western Hemisphere;
- Initiating the BBS across the U.S. and Canada, and later making the summaries of trends of species available on the World Wide Web;
- Developing and expanding new applications of capture-recapture and occupancy modeling beyond estimating survival and abundance parameters of populations;
- Applying ARM and SDM to complex natural resource problems, including more informed management of harvests of migratory game birds;

- Drafting national plans to manage and conserve waterfowl, waterbirds, shorebirds, and raptors; and
- Studying the movements of waterfowl in East Asia and investigating mechanisms of the transmission and spread of avian influenza (H5N1) within wild populations and among wild and domesticated poultry during seasonal movements.

The inclusion of Patuxent as part of the USGS—an agency dominated by the physical sciences—has broadened its purpose, and studies of migratory birds continue in different forms. More specifically, studies of bird populations and the development of methods for effectively managing those populations are now typically cast in relation to predicted climate change, threats to conservation, effects of mineral and energy facility expansion, and considerations of human and animal health.

Within the USFWS, a separate programmatic home, apart from the Refuge program, was created for migratory birds in the early 2000s under a new assistant director (first, Tom Melius as Assistant Director for Migratory Birds and State Programs in 2000; and later, Paul Schmidt as Assistant Director for Migratory Birds in 2003). This change provided many obvious benefits and advantages in terms of priority-setting and program delivery. In recent years, however, a broadening of the program's mission has been observed in this agency as well, with more involvement of migratory bird staff, including those at Patuxent, in large-scale initiatives on the landscape.

Another challenge for both the USGS and USFWS in the future is coordination among the many Federal, NGO, State, university, and other agencies and organizations interested in both research on and management of birds and their habitats at different scales. Just a partial list reveals how large the scope of partnerships has become: regional, national, and international Joint Ventures and other bird conservation plans under the North American Waterfowl Management Plan and North American Bird Conservation Initiative (NABCI); the new USGS National Climate Change and Wildlife Center, with eight centers distributed around the county; the new Landscape Conservation Cooperatives (joint Federal and university projects, with USFWS and USGS); The Nature Conservancy's Conservation By Design program; and others, such as programs shared with Ducks Unlimited, the U.S. Forest Service, and various State programs (for example, Florida's Forever Wild). Without a scorecard, it will be very difficult to keep up with developments in all these initiatives to reduce redundancy and overlap. In these times of very limited public funding, it is essential to ensure that management and research dollars are allocated in the most effective way possible.

Finally, Patuxent's many accomplishments over the last 80 years could not have been achieved without a conscious effort on the part of research and management staff to maintain longstanding and productive working relationships. These professional bonds formed at Patuxent have ensured continual collaboration among staff, despite those many factors, both internal and external, that have continued to threaten program viability. It is a rich history and a lasting testament to these individuals that research and management programs at Patuxent have sustained their high visibility and value to the conservation and management of our natural resources for three-quarters of a century. There is no reason to believe that this relationship will not endure well into the future.

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Tom Custer weighing heron chick at a dredge island site in Lavaca Bay, Calhoun County, TX, in 1988. Photo by R. Will Roach, U.S. Fish and Wildlife Service.

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Blue-winged teal, Little Compton, RI, 1966. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

The Bird Banding Laboratory: Support for and Collaboration with Research at Patuxent

By John Tautin

Located at Patuxent Research Refuge (PRR) and functionally part of the Patuxent Wildlife Research Center (Patuxent), Laurel, MD, the Bird Banding Laboratory (BBL) is the service and administrative center for bird banding in the United States. Over the years, the BBL has been associated with both the PRR and Patuxent, which collectively are commonly referred to by the public (and in this chapter) as "Patuxent." The BBL issues permits and bands; supplies banding software, instructional materials, and technical advice; coordinates the use of auxiliary markers such as neck collars and radio transmitters; serves as the repository for banding records and the clearinghouse for reports of banded birds; disseminates data to researchers and managers; and assists in the development and coordination of banding projects. The BBL is a large and complex operation with a long and rich history that predates its transfer to PRR in 1942, when it began a remarkably successful and mutually beneficial collaboration with research and management functions colocated at PRR. Prior to 1961, the BBL was known simply as the "bird banding office."

Bird Banding Begins: The Bird Banding Laboratory before Patuxent

Scientific bird banding began in 1902, when Smithsonian Institution scientist Dr. Paul Bartsch banded several black-crowned night-herons (*Nycticorax nyticorax*) along the Anacostia River in Washington, D.C. Bartsch used serially numbered bands with a Smithsonian return address on them and, in 1904, he published results from his banding study (Bartsch, 1904). In a prescient statement that began, "There are still many unsolved problems about bird life…." Bartsch suggested that bird banding would become a useful scientific tool.

Indeed, banding caught on quickly in the U.S. and Canada (Cole, 1922; Jackson, 2008). It was managed privately until 1920, when the Federal bird banding office was established in Washington, D.C. Federal involvement in bird banding was both logical and welcome. The 1916 Convention between the U.S. and Great Britain (for Canada) for the Protection of Migratory Birds had established Federal preeminence in migratory bird matters, and the subsequent 1918 Migratory Bird Treaty Act made it law. The banding community actually encouraged the entry of the Federal government into the management of bird banding. World War I was underway, private support for banding had waned, and an entity with sufficient resources and authority to manage bird banding was needed. That entity was determined to be the already well-established U.S. Bureau of Biological Survey (Bureau).

The Bureau had some experience with bird banding (Wetmore, 1915), and Bureau administrators, notably Edward Nelson, Bureau Chief, and Harry Oberholser, head of bird studies, were supportive and recognized the need for a well-organized, central banding office. Therefore, in 1920, in arguably one of the most fortuitous appointments in the history of North American ornithology, they recruited Frederick C. Lincoln to organize the bird banding office (Tautin, 2008).

Lincoln was a remarkably accomplished biologist, writer, and administrator. By the end of the 1920s, he had organized the banding office, developed numbering schemes and record-keeping procedures, established standards, recruited bird banders, and fostered international cooperation. He was also a visionary who tirelessly promoted banding as a tool in scientific research and management. His contributions were significant and included the development of the Lincoln index (Lincoln, 1930; later modified to become the Lincoln-Petersen index), which ultimately proved to be a true population estimator (Nichols and Tautin, 2008), and the flyways concept (Lincoln, 1935), which is still applied in waterfowl management today. As his career progressed, Lincoln took on additional responsibilities, but he remained the primary official of the bird banding office until 1946, overseeing its transfer from Washington, D.C., to Patuxent in 1942. Lincoln retired in 1947, leaving a remarkable legacy. Much has been written about his career and achievements (Terres, 1947; Gabrielson, 1961; Reeves, 1984; Tautin, 2005). Frederick C. Lincoln truly was the founder of the bird banding program as we know it today.

The Bird Banding Office Moves to Patuxent

World War II prompted the move of the bird banding office to PRR. During the summer of 1942, in accordance with a decentralization order by President Roosevelt, the main offices of the U.S. Fish and Wildlife Service (USFWS) were moved temporarily to Chicago. However, the bird banding and other migratory bird files, together with the staff members who worked with those files, were moved to PRR (later Patuxent), where space in Nelson Laboratory was available.

After the war, the USFWS returned to Washington, D.C., but the bird banding office stayed at Patuxent, where it remains today, known as the BBL. The move to Patuxent was most fortunate for bird banding, because Patuxent would eventually become a world-class center for migratory bird research and management. The colocation of the bird banding office with scientists, who developed methods for analyzing banding data, and with management-oriented biologists, who used the data, proved to be mutually beneficial.

Lincoln remained in Washington, D.C., but retained administrative responsibility for the bird banding office through 1946. Management assistance at Patuxent was provided by May Thacher Cooke; two clerks, Marge Stewart and Lois Horn; biologist Chandler Robbins, beginning in 1943; and John Aldrich, who had transitional responsibilities between Lincoln's retirement and the appointment of Seth H. Low as the head of the bird banding office on January 5, 1948 (Steele, 1948; A.J. Duvall, 1968, unpublished letter on file at the U.S. Geological Survey Bird Banding Laboratory, Patuxent Wildlife Research Center, Laurel, MD).Low served in that capacity until 1954, when Allen J. Duvall transferred from the Museum of Natural History to PRR, where he was put in charge of migratory bird work, including the bird banding office. In a 1961 reorganization at Patuxent, the bird banding office was formally designated the Bird Banding Laboratory (BBL), and its leader, Duvall, was designated "Chief." Duvall remained BBL Chief until 1964, when he assumed a position with the Pesticides Review Board in Washington, D.C. The designations "BBL" and "Chief" remain today.

The internal written record of BBL's support for research during the tenures of Low and Duvall is relatively sparse, but that support was very likely given. Evidence exists in the form of external publications, notably two written by Aldo Leopold proteges Arthur S. Hawkins (1949) and Joseph J. Hickey (1952), who spent time at Patuxent researching the files at BBL.

Post-War Developments Influence Bird Banding

Outside the bird banding office during the late 1940s and 1950s, much was happening that would influence the office for decades to follow. As the Nation returned to "business as usual" after World War II, many young war veterans went to college under the Servicemen's Readjustment Act of 1944 (G.I. Bill), with increasing numbers entering the developing field of wildlife management. Surplus aircraft were made available for waterfowl surveys. Reliable funding from the Wildlife Restoration Act of 1937 (Pittman-Robertson Act) helped the States match the Federal Government's investment in waterfowl management. These efforts were stimulated by the resurgence of waterfowl hunting after G.I.s returned home and sporting ammunition became readily available. The development of cooperative bodies such as the four Flyway Councils furthered growth in waterfowl management. By 1960, State and Federal agencies were implementing cooperative, integrated, large-scale breeding ground surveys, harvest surveys, and banding programs specifically designed to yield data needed for waterfowl management. Martin and others (1979) and Hawkins and others (1984) provide interesting and comprehensive histories of these developments.

Seth Low, second chief of the Bird Banding Laboratory, Laurel, MD, 1951. Photo by Chandler S. Robbins, Patuxent Research Refuge.

Allen J. Duvall, third chief of the Bird Banding Laboratory, Laurel, MD, 1961. Photo by U.S. Fish and Wildlife Service.

Laverne Casteline checking schedules, Bird Banding Laboratory, Laurel, MD, 1951. Photo by U.S. Fish and Wildlife Service.

Waterfowl Concerns Dominate at the Bird Banding Laboratory during the 1950s and 1960s

During the 1950s and 1960s, Patuxent became a leader in developing and managing surveys that supported research on and management of migratory game birds. In a supporting role, the BBL followed suit. The BBL adopted permit and data policies that clearly favored game-bird banding. Operational procedures were developed to accommodate game-bird interests; for example, banding and recovery records were modified to include codes for flyways, and all recovery records contained a "hunting seasons survived" code, even for nongame birds. Large numbers of waterfowl being banded reflected the emphasis on game-bird banding, and soon the mallard (*Anas platyrhynchos*) became the most frequently banded bird in North America, a distinction that it holds to this day.

The BBL modernized data management in the early 1960s, partly to better serve research and management, and partly in response to a disastrous fire that destroyed many paper banding records in 1959. Chan Robbins explains that few records were actually lost in the fire, but all the punch cards were distorted or singed from the heat and had to be replaced (Chandler Robbins, U.S. Fish and Wildlife Service, oral commun., 1983). BBL staff and other Patuxent personnel spent approximately 2 years reconstructing the file after the fire. Entry into the newly emerging field of electronic data management was accelerated in the mid-1960s with the installation of a modern IBM® computer capable of managing the now millions of banding records being used by scientists at Patuxent and other locations. Added impetus to modernization efforts at the BBL arrived in late 1964 with the appointment of the engaging and energetic Earl B. Baysinger as the fourth BBL chief.

By the mid-1960s, the importance of the BBL's role in supporting research and management programs in the U.S. and Canada was recognized at the highest agency levels in Washington, D.C. In January 1967, the General Services Administration announced plans for the construction of a $1.1 million Bird Banding Records Center at Patuxent (The Washington Post, 1967). Construction was completed promptly, and in 1968 the BBL was housed in its new, state-of-the-art home named Gabrielson Laboratory (U.S. Fish and Wildlife Service, 1972) in honor of Ira N. Gabrielson, an accomplished ornithologist, conservationist, and former director of the USFWS. Gabrielson Laboratory offered far more space than the BBL needed, and therefore was soon filled by other offices, including the Migratory Bird Populations Station and a burgeoning computer section. The BBL remains housed in Gabrielson Laboratory at Patuxent to this day (2016).

New Analytical Models Begin to Influence Bird Banding

During the 1960s, a quiet, but profound, revolution in banding data analysis had begun outside the BBL and Patuxent with the development of the Jolly-Seber-Cormack models (Nichols and Tautin, 2008). Statistically, these models were vastly superior to the then commonly used life tables. Over the next four decades, these new models would lead to a tremendous expansion of analytical methods that would further validate the importance of banding data, and therefore the BBL, to research. As was historically the case with many developments in bird banding, this one also was driven by game-bird management priorities. Waterfowl management and the setting of annual hunting regulations was becoming more complex, and Federal and State agencies needed more accurate scientific results from banding (Tautin, 1993).

Helen Webster punching return card, Bird Banding Laboratory, Laurel, MD, 1951. Photo by U.S. Fish and Wildlife Service.

The availability of these statistically reliable models, particularly the so-called Seber-Robson-Brownie models for estimating survival and recovery rates from band recovery data (Brownie and Robson, 1976), led to the publication of the eight seminal "Mallard Reports" by Patuxent scientists (for example, Anderson and Burnham, 1976). In the 1970s, two of those scientists, David Anderson and Ken Burnham, moved from Patuxent to Colorado State University and collaborated with Gary White to produce many more reports related to the analysis of bird banding data. In testimony to their enduring contributions to wildlife conservation, all three later received the Aldo Leopold Award, the wildlife field's most prestigious honor.

Nongame-Bird Banding Comes of Age

During the 1970s and 1980s, game-bird considerations continued to dominate the banding program, but several events caused nongame-bird banding to become more prominent. The Endangered Species Act of 1973 formally gave the USFWS responsibility for threatened and endangered birds, most of which were nongame birds. Universities and colleges began to employ more ornithologists and, by the end of the 1980s, nearly one-third of all banders had an academic affiliation. Research centers like Patuxent devoted increasing attention to nongame-bird species. As evidenced by the many published reports cited in the other chapters in this volume, Patuxent in particular became renowned for its work with both endangered and nonendangered birds.

Institutional banders at Patuxent and in the broader ornithological community, having more scientific knowledge than nonprofessional banders, commonly used auxiliary markers such as colored leg bands, neck collars, and radio transmitters that yielded additional and more accurate data. The BBL worked closely with them to ensure that advanced marking techniques were both effective and safe for birds. For some widely studied species, the BBL also worked with banders and other stakeholders to develop cooperative marking protocols. These cooperative efforts led to a great increase in observations of marked birds that supported the use of analytical models, which had moved rapidly beyond game-bird band recovery models to include more versatile mark-recapture models well suited for nongame-bird studies.

Nongame-bird banding received an additional boost during the 1970s and 1980s after George Jonkel became the fifth BBL chief in 1971. Jonkel had been with the USFWS for many years, and had been an active bander of both game and nongame birds. Under Jonkel's leadership, the BBL encouraged and supported nongame-bird research by both professional and amateur banders, and maintained close ties to the amateur regional banding associations.

Furthermore, during this era and into the next millennium, BBL chiefs and staff biologists, themselves licensed bird banders, also lent "hands-on" support to banding projects at Patuxent and other banding places. Some examples were John Tautin's and B.H. Powell's tours of duty banding ducks in Canada under the cooperative prehunting-season banding program, Kathy Klimkiewicz's decade-long study of wintering birds, Danny Bystrak's long-term study of fall migrants on the Patuxent powerline right-of-way, Mary Gustaphson's operation of a constant effort banding station under the USFWS continent-wide Monitoring Avian Productivity and Survivorship program, and Bruce Peterjohn's study of hummingbirds.

Science Triumphs over the Challenge of Administrative Changes

In late 1988, John Tautin became the sixth BBL chief. Tautin, a bander and a career employee with the USFWS Office of Migratory Bird Management (MBMO), had worked as a biologist at the BBL during the mid-1970s. During his tenure, which lasted until 2002, the BBL faced difficult administrative challenges following its transfer from the USFWS to the newly created National Biological Survey (later Service; NBS) in 1993 and later to the U.S. Geological Survey in October 1996. Fortunately, during these transfers the BBL remained at Patuxent, where its close ties with research scientists and the MBMO helped ensure that it would continue to receive sufficient resources to remain functional.

John Tautin, sixth chief of the Bird Banding Laboratory, Laurel, MD. 2009. Photo by Tara Dodge, Purple Martin Conservation Association.

Kathy Klimkiewicz capturing white-breasted nuthatch with color-coded band, Patuxent Research Refuge, Laurel, MD, 1977. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

The importance of the BBL to research at Patuxent, and indeed to scientists across North America, was underscored in an extensive report (Buckley and others, 1998) by an external review panel commissioned by the NBS.

The review panel's report added impetus to ongoing efforts by the BBL to make the banding program more scientific. These efforts included re-engineering the BBL's database and computer operations, developing software for banders to manage and report banding data, designing a recapture/resighting database, and implementing a toll-free telephone number that people could call to report bird bands.

The internal efforts made by the BBL to improve the management of millions of banding records have typically gone unheralded, but their importance to Patuxent scientists and the broader ornithological community cannot be overstated. For example, banders commonly replace bands on long-lived birds when they recapture them. The bird then has two, if not more, unique band numbers assigned to it, causing a record-keeping problem. Over the years, without direction or fanfare, BBL biologists, clerks, and computer staff developed ever better procedures for processing replaced bands, enabling scientists to maintain continuous records of the birds. Without these procedures, tracking the remarkable life of 62-year-old Wisdom, an albatross originally banded by Patuxent's Chandler Robbins in 1956 and subsequently rebanded several times, would not have been possible.

Among the BBL's efforts to improve operations, the toll-free number was a particularly important and successful development. In a late 1980s study, Patuxent scientists (Nichols and others, 1991) had determined that only 32 percent of hunters who killed a banded mallard actually reported the band. This low rate was inadequate to supply input to the data-hungry analytical models and adaptive management principles being applied in an effort to develop a more scientific approach to setting hunting regulations. Providing hunters with a convenient toll-free number to call for band reporting was the ideal solution to the need for more and better band-recovery data. The availability of the toll-free number doubled the reporting rate in only a few years.

During all of these operational developments, the BBL directly supported many individual Patuxent research projects (for example, Spendelow and others, 1995) and strengthened ties with Patuxent scientists. Some of these scientists were world leaders in developing ever more sophisticated models for analyzing banding and other data, while also developing new approaches to science-based decision making. Patuxent scientists Byron (Ken) Williams, James Nichols, and Michael Conroy cite many examples of their work in the monumental publication "Analysis and Management of Animal Populations" (Williams and others, 2002). The BBL helped by publicizing the new analytical models, participating in international technical conferences held to advance the models (Tautin, 1993; Tautin and others, 1999), organizing analytical workshops at ornithological meetings, and otherwise encouraging bird banders to use these powerful new tools.

Tautin retired from Federal service in late 2002. Succeeding BBL chiefs Monica Tomosy (2003) and Bruce Peterjohn (2008) and their staff continued the BBL's support of research at Patuxent and across North America. After completing the initial re-engineering effort at the BBL, they expanded Web-based procedures that improved data collection and distribution; developed Bandit software, which improved the efficiency of submitting banding data for both the banders and the BBL; and developed Web-based band reporting procedures that cut costs and facilitated bird-band reporting by the public. The BBL also modernized permit policies and expanded support for bird banding in Latin America. And, as it had always done, during Tomosy and Peterjohn's tenures, the BBL continued to work with scientists from Patuxent and elsewhere to develop and apply advanced technology for bird studies, most notably the use of geolocator data loggers, which revolutionized studies of migratory songbirds in 2007 (Stutchbury and others, 2009).

The Patuxent Wildlife Research Center Looks Ahead

The transfer of the bird banding office to PRR in 1942 marked the beginning of a highly successful and mutually beneficial collaboration with research and management functions colocated there. So long as the BBL and Patuxent remain viable and continue to coordinate work, it is reasonable to assume that this remarkable 70-year legacy will continue. Maintaining this relationship is desirable because, as Paul Bartsch noted when bird banding first began in North America, "There are still many unsolved problems about bird life…."

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G. Michael Haramis banding a male canvasback in Chesapeake Bay, 1978.
Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

Patuxent's Role in the Development of the North American Breeding Bird Survey

John R. Sauer

The North American Breeding Bird Survey (BBS) is a roadside survey of the breeding birds of North America. The BBS provides data from the contiguous United States, Alaska, southern and central Canada, and northern Mexico. Begun in 1966 by Chandler (Chan) S. Robbins at the U.S. Geological Survey (USGS) Patuxent Wildlife Research Center (Patuxent), and now jointly managed by Patuxent, the Canadian Wildlife Service, and the Mexican Commission for the Knowledge and Use of Biodiversity, the survey is conducted primarily in June along more than 5,000 roadside survey routes that are surveyed once each year. Volunteer observers drive the 39.4-kilometer (24.5-mile [mi]) routes, stopping approximately every 800 meters (m) (0.5 mi) to conduct fifty 3-minute point counts during which they record all the birds heard or seen within a 400-m (0.25-mi) radius of the counting location. Observers submit their data for each stop along their routes to the BBS offices in their respective countries, after which the information is made available to the public.

K.A. Smith and J. Rensel. Breeding Bird Survey volunteers, along historic intercontinental railroad grade on the Peplin Mountain, UY (Utah Breeding Bird Survey route 85251). Photo by U.S. Fish and Wildlife Service.

The BBS is unique in its temporal and geographic scale, and it is often the only source of information for geographic studies of important scientific issues such as the effects of climate change, disease, and land-use change on North American bird populations. Wildlife researchers and managers rely on the survey as the authoritative source of information on population change for more than 400 species of North American birds. It was the primary source of data for the State of the Birds Report (North American Bird Conservation Initiative, 2009), a publicly accessible summary of the "big picture" of population change and conservation of North American birds. Nevertheless, even after more than 45 years successfully providing population change data, Patuxent researchers are continuing their efforts to strengthen the BBS and similar surveys. Keeping a survey such as the BBS current in terms of field methods, data management, and analyses is a formidable task, and Patuxent has devoted substantial resources toward all of these activities throughout much of its existence. This chapter describes some of the themes and approaches to the design and analysis of roadside bird surveys that have been used at Patuxent, where the BBS and related surveys conducted by the U.S. Fish and Wildlife Service (USFWS) for mourning doves (*Zenaida macroura*) (the Call-Count Survey [CCS]; Sauer and others, 2010) and American woodcock (*Scolopax minor*) (the Singing-Ground Survey [SGS]; Sauer and others, 2008) have been the focus of research activity since the 1940s.

In this chapter, the term "Patuxent" is used in the "greater Patuxent" sense that Jim Kushlan used during his tenure as Patuxent's director—that is, the historical components that have been merged and divided over the years to become the current-day Patuxent Wildlife Research Center, as well as the colocated USFWS and other groups that once were part of entities such as the Migratory Bird Populations Station.

Background of the Breeding Bird Survey

The USFWS had a long history of bird population research before the initiation of the BBS. Roadside surveys of singing grounds of American woodcock were pioneered by Mendall and Aldous (1943), and became a standard approach for monitoring the species. Sheldon (1953) conducted studies to address the number, duration, and protocols for a stop-based roadside woodcock survey, and Kozicky and others (1954) conducted a statistical review of the approach, recommending random route locations. Chan Robbins helped analyze and summarize woodcock and mourning dove surveys during the 1950s, and participated in the preparation of status reports used in setting harvest regulations for these species. Although Chan had a great deal of experience with alternative bird counting approaches such as atlases, breeding bird censuses, Christmas Bird Counts (CBC), and roving censuses, he realized that the roadside survey had advantages over the alternatives as an efficient and relatively consistent way of collecting data over large areas. The method also had the advantage of having undergone a substantial evolution in approach and several methodological reviews while the USFWS was implementing the woodcock and dove surveys.

The critical difference between a nongame survey and the dove and woodcock surveys was that states were willing to devote resources to ensure adequate monitoring of harvested species, but no resources were available for nongame species. Consequently, when considering how to implement a North American breeding bird survey, Chan could not rely on the existing network of State personnel to conduct the counts. Fortunately, his birding activities provided him with a unique connection to the nationwide pool of birdwatchers. Chan was a major figure in birdwatching and, through State and regional bird clubs, the National Audubon Society, and a wide array of friends and colleagues throughout the continent, he envisioned staffing a survey that would utilize volunteers in the same way that the CBC had, but that would also have the rigor of the USFWS roadside surveys. Chan described his pioneering activities in developing the BBS in several presentations and publications (for example, Robbins and others, 1986; C.S. Robbins, U.S. Geological Survey, oral commun., 2006; Robbins, 2016). The reader is referred to these sources for Chan's first-hand account of his use of the environmental awareness spawned by Rachel Carson's work to establish the need for a nationwide breeding bird survey (see also Sauer, 2008).

Tending to the Survey: Research and Management of a Complex Survey

Chan Robbins wanted the BBS to be relevant, and recognized from the start that relevance would require (1) designing a survey that would provide credible information; (2) implementing the survey efficiently in terms of the logistics of recruiting the observers and providing support in the form of information (data forms, maps) and communications (a labor-intensive task in the 1960s); (3) managing data (also very labor intensive); and (4) analyzing and effectively presenting the results. These needs are reflected in Chan's early requests for volunteers (Robbins, 1965b) and his prompt summary of the data (Robbins, 1965a). Because availability of and access to results as well as timely feedback to observers are critical aspects of a successful survey, Chan presented the summarized results on maps to facilitate the public's appreciation of the data (fig. 1; Robbins, 1965a).

The scope and goals of the BBS are extremely ambitious, and constant research and innovation are needed to keep pace with technological advances and maintain the credibility of the survey. Research associated with the survey has been a focus of field and statistical work at Patuxent over the past 45 years. The sections below summarize some of this research and describe how it has enhanced the value of the survey. They are organized in parallel with the essential elements of a successful survey listed above, but focus particularly on

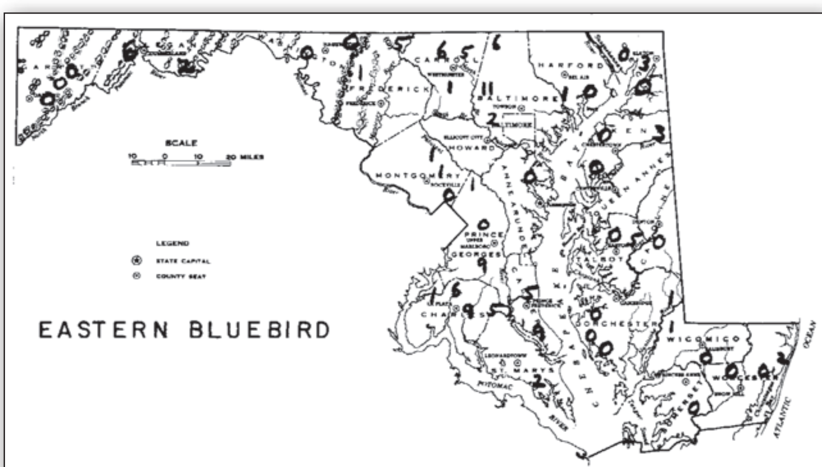


Figure 1. Eastern bluebird (*Sialia sialis*) counts for Maryland from the 1965 Breeding Bird Survey test run. (From Robbins, 1965a)

features 2 and 4 (survey implementation and communication of results), both of which are traditional functions of research that have been an important component of Patuxent for the duration of the survey.

Survey Design

Chan designed the survey to be consistent with the general approaches used by the CCS and SGS. As both of these surveys were used by management and had been tested through years of critical review and methods development, they were a good model for a logistically feasible survey that provided relevant data. Chan also conducted a variety of methodological studies in 1965 to evaluate specific aspects of the design, such as duration of counts and number of stops along the roadside routes (Robbins and others, 1986). From the start, however, Patuxent researchers criticized two important aspects of the survey. First, roadsides constitute an incomplete framework for sampling, as off-road habitats are not covered. Second, no observers count all the birds on a BBS route, and the proportion of birds missed in counting varies by species, observer, environmental conditions, date, time of day, and many other variables. Quantitative researchers at Patuxent in the 1960s were particularly critical of the BBS design, and vigorous arguments occurred about the need to conduct off-road counts and to collect additional data to control for variations in rates of bird detection (Charles Henny, U.S. Fish and Wildlife Service, oral commun., 1965). These issues have been the focus of much research at Patuxent over the past 40 years.

The question of whether the BBS needs to incorporate methods that allow estimation of rates of bird detection was, and still is, particularly controversial at Patuxent. Detectability estimation from count-based surveys has been a productive research area for Patuxent investigators, and many current and former Patuxent staff members have made important contributions in this area; all of the methods considered as possible approaches for adding detection rates to the BBS have been the subject of Patuxent studies. Patuxent alumni David Anderson and Kenneth Burnham, along with many students, have promoted line transect and capture-recapture methods for estimating detection rates of birds and other taxa.

At Patuxent, James Nichols and colleagues pioneered the use of capture-recapture and other approaches for analyzing count data to estimate species occupancy, abundance, and species richness. Andy Royle and colleagues described and implemented innovative ways of estimating detection rates from replicate surveys. William Link, William Kendall, and others addressed the question of detectability from a different perspective, considering it to be a feature of known covariates (such as the observer running the route), and modeling and controlling for these covariates in the analysis. Other quantitative ecologists, notably Ted Simons, Kenneth Pollock, and colleagues at North Carolina State University (Raleigh), have continued method development and conducted field trials to implement approaches for estimating detection rates. Finally, in his dual role as State BBS coordinator in Mississippi and Patuxent researcher, Daniel Twedt has implemented a pilot project to test the applicability of some of the field methods for estimating detectability along routes established in the Gulf Coast Network of national parks.

Most of these studies have included enthusiastic participation by field-oriented researchers and BBS coordinators, including (among many others) Patuxent biologists Chan Robbins, Deanna Dawson, Barbara Dowell, Daniel Boone, Danny Bystrak, Sam Droege, Bruce Peterjohn, Keith Pardieck, Jane Fallon, and David Ziolkowski. The volunteer BBS observers have also been more than willing to donate their time to participate in studies that use BBS routes as sample units, permitting regional analysis. This involvement of a large number of Patuxent staff members and volunteers is a model for collaborative science.

Evaluation of the consequences of the roadside nature of counts has also invoked the collaborative spirit of Patuxent staff members, most notably in a U.S. Environmental Protection Agency-funded study, in which data were collected both on survey routes and on nearby off-road routes. This study documented differences in species abundance on and off roads (Sauer and others, 2013). Another approach to addressing this question over the years has been to evaluate habitat differences between on- and off-road routes, first from aerial photographs (Keller and Scallan, 1999), then from interpreted Landsat data (National Land Cover Data [NLCD]) (Vogelmann and others, 2001) (Sauer and others, 2013; fig. 2).

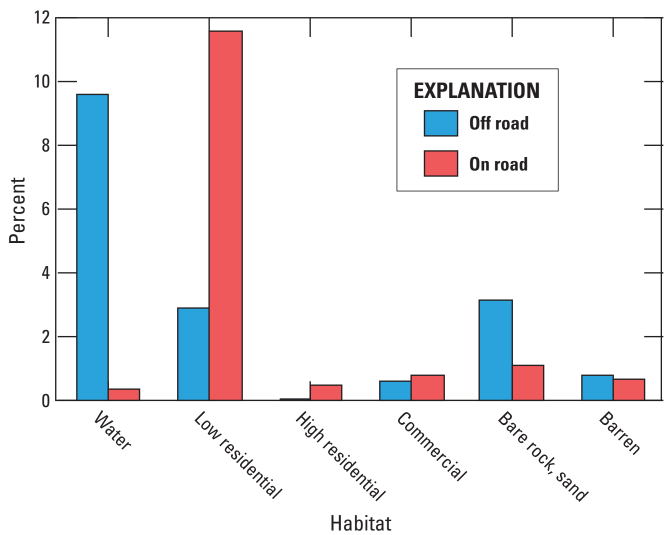


Figure 2. Percentages of six habitats near roads (at sampling sites within 400 meters [0.25 miles] of Breeding Bird Survey routes) and off roads (at sampling sites more than 400 meters from roads) in a study conducted in Maryland. (Data from Keller and Scallan, 1999; Sauer and others, 2013)

NLCD data provide excellent opportunities to evaluate habitats (fig. 3); several investigators have used them to assess whether habitats differ between on- and off-road routes (for example, Veech and others, 2012), or even to assess differences in rates of change in habitats between on- and off-road routes (Hanan, 2009). These studies have not shown major differences in habitats or rates of change in habitats between on- and off-road routes, although they have revealed that some habitats appear to be found more frequently near (for example, residential housing) or away from (for example, water) roads.

Survey Analysis and Presentation

Several themes emerge with respect to the history of the BBS. The first is that improvements in BBS analysis commonly were made possible by advances in computational technology. Early on in the BBS program, Patuxent's computers were not adequate to conduct analyses. Enormous amounts of time were spent trying to develop methods that could be used with the available computers, and the methods that ultimately were used to summarize BBS data typically were only approximations of the desired estimation. This limitation was more

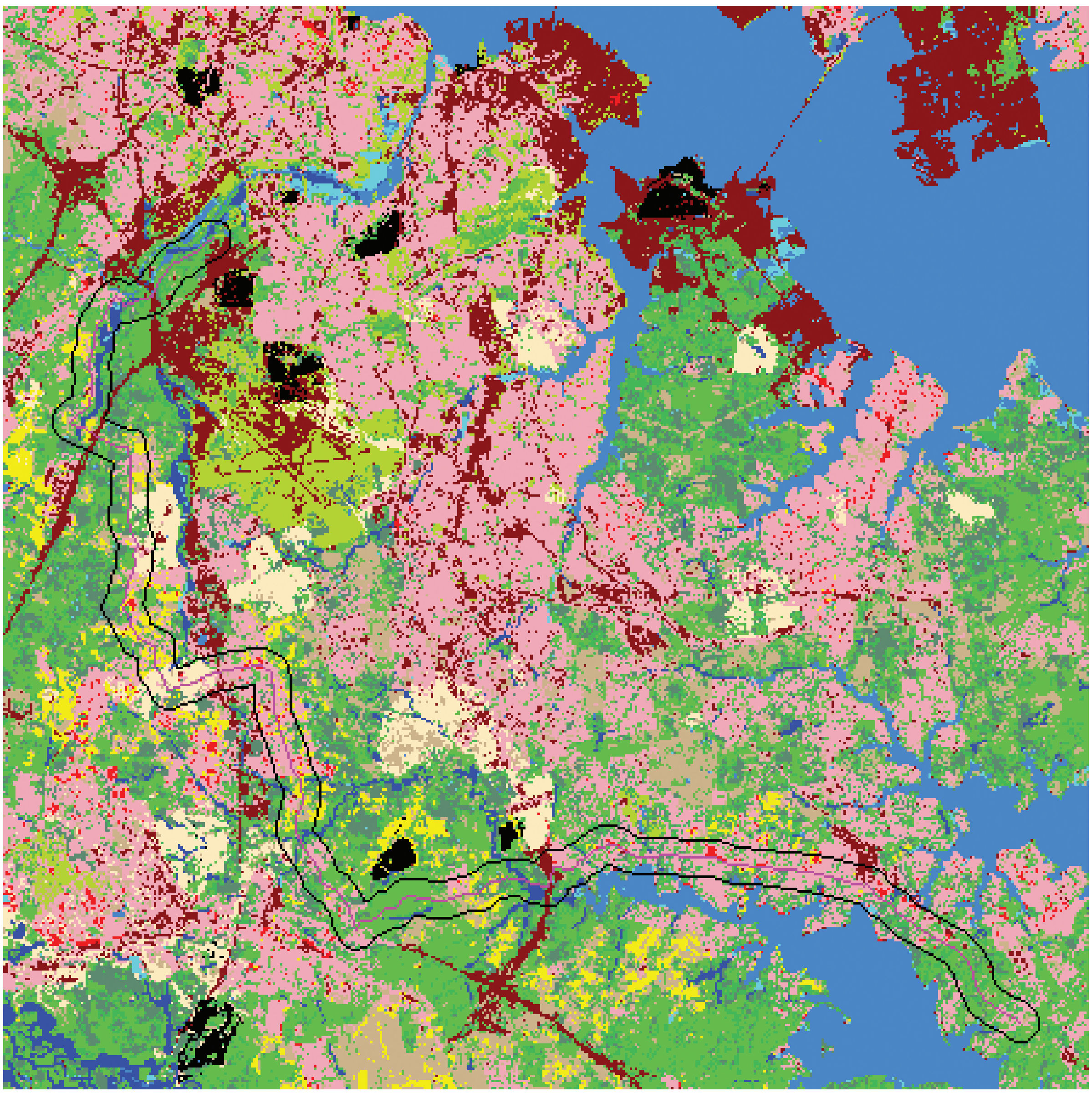


Figure 3. Severna Park, MD, Breeding Bird Survey route path (buffered at 400 meters [0.25 miles]) superimposed on National Land Cover Database (Vogelmann and others, 2001). (From U.S. Geological Survey, n.d.; map metadata accessed March 25, 2015, at http://www.mbr-pwrc.usgs.gov/bbs/trend/rtehtm13a_nlcd.html)

than just a computer issue, as new and increased computing capabilities expanded the space for and generated statistical innovation. This was clearly the case in BBS analyses.

A second theme is that innovation in methods at Patuxent has always been a collaborative effort, facilitated by the presence of mathematical statisticians, statistician/programmers, and biologists, all of whom work together to adapt existing computational resources to research needs, develop new approaches to analysis that can fully use new technology, and track emerging technologies for use in BBS analyses. This collaboration has been particularly important in terms of the deeper statistical aspects of estimation of population change, and Patuxent has been fortunate that a mathematical statistician with a focus on count surveys has been directly involved in analyzing BBS data. This involvement has paved the way to innovations such as estimating equations and hierarchical models, and has provided the expertise needed to apply the computer-intensive Bayesian statistical approaches that represent the current analysis paradigm.

The third theme is long-term participation by scientists. Consistent support for the program has led to great institutional memory and long-term stewardship of the survey. Chan Robbins has been present from the start; Danny Bystrak, Sam Droege, and Bruce Peterjohn are all former BBS coordinators working at Patuxent and are still active in the program, and collectively Paul Geissler, Bill Link, and I (John Sauer) have participated in the analysis of BBS data through 30 years. Consequently, data analysts have the great advantage of being able to talk to the people who actually designed the survey, managed the data, and conducted earlier analyses.

Three Analytical Approaches

Analysis of BBS data is difficult because (1) the survey has a very large geographic scope; (2) survey routes vary greatly in consistency of coverage within and among regions; (3) the counting abilities of different observers, even those judged to be competent birders, can differ greatly; and (4) modeling change through time is fundamentally controversial, even without these other factors. Consequently, all serious analyses of these data attempt to address these four characteristics of BBS data analysis, and many methods have been developed to control and model this “unruly” dataset. Moreover, many investigators download BBS data and conduct summary analyses that ignore one or more of these inherent characteristics of the dataset. Evaluating these analyses and, if necessary, controlling for them has been an ongoing concern for Patuxent scientists.

BBS analysis conducted at Patuxent during the period 1966–2013 can generally be placed into one of three “paradigms,” each of which takes an alternative approach to accommodating these concerns by using statistical methods and computing technologies available at the time they were used. Placed in temporal order, the paradigms are (1) fairly simple summary analyses that relied on estimating regional change between adjacent years as ratios of comparable counts on routes and portraying them as scaled changes from some base year; (2) route-regression approaches, in which route-specific trends are used as replicates for estimating change; and (3) hierarchical models that use Bayesian methods to fit log-linear models with year effects.

Base Year Methods

Base year methods were used to analyze data from roadside surveys for American woodcock and mourning dove well before the initiation of the BBS, and are described in the scientific reports that provided summary results to managers (for example, Robbins, 1960; Kiel, 1960). The methods described in these reports show the essential components of a regional analysis. Within a region, computation of estimated change between adjacent years was estimated by using routes surveyed by the same observer, and the composite change over a longer interval was determined by multiplying a series of yearly change estimates by an estimated mean count in a base year. These indexes of change from the base year described an estimated composite time series for the region. Change for groups of regions was calculated by using an area-weighted average of the indexes from the component regions (Kiel, 1960).

Early summaries of BBS data show these general ideas, but also show a variety of alternative summaries as Chan and his colleagues explored the possibilities of summarizing North American bird population change (for example, Robbins and Van Velzen, 1969, 1974). Unfortunately, analysis of BBS data, which included data from more than 500 species of North American birds collected on thousands of survey routes distributed over both the United States and southern Canada (fig. 4), proved to be very challenging. Many species were encountered only infrequently on routes, observers tended to differ greatly in quality of information, not all routes were surveyed, and the expansion of the survey into new regions resulted in data that were very unequally distributed in space and time. Analysts were greatly constrained in the types of analyses that could be conducted, and cost was typically an issue, limiting the ability to apply complicated linear models. Computing proportional changes on comparable routes from a base year was relatively simple and could be readily implemented for BBS data.

Route Regression Approaches

Geissler and Noon (1981) provide a comprehensive summary of the analysis of the BBS through the 1970s. They acknowledge the need to control for differing routes used in change estimation, but identify several statistical concerns associated with the base year approach of multiplying mean counts from some initial year by yearly changes based on

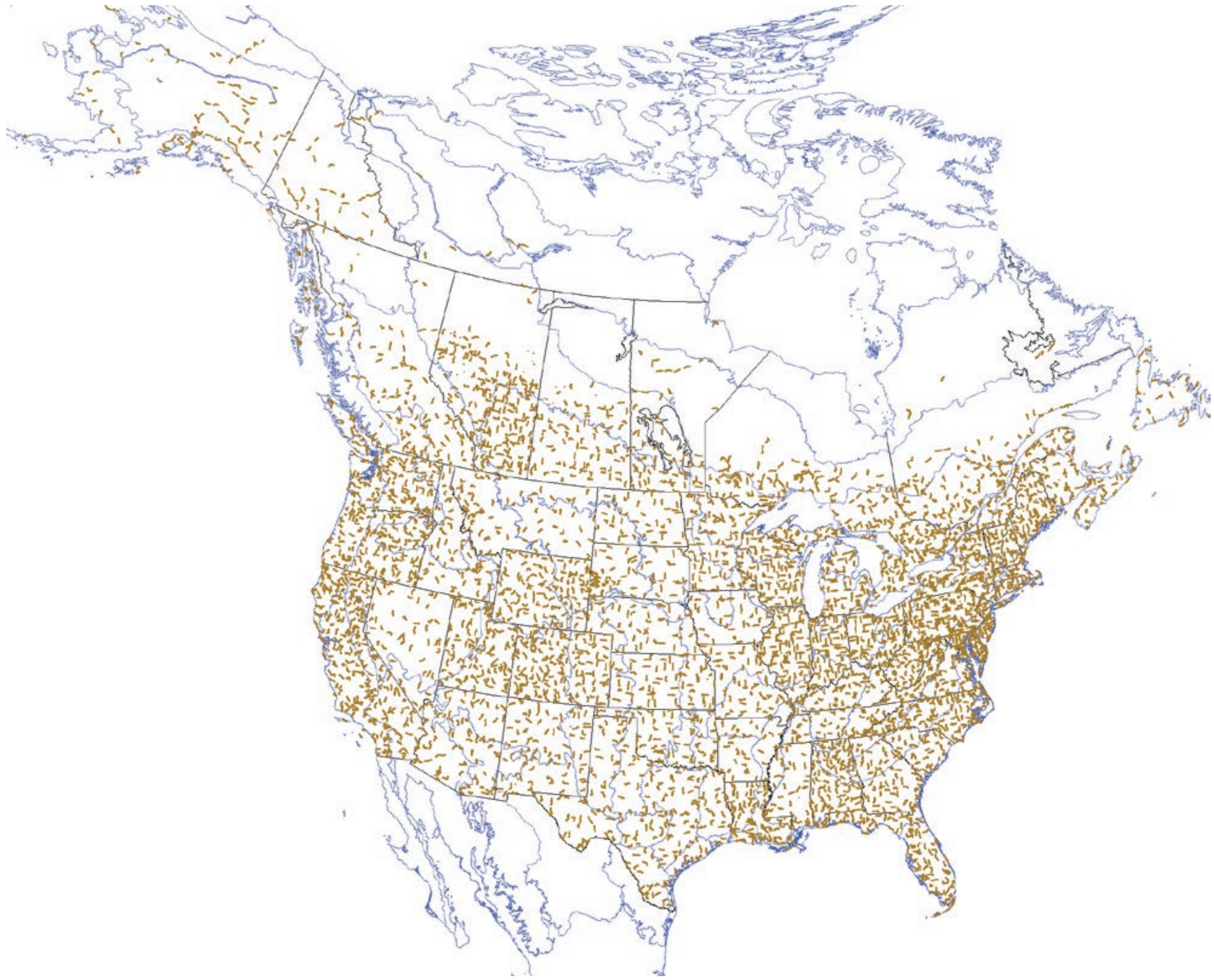


Figure 4. North American Breeding Bird Survey route locations. (From Sauer and others, 2013; note limited density of locations in northern and western regions; map metadata accessed March 25, 2015, at http://www.mbr-pwrc.usgs.gov/bbs/geographic_information/GIS_shapefiles_2013.html)

comparable routes. They instead suggest a "route regression" analysis, in which change is estimated by using regression analysis (log counts as a function of years) on individual routes, and then combined in a weighted average to form a regional composite estimate of change. The advantage of this approach is that observer differences can be controlled for in the analysis by including observer information as a covariate. Route regression methods were implemented for the survey and used in the 15-year summary of the BBS (Robbins and others, 1986), an important summary of the survey. Paul Geissler, a key figure in its development, did an admirable job of developing a robust analysis that could be applied to almost any BBS dataset.

The route regression method, with several modifications, was used as the primary BBS analysis method from 1986 to 2008. Like the base year method, route regression analyses could be implemented with relatively limited computer resources. It was a robust approach in that it could be implemented for almost any dataset, no matter how unbalanced with respect to patterns of years when routes were surveyed. Unfortunately, this adaptability had a cost in terms of limited capability for inference, and aspects such as the precision weightings that were criticized as being extemporaneous (Sauer and Link, 2011). With this complicated weighted average, no overall model could form a framework for estimation; variances needed to be calculated through bootstrapping, a tedious nonparametric procedure. Route regression produced a summary of interval-specific trend, but many people wanted more information—at least a graph showing population indices by year. Sauer and Geissler (1990) suggested an approach for estimating composite yearly indices of abundance that summarized the pattern around the trend line, but estimating variances of these annual indices was not possible.

Paul Geissler weathered a great deal of criticism before the route regression method was accepted, and it underwent periodic review and modification throughout the time of its use. Concerns about estimation of change on routes done by using simple regression on log counts was addressed in 1994, when Link and Sauer (1994) suggested using estimating equations to estimate trend on routes. However, the limited nature of the trend summaries, and the advent of methods that permitted comprehensive summaries with variances from the data, ultimately led to the replacement in 2008 of the route regression method with a hierarchical model.

Hierarchical Models

In 2002, Link and Sauer (2002) suggested the use of a log-linear hierarchical model for analysis of BBS data. Hierarchical models are a flexible means of modeling complex, multiscale longitudinal surveys such as the BBS. Attributes can be estimated at different scales (for example, routes, strata, continent-wide); the repeated nature of counts within survey routes can be modeled; nuisance factors such as differences in counting ability among observers and observer start-up effects can be controlled for; and year effects can be treated as random and estimated even when some years are poorly sampled (again, a common issue in the BBS). Most important, the model can be fit by using Markov chain Monte Carlo, an extremely computer-intensive method that became accessible to the scientific community when the software program WinBUGS (Lunn and others, 2000) was released in 1989. These methods require a Bayesian approach to statistics, in which all quantities are random and, rather than providing estimates of unknown fixed parameters, the goal of inference is to estimate the distributions of unknown (but variable) quantities of interest. Bayesian methods have an appealing conceptual simplicity and avoid the nuanced discussions that commonly afflict standard (non-Bayesian, or "Frequentist") statistical inference; they also have the great practical advantage of providing the only way to develop a comprehensive statistical framework for estimating population change from BBS data.

Bill Link became interested in these methods when he was developing approaches for summarizing collections of species trends (that is, how many species are increasing in population), and it became evident that Bayesian methods were a natural approach for estimating BBS and other data. He gradually became an important proponent of the use of these methods in ecological statistics (for example, Link and Barker, 2010).

Sauer and Link (2011) published a comprehensive comparative analysis of population change using these hierarchical models in 2011, and routinely continue to provide hierarchical model results to users. One great advantage of hierarchical models is their extreme flexibility. They provide a basis for an infinite number of elaborations, and users can associate attributes with population relative abundance and change at any scale of interest. They also can include submodels to accommodate observational components such as detectability.

Maps of Breeding Bird Survey Data

The benefits of the visual display of BBS data have long been obvious. Chan Robbins (1965a) made simple maps by writing numbers of birds encountered on routes in Maryland from the 1965 test survey (fig. 1); Danny Bystrak qualitatively estimated contour lines for maps in a summary of the BBS's first 15 years (Robbins and others, 1986) and other publications. By 1995, Patuxent was producing contour maps from surfaces based on Kriging and other surface modeling procedures (Sauer and others, 1995). Currently (2016), inverse-distance maps of both trend and abundance are made for more than 420 bird species (fig. 5). More sophisticated approaches such as hierarchical models have been implemented for selected species, but are not routinely applied to BBS data (Thogmartin and others, 2004).

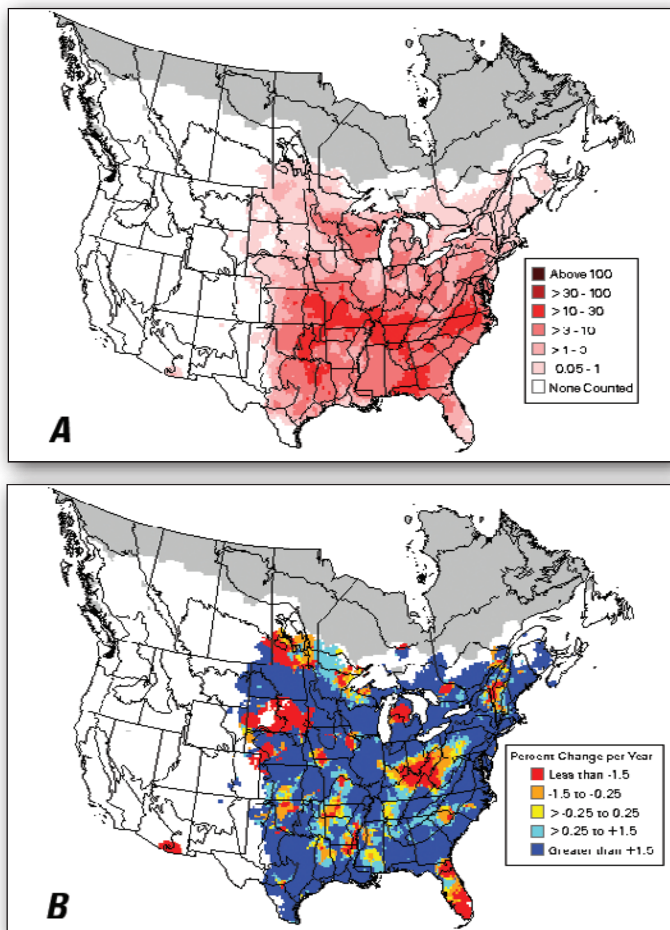


Figure 5. *A*, Relative abundance (summer distribution), 2006–10, and *B*, population change (trend) of Eastern bluebirds (*Sialia sialis*) in the 1966–2010 Breeding Bird Survey (BBS) analysis. (From Sauer and others, 2011; accessed February 16, 2011, at *A*, http://www.mbr-pwrc.usgs.gov/bbs/ra2010/ra7660.htm and *B*, http://mbr-pwrc.usgs.gov/bbs/tr2010/tr07660.htm; gray areas are regions outside the BBS area)

Internet-Based Summaries

In 1997, Patuxent began providing comprehensive summaries of BBS data to users on the World Wide Web (WWW) (Sauer and others, 1997). Jim Hines and I had been developing a stand-alone, PC (personal computer) -based program for summary and display of population trends, annual indices, and abundance and trend maps that we called program VUBBS. The material we had been producing was easily converted to the HyperText Markup Language (html) format that is still (2016) a primary means of displaying WWW content on browsers. Many of the results were prepackaged; we conducted the analysis, reviewed the results for consistency and correctness, and then provided interactive lists from which users could select species data for display. Because the results are served from a computer at Patuxent, we had great flexibility to develop new summaries by means of Perl scripts and other programs that allowed users to run programs on Patuxent's computers. In this way, users could estimate population trends interactively for any species using predefined regions. These online summary results are revised annually, are available to any user, and have proven to be effective tools for bird conservation (figs. 6 and 7).

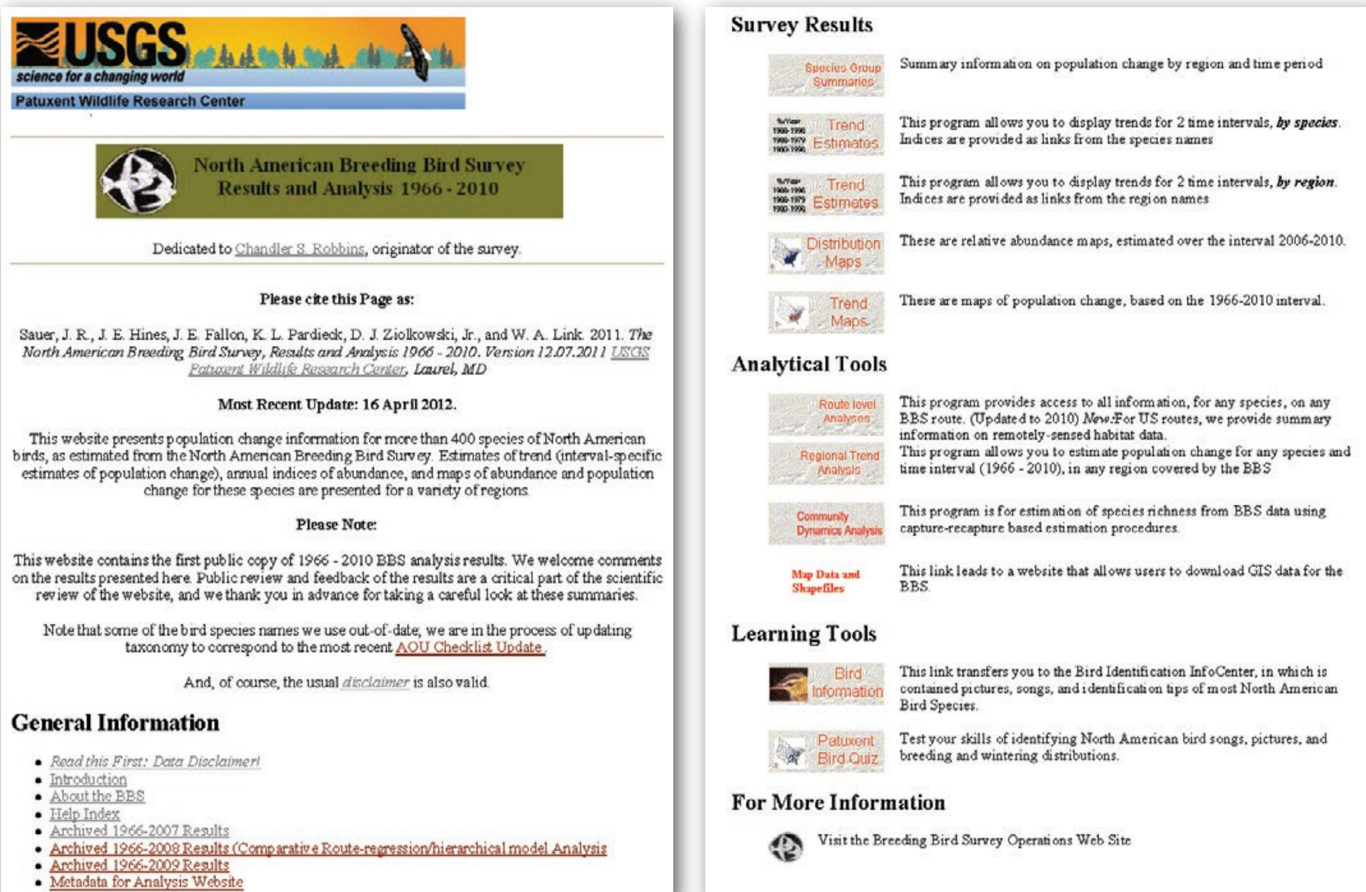
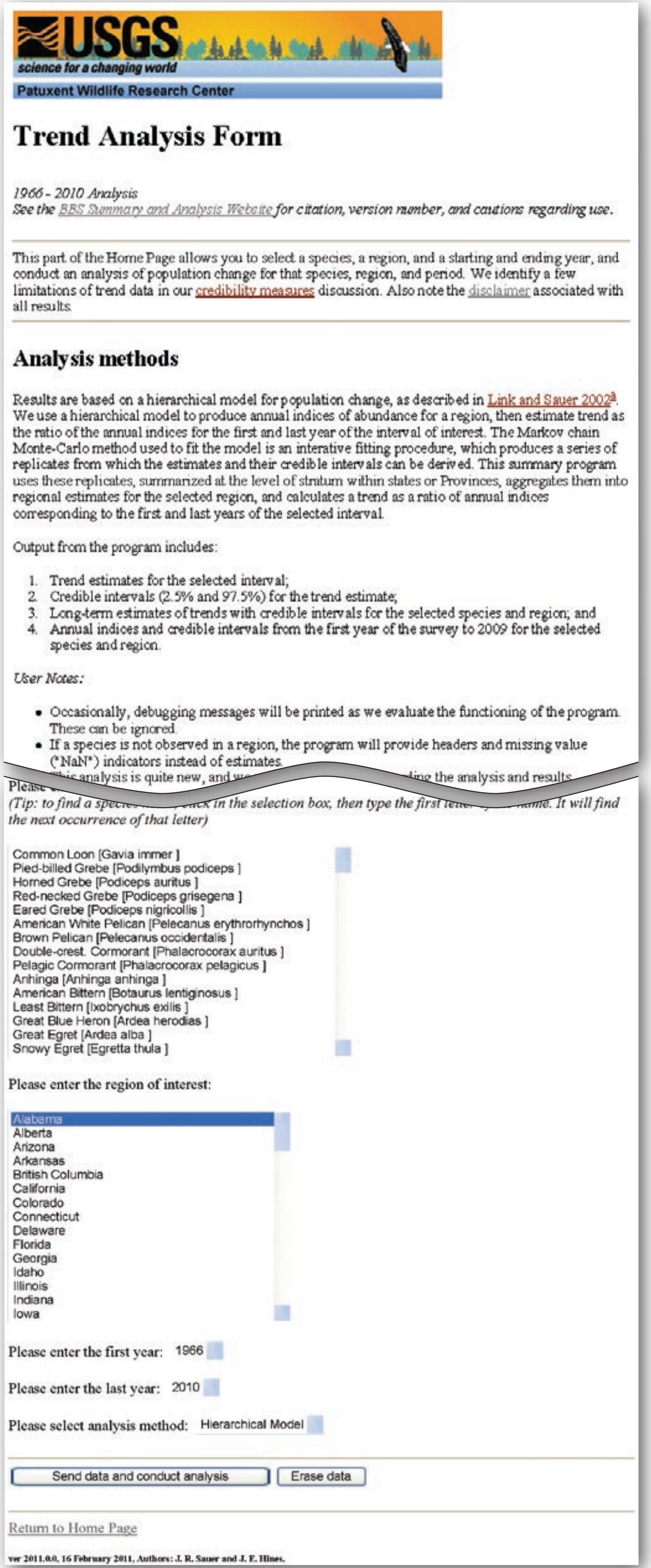


Figure 6. Screen capture of the home page of the North American Breeding Bird Survey results and analysis Web site, 1966–2010. (From Sauer and others, 2011)



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Trend Analysis Form

1966 - 2010 Analysis
See the BBS Summary and Analysis Website *for citation, version number, and cautions regarding use.*

This part of the Home Page allows you to select a species, a region, and a starting and ending year, and conduct an analysis of population change for that species, region, and period. We identify a few limitations of trend data in our credibility measures discussion. Also note the disclaimer associated with all results.

Analysis methods

Results are based on a hierarchical model for population change, as described in Link and Sauer 2002. We use a hierarchical model to produce annual indices of abundance for a region, then estimate trend as the ratio of the annual indices for the first and last year of the interval of interest. The Markov chain Monte-Carlo method used to fit the model is an interative fitting procedure, which produces a series of replicates from which the estimates and their credible intervals can be derived. This summary program uses these replicates, summarized at the level of stratum within states or Provinces, aggregates them into regional estimates for the selected region, and calculates a trend as a ratio of annual indices corresponding to the first and last years of the selected interval.

Output from the program includes:

1. Trend estimates for the selected interval;
2. Credible intervals (2.5% and 97.5%) for the trend estimate;
3. Long-term estimates of trends with credible intervals for the selected species and region; and
4. Annual indices and credible intervals from the first year of the survey to 2009 for the selected species and region.

User Notes:

- Occasionally, debugging messages will be printed as we evaluate the functioning of the program. These can be ignored.
- If a species is not observed in a region, the program will provide headers and missing value ("NaN") indicators instead of estimates.
- This analysis is quite new, and we ... ding the analysis and results.

Please ...
(Tip: to find a species ... click in the selection box, then type the first letter ... name. It will find the next occurrence of that letter)

Common Loon [Gavia immer]
Pied-billed Grebe [Podilymbus podiceps]
Horned Grebe [Podiceps auritus]
Red-necked Grebe [Podiceps grisegena]
Eared Grebe [Podiceps nigricollis]
American White Pelican [Pelecanus erythrorhynchos]
Brown Pelican [Pelecanus occidentalis]
Double-crest. Cormorant [Phalacrocorax auritus]
Pelagic Cormorant [Phalacrocorax pelagicus]
Anhinga [Anhinga anhinga]
American Bittern [Botaurus lentiginosus]
Least Bittern [Ixobrychus exilis]
Great Blue Heron [Ardea herodias]
Great Egret [Ardea alba]
Snowy Egret [Egretta thula]

Please enter the region of interest:

Alabama
Alberta
Arizona
Arkansas
British Columbia
California
Colorado
Connecticut
Delaware
Florida
Georgia
Idaho
Illinois
Indiana
Iowa

Please enter the first year: 1966

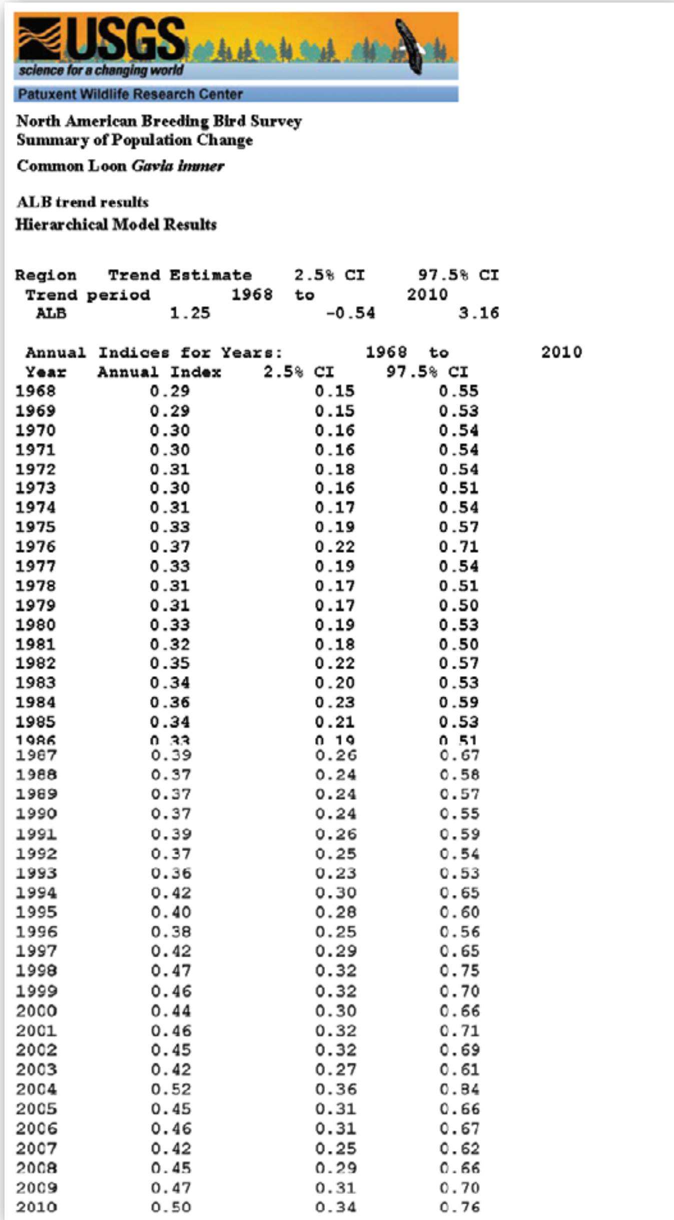
Please enter the last year: 2010

Please select analysis method: Hierarchical Model

Send data and conduct analysis | Erase data

Return to Home Page

ver 2011.0.0, 16 February 2011, Authors: J. R. Sauer and J. E. Hines.



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North American Breeding Bird Survey
Summary of Population Change
Common Loon *Gavia immer*

ALB trend results
Hierarchical Model Results

Region	Trend Estimate	2.5% CI	97.5% CI
Trend period	1968	to	2010
ALB	1.25	-0.54	3.16

Annual Indices for Years: 1968 to 2010

Year	Annual Index	2.5% CI	97.5% CI
1968	0.29	0.15	0.55
1969	0.29	0.15	0.53
1970	0.30	0.16	0.54
1971	0.30	0.16	0.54
1972	0.31	0.18	0.54
1973	0.30	0.16	0.51
1974	0.31	0.17	0.54
1975	0.33	0.19	0.57
1976	0.37	0.22	0.71
1977	0.33	0.19	0.54
1978	0.31	0.17	0.51
1979	0.31	0.17	0.50
1980	0.33	0.19	0.53
1981	0.32	0.18	0.50
1982	0.35	0.22	0.57
1983	0.34	0.20	0.53
1984	0.36	0.23	0.59
1985	0.34	0.21	0.53
1986	0.33	0.19	0.51
1987	0.39	0.26	0.67
1988	0.37	0.24	0.58
1989	0.37	0.24	0.57
1990	0.37	0.24	0.55
1991	0.39	0.26	0.59
1992	0.37	0.25	0.54
1993	0.36	0.23	0.53
1994	0.42	0.30	0.65
1995	0.40	0.28	0.60
1996	0.38	0.25	0.56
1997	0.42	0.29	0.65
1998	0.47	0.32	0.75
1999	0.46	0.32	0.70
2000	0.44	0.30	0.66
2001	0.46	0.32	0.71
2002	0.45	0.32	0.69
2003	0.42	0.27	0.61
2004	0.52	0.36	0.84
2005	0.45	0.31	0.66
2006	0.46	0.31	0.67
2007	0.42	0.25	0.62
2008	0.45	0.29	0.66
2009	0.47	0.31	0.70
2010	0.50	0.34	0.76

Figure 7. Screen capture of Web site showing an example of the results obtained by using the interactive program for summarizing population change from North American Breeding Bird Survey data (http://www.mbr-pwrc.usgs.gov/bbs/trend/tf11.html, accessed February 16, 2011). The program is shown in the left and center columns; the right column shows a results summary for Common Loons (*Gavia immer*) in Alberta, Canada.

A "Living" Survey (Past, Present, and Future)

The BBS, like any survey, can never be considered a finished product, but must be subject to modification to incorporate new ideas and address newly discovered (or even long-term) deficiencies. Patuxent researchers have focused on improving the analysis of this important survey, conducting field studies on the process of counting birds (for example, Keller and Fuller, 1995), and evaluating the consequences of detectability and roadside survey constraints. In addition, Patuxent has made the survey and analyses increasingly accessible to the scientific community through computer programs and technical support. Many researchers use BBS data, and their analyses often generate new ideas and raise (or quell) concerns about the survey. Making the survey analytical results and tools available facilitates that work. The interactive analysis program on the Breeding Bird Survey Web site (http://www.mbr-pwrc.usgs.gov/bbs/bbs.html, accessed February 16, 2011), for example, allows users to select data by region and period for analysis. This interaction between the organization that conducts the survey and the community that uses the survey data is critical for the long-term sustainability of the survey, as it maintains a focus on ascertaining and meeting user needs.

Patuxent has long taken a leadership role in summarizing this important survey. The key to the survey's success is constant revision and research input into the "routine" yearly summaries of the data. Another key component of this success is the mutual respect and collaborative research skills of the BBS staff members, ranging from ornithologists, who inform the analysis with natural history and taxonomic information; to computer programmers, who provide the programming skills and Internet expertise to allow implementation of analysis and summary programs; to mathematical statisticians, who authoritatively navigate the increasingly complicated methods now employed for BBS data analysis. Although administrators may, at times, underestimate the value of statistical analysis in ecological research and relegate statisticians to a supporting role, such a philosophy could undermine the success of a complex and evolving survey such as the BBS. BBS researchers have been fortunate over the years that Patuxent's administrators have recognized that the effective running and maintenance of the survey requires a collaborative partnership.

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Female killdeer guarding eggs at Patuxent Research Refuge, Laurel, MD, 2007. Photo by Matthew C. Perry, U.S. Geological Survey.

The Migratory Bird and Habitat Research Laboratory and the Accelerated Research Program

By Richard A. Coon

The Patuxent Wildlife Research Center (Patuxent) housed two important programs that were not supervised through the office of the Director of Patuxent during the 1960s and 1970s. Although they received administrative support from Patuxent, they were supervised from the U.S. Fish and Wildlife Service (USFWS) headquarters in Washington, D.C. One, the Migratory Bird Populations Station (MBPS), was established in 1961; the other, the Migratory Bird and Habitat Research Laboratory (MBHRL), was established in 1972 (Perry, 2004). This chapter briefly discusses MBPS and how some of its functions were transferred to MBHRL when this new laboratory was created.

Migratory Bird Populations Station

The main purpose of MBPS was to be a central location for the USFWS to study migratory bird population dynamics across political and administrative boundaries. Its responsibilities were international in scope, carried out in cooperation with Canada, Mexico, and the 50 States, as well as universities and private organizations.

Included as part of MBPS was the internationally recognized Bird Banding Laboratory, along with key staff tasked with collecting harvest information, analyzing population and production data, and helping to develop annual hunting regulations for migratory game birds. When the Gabrielson Laboratory was dedicated in 1969 as a major location for USFWS migratory bird programs, all MBPS personnel were moved there, including the Atlantic Flyway Representative position, which had been located in Delaware. The major computer system of the USFWS was then in the Bird Banding Laboratory and functioned to process and analyze the millions of bird banding records to estimate the abundance, survival, and distribution of migratory birds during their annual cycle.

Creation of the Migratory Bird and Habitat Research Laboratory

In July 1972, the management and research functions of MBPS were split and transferred to two newly organized entities. One was the Office of Migratory Bird Management (MBMO), housed at Patuxent but supervised from USFWS headquarters in Washington, D.C. Dr. John P. Rogers was the office's first chief. The other was the newly organized MBHRL at Patuxent, which was added to the Division of Wildlife Research, with Dr. Robert I. Smith as its first director. Dr. Fant W. Martin became director of MBHRL when Smith was called to Washington, D.C., with Jerry Longcore in 1973 to work on the national issue of lead poisoning in waterfowl. Fant's secretary was Marylu Lammers. Fant hired Drs. Franklin Percival and Stanley Anderson to supervise the Game and Non-Game Sections, respectively. Members of the Game Section included Byron (Ken) Williams, Chuck Kimball, Bob Munro, Lois Moyer, Richard Coon, Paul Geisler, George Haas, Jerry Longcore, Jim Nichols, Jim Hines, Tom Dwyer, Matt Perry, Mike Haramis, Holly Obrecht, Fran Uhler, Ralph Andrews, and Frank McGilvrey. Among those involved in nongame work were Chan Robbins, Mark Fuller, Mike Erwin, Deanna Dawson, Barbara Dowell, Elwood Martin, and Marshall Howe.

Migratory Bird Habitat and Research Laboratory Activities

During the 1970s, Patuxent was growing larger. Its staff was concentrating on contaminants research as well as its newest function, the Endangered Species Program, whereas activities such as wetland research (Wetland Ecology Section) were receiving less emphasis. Additionally, Patuxent increased the number of field stations around the country. Because of this shift in emphasis and an expansion of field station responsibilities, the Wetland Ecology Section was transferred to MBHRL.

Shortly after the transfer, the long-running impoundment management program at Patuxent was discontinued.

MBHRL activities in the 1970s were divided between field research and in-house work at Patuxent. One noteworthy feature of work at Patuxent was the increased responsibility for analyzing migratory bird population data. Drs. Dave Anderson and Jim Nichols achieved international prominence with their sophisticated modeling techniques, which improved the management potential for waterfowl populations and other migratory birds on a large scale.

Off-site work on species of concern and species groups was conducted in specific geographic areas. In Maine, Tom Dwyer and Bill Krohn worked on the American woodcock (*Scolopax minor*), and Jerry Longcore focused on the diminishing population status of black ducks (*Anas rubripes*). Matt Perry and Mike Haramis conducted canvasback (*Aythya valisineria*) studies both at Patuxent and on Chesapeake Bay. In South Carolina and Georgia, George Haas conducted extensive research on mourning doves (*Zenaida macroura*). In many of these studies, radiotelemetry techniques were used widely to collect data that otherwise would not have been available.

MBHRL disbanded in 1981, and Patuxent absorbed its functions and responsibilities. Fant Martin had transferred to MBMO in 1980 and, after another year under interim Patuxent Director John Rogers, Jr., the lab was closed as directed by USFWS headquarters.

George Haas, U.S. Fish and Wildlife Service, capturing a dove in South Carolina, 1977. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

Accelerated Research Program for Migratory Shore and Upland Game Birds

Since the passage of the Migratory Bird Treaty Act in 1918, the Federal Government and, ultimately, the USFWS, has been responsible for the management and study of migratory birds. One group, generally known as webless migratory birds, had been largely understudied, however. By the mid-1960s, a growing belief existed among wildlife managers that this situation needed to be remedied. Consequently, State wildlife managers working with the USFWS acted to obtain congressional funding for the Accelerated Research Program (ARP), which focused on migratory shore and upland game birds, in 1967 (MacDonald and Evans, 1970).

In 1972, the ARP, under the overall direction of Fant Martin, became one of the programs within MBHRL at Patuxent. The following biologists provided oversight to the program by serving as contract managers: Henry (Milt) Reeves, 1967–68; Duncan MacDonald, 1968–71; Fant Martin, 1971–75; Richard Coon, 1975–80; and Tom Dwyer, 1980–82.

The two primary forces behind the formation of the ARP were the Southeastern Association of Game and Fish Commissioners and the International Association of Game, Fish and Conservation Commissioners (later the International Association of Fish and Wildlife Agencies [IAFWA]). The species to be studied included Wilson's snipe (*Gallinago delicata*), rails (Rallidae), American coots (*Fulica americana*), sandhill cranes (*Grus americana*), American woodcock, and the various doves, principally the mourning dove, and white-winged dove (*Zenaida asiatica*).

The paucity of biological information on these species was reducing the capability of the USFWS and the States to manage them as game birds (for example, setting hunting seasons, determining season length, establishing bag limits).

Young woodcock banded at Patuxent Wildlife Research Center, Laurel, MD, by Brooke Meanley, U.S. Fish and Wildlife Service, 1979. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

Frank Percival, U.S. Fish and Wildlife Service, recording data on September dove survey at Patuxent Wildlife Research Center, Laurel, MD, summer 1979. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

Their food habits, population status, migration characteristics, and general life histories would be the target of the new research effort. With the loss of habitats for these species increasing, the need for information about the population health, status, and distribution was becoming critical. Techniques such as radiotelemetry, cannon netting, mist netting, night lighting, banding, and color marking were important research tools. In addition to the State wildlife agencies that were seeking funds, many universities and cooperative wildlife units competed for money to support M.S. and Ph.D. studies. After a few years, workshops were held to present, publish, and disseminate tribute research results.

In July 1967, Congress initiated an annual appropriation of $250,000 to fund the ARP. Of this amount, $175,000 was to be contracted to the States to support individual research projects, $50,000 was retained by the USFWS for research on woodcock and mourning doves, and $25,000 was retained for program administration. The USFWS administered the contracts, provided oversight and review for selected projects, and received the final research reports. In the 16 years during which the program was active, 122 research projects were completed in 41 States (Eshmeyer and Harris, 1974).

Research by the USFWS under the ARP was conducted on woodcock in Maine, mainly at the Moosehorn National Wildlife Refuge, first by William Russell and then by William Krohn and Tom Dwyer. In South Carolina and Georgia, Spencer Amend was the first biologist to study mourning doves with ARP funding; he was followed by George Haas.

Termination of the Accelerated Research Program

The ARP was terminated in October 1982, when annual funding was discontinued because of fiscal constraints imposed on the USFWS. Approximately $2.5 million had been awarded to the States over the course of the 16-year program. An estimated 340 publications resulted from the ARP (Ronnie George, Texas Parks and Wildlife Department, written commun., 1985).

An important outgrowth of the ARP was the publication of “Management of Migratory Shore and Upland Game Birds in North America” in 1977, under the direction of the IAFWA (Sanderson, 1977). This book, edited by Glen C. Sanderson of the Illinois Natural History Survey, summarized the data and other information that had been collected to that point, primarily through ARP funding, about migratory shore and upland game birds. Additionally, it identified future actions and needs for these birds, including financial support, to ensure sustainable populations for the public to enjoy. The book was updated and reissued in 1994 (Tacha and Braun, 1994).

Importance of the Accelerated Research Program

A primary value of the ARP was its direct benefit to wildlife managers, particularly at the State level. The vast majority of the studies consisted of applied research that focused on important webless migratory game-bird species. In addition, because proposals for research were guided by the States, the studies were needs based. The ARP arguably enhanced our collective understanding of the biology of webless migratory game birds more than any other wildlife management program. Listed below are a few examples of the many outcomes and benefits that resulted from this important cooperative program:

1. The hunting of mourning doves was legalized in Wyoming, Nebraska, and North Dakota.

2. Hunting pressure and harvest rates were shown to have little adverse effect on mourning dove survival.

3. Hunting seasons on band-tailed pigeons (*Columba fasciata*) were reinstituted in Arizona, Colorado, New Mexico, and Utah.

4. The redefinition of harvest unit boundaries resulted in increased hunting opportunity for snipe and rail hunters.

5. The understanding of the timing of American coot migration was improved.

6. Subpopulations of sandhill cranes were identified.
7. Estimates of allowable harvest rates for sandhill cranes were improved.
8. Identification of woodcock migration routes and wintering locations through intense banding programs allowed for the development of two management units (eastern and western) for improved harvest management.
9. Wetland habitats preferred by rails and common snipe were identified.
10. Census procedures for rails were developed.
11. The interchange of knowledge, thoughts, and ideas among individuals working within the States, the regions, and various other agencies, universities, and organizations was facilitated.

Revitalization of the Accelerated Research Program

Beginning in 1986, there was renewed interest on the part of the States and the USFWS to revitalize the ARP with new funding. After a 9-year delay, $300,000 was made available for the program, which was renamed the Webless Migratory Game Bird Research Program (Dolton, 2002). Funds were set aside by Dr. Ronald Pulliam, then Director of the Biological Resources Division of the U.S. Geological Survey. This one-time funding was followed in 1996 by an annual allocation of $150,000 from the USFWS. Dolton (2002) of the USFWS, Office (now [2016] Division) of Migratory Bird Management, in Denver, CO, reported that in the first 6 years of the renewed program, 32 research projects were completed with more than $1.1 million of program funds. This number increases to approximately $4 million when the contributions of materials, time, and additional support made by State wildlife agencies, universities, and other non-USFWS sources as the research projects were conducted are considered.

Summary

The unique quality of a major wildlife research center like Patuxent is its ability to adapt to changing times, changing research needs, and changing budgets. As managers and directors come and go, new programs are born and older programs disappear. The Migratory Bird and Habitat Research Laboratory (MBHRL) and the Accelerated Research Program (ARP) exemplified changing times and priorities; nevertheless, the achievements of both while they existed left a lasting mark on natural-resource conservation. Since then, Patuxent-wide work has carried on as former MBHRL personnel, including ARP staff, were absorbed into other Patuxent programs. Throughout its history, Patuxent has maintained its reputation as a world-renowned wildlife research center—a tribute to the resiliency and dedication of its staff, whose extraordinary productivity has been sustained throughout.

Normal and albino Virginia rails banded by Mike Haramis at Patuxent River, 1992. Photo by G. Michael Haramis, U.S. Fish and Wildlife Service.

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Patuxent's American Black Duck Studies from Chesapeake Bay to Maine and Beyond

By Jerry R. Longcore

Introduction

The information in this chapter draws on published literature and unpublished reports written by staff members of the U.S. Geological Survey, Patuxent Wildlife Research Center (Patuxent), during its 75-year history. Reports by Bureau of Biological Survey (Biological Survey) and U.S. Fish and Wildlife Service (USFWS) personnel are included because the research entity currently known as Patuxent was formerly administered by these agencies. Some of the cited reports were prepared by USFWS scientists while they were not working at Patuxent. Literature resulting from work at other Federal and State agencies and private and academic institutions that influenced research at Patuxent on the American black duck (*Anas rubripes*, hereafter referred to as black duck) and that is essential to the discussion of black duck studies is included. Literature citations are selective, but include representative papers that cover four research topics: chemical contaminants, ecology, analyses of banding and survey data and population changes, and the now discredited hypothesis that the mallard (*Anas platyrhynchos*) could competitively exclude black ducks from fertile wetlands.

Captive black ducks at Patuxent Wildlife Research Center, Laurel, MD, March 1992. Photograph by Matthew C. Perry, U.S. Fish and Wildlife Service.

Background

The black duck, a sporting game duck ardently sought throughout its range by waterfowlers, is regaled as "the most sagacious, wary and wildest of all ducks" (Kortright, 1942, p. 164). This species has been a favorite target of coastal gunners along the Atlantic Flyway (Wright, 1947; Sullivan, 2003), inland throughout the Mississippi Flyway (Bellrose and Chase, 1950), and throughout its range in Canada. Regulations governing hunting of waterfowl were historically nearly nonexistent or extremely liberal, with 107-day seasons and large daily bag limits of 75 birds in the 1920s. Shooting was allowed during spring migration, and hunters took sport in seeing how many sitting ducks could be killed with one shot, usually with 8- or 10-gage double-barreled shotguns (Day, 1949, p. 10). Baiting of ducks was allowed (Leopold, 1931), live decoys referred to as "call" ducks (Perry, 1984) were used, and killing of ducks to sell in the markets of large cities occurred with impunity (Buckingham, 1937). The great market hunting areas were along the Atlantic Coast, Lower Mississippi Flyway States, and the Pacific Coast States, especially California (Hornaday, 1913).

Studying the ecology of black ducks and their management was not a research priority during the early years of the Biological Survey, which evolved in 1896 from the Division of Economic Ornithology, formed by an Act of Congress in 1886 and located in the U.S. Department of Agriculture (Perry, 1984). Scientists at that time focused on recording the negative economic effects of avian species on agricultural crops, although they did publish on foods of waterfowl (McAtee, 1913) and bird migration (Cooke, 1906). The Biological Survey, which was in its infancy in 1920 (Hawkins, 1984), started a bird-banding program headed by Frederick C. Lincoln. The Biological Survey was the forerunner of the Bureau of Sport Fisheries and Wildlife, later renamed the U.S. Fish and Wildlife Service and transferred to the Department of the Interior (DOI).

1930s

The Patuxent Research Refuge was established in 1936 by Executive Order 7514 as part of the U.S. Department of Agriculture. In 1939, the Bureau of Fisheries and the Biological Survey were consolidated into one agency and, in 1940, it was transferred to DOI to form the Fish and Wildlife Service (FWS). In 1956, the FWS was divided into the Bureau of Sport Fisheries and Wildlife (BSFW) and the Bureau of Commercial Fisheries, and the FWS became the U.S. Fish and Wildlife Service. In 1970, the Bureau of Commercial Fisheries was transferred back to the Department of Commerce and the BSFW designation was discontinued.

The name "Patuxent Research Refuge" was changed to "Patuxent Wildlife Research Center" in 1956. Scientists during the earliest years of Patuxent Research Refuge pursued work that had been begun in the Biological Survey days, mainly exploring the mystery of bird migration (Cooke, 1915; Lincoln, 1935), that led to the concept of biological flyways of birds as espoused by F.C. Lincoln (Hawkins, 1984), and identifying foods of waterfowl (Cottam, 1939; Martin and Uhler, 1939). During this time, concern for the future of diminishing stocks of waterfowl was acknowledged. Earlier, Cooke (1906, p. 10) had stated, "The principal causes of the diminished numbers of waterfowl have been market hunting, spring shooting, and the destruction of the breeding ground for farming purposes." Waterfowlers on Chesapeake Bay during the "days of plenty" shot from the deadly sinkbox in the 1800s; from 1870 to 1875, it was not uncommon for 15,000 ducks to be killed on Chesapeake Bay in a single day (Sullivan, 2003). A report about gunning on the Eastern Shore of Maryland described the use of corn bait and unplugged guns, the shipping of ducks to markets in Baltimore, and the use of live decoys, but stated that "The activities of the Biological Survey men have been such as to make the natives take precautions" (National Association of Audubon Societies, 1937).

1940s

During the next decade**,** Ira Gabrielson (1947) sounded a call to address the declining black duck population, stating that the "program should be accompanied by restrictions on shooting sufficient to limit kill to less than the annual number of ducks put on the wing." Cottam (1948) addressed the causes of the waterfowl crisis as "destruction of habitat," "subnormal production," and "overshooting." In this period, studies of black ducks by State biologists, especially in Massachusetts, were initiated. Wright (1947, p. 138–139) reported his findings on the black duck in eastern Canada in a progress report to the Chief Naturalist of Ducks Unlimited and concluded the following:

> "The evidence therefore indicates that all is not well with the black duck of the Atlantic Flyway, and that the trouble is probably not to be found in the part of life he spends in reaching the breeding ground and producing the annual crop, but in the gauntlet of gun-fire he faces from southern Canada to the wintering ground and on the wintering ground. The gradual increase in hunting pressure together with the dying off of his favourite winter food, the eelgrass, and the reduction of winter range caused by the steady building up of the human population with its attendant demand for mosquito-free summer cottages along the Atlantic seaboard, has reduced the species to the point where it is impossible, in the east, to find only one duck of any kind in 14 acres of marsh where they were once found in sufficient number that they could be secured with a club."

1950s

During this period, Stewart (1958) published distribution maps for breeding and wintering black duck populations, and Addy (1953) reported on the fall migration of the black duck. In the mid-1950s, the USFWS initiated a series of mid-winter surveys in cooperation with States in the Atlantic and Mississippi Flyways to inventory waterfowl. These mid-winter inventory (MWI) data indicated a total black duck population of 500,000 to 600,000, but this number was declining about 2 percent annually (Serie, 1997, p. 14).

1960s

During the 1960s, an evaluation of the role of chemical contaminants in the decline of the black duck was initiated by analyzing for pesticides in eggs (Reichel and Addy, 1968) and wings (Heath and Prouty, 1967; Heath, 1969). Several contaminants, especially dichlorodiphenyltrichloroethane (DDT) and its metabolites, were detected in eggs and wings, which prompted experimental pen studies in the early 1970s to determine if and how DDT affected reproduction. Stewart (1962) analyzed 1953–59 MWI data and described waterfowl populations, including that of the black duck, in the Upper Chesapeake Bay region. Lucille Stickel edited Stewart's 208-page manuscript, and several Patuxent staff members (Francis M. Uhler, Alexander Martin, Neil Hotchkiss, and Robert Mitchell) assisted in identifying foods of waterfowl sampled in Chesapeake Bay. Chuck Kaczynski and Jake Chamberlain (1968) reported the number of black ducks counted during aerial surveys in eastern Canada. John Sincock (1962) estimated the amounts of food consumed by waterfowl, including the black duck, in Back Bay, Virginia/Currituck Sound, NC.

Atlantic Flyway representatives, who were trained biologists, supported black duck research studies, surveys, and banding projects. In 1967, the Atlantic Flyway Council, Technical Section, created a Black Duck Committee (Serie, 2002); its first action was to organize a Black Duck Symposium in

Chestertown, MD (Barske, 1968). C.E. Addy (1968, p. 2) provided a general review of black duck status at the symposium, which brought together American and Canadian biologists and administrators to review known information about and identify the needs of the black duck. Several Patuxent scientists contributed papers on topics such as harvest and population dynamics (Martinson and others, 1968), aerial surveys (Chamberlain, 1968), environmental pollution (Stickel, 1968), and control of predators and competitors (McGilvrey, 1968). Comments made in the symposium proceedings included, "…it seems obvious that measures need to be taken immediately to bring controllable kill in line with production…" (Wilder, 1968); "We need more quantitative information about nonhunting mortality" (Loughrey, 1968); "Most Canadian biologists are of the opinion that not all available habitat is being used because there are not enough black ducks to occupy it" (Munro, 1968); and "Any rational attempt to reduce the legal take of black ducks should consider the situation in both Canada and the U.S." (Wilder, 1968). At this time, American and Canadian personnel agreed that the harvest of black ducks was affecting the black duck population. This consensus provided a unique opportunity to implement a plan to curtail harvest. This opportunity, however, was not embraced and, in fact, was delayed for years. In addition, Johnsgard (1967) raised the possibility that the black duck (whose gene pool was smaller than that of the mallard) could eventually disappear as a distinct entity through hybridization with the mallard, although such a development was considered unlikely in the near future. This paper and other, similar reports put forward a speculative view that mallards could be the cause of the decline in the number of black ducks. Such speculation may have confounded black duck population studies and fostered controversy that delayed the confirmation of the actual causes of the decline for the next 30 years.

Jerry Longcore, U.S. Fish and Wildlife Service, checking eggs for cracked shells, DDE study, Patuxent Wildlife Research Center, Laurel, MD, spring 1972. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

American black duck female and brood, DDE study, Patuxent Wildlife Research Center, Laurel, MD, spring 1972. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

1970s

This decade brought additional surveys to document concentrations of polychlorinated biphenyl (PCB) and DDT contaminants in black duck eggs (Longcore and Mulhern, 1973) and a survey of lead in wing bones (Stendell and others, 1979). Experimental studies of the effects of dichlorodiphenyldichloroethylene (DDE) on the thickness of black duck egg shells (Longcore and others, 1971) documented extensive shell thinning in the eggs examined compared to those collected in 1968 (Reichel and Addy, 1968). Longcore and Samson (1973) reported a fourfold increase in shell cracking when females were allowed to incubate their own clutches. This finding confirmed that the productivity of some breeding females was decreasing because of the loss of eggs with cracked shells in nests. Negative reproductive effects caused by DDE persisted into the next year, even after the dosage was curtailed (Longcore and Stendell, 1977), adding credence to the hypothesis that chemicals were affecting reproduction. Monitoring of organochlorine residues and mercury in black duck wings continued (Heath and Hill, 1974; White and Heath, 1976; White, 1979), and effects of mercury on black duck survival and reproduction were shown to include reduced egg hatchability and lower duckling survival in captive ducks fed 3 parts per million of methylmercury over 2 years (Finley and Stendell, 1978).

Geis and others (1971) analyzed data from several harvest surveys and concluded that hunting regulations affect hunting mortality rate, which in turn affects the annual survival rate; however, the statistical methods used in this study were later shown to be invalid (Anderson and Burnham, 1976). Because nest loss of ground-nesting black ducks could affect the population, McGilvrey (1971) conditioned black duck females to elevated nest cylinders on a support post equipped with a predator guard. Of 169 captive-reared female black ducks imprinted to these cylinders and then released in the fall, only 39 returned to nest the next spring.

After joining the Patuxent Migratory Bird and Habitat Research Laboratory, which had been established in 1972, Reinecke (1979) reported on the important foods, growth, and development of juvenile Maine black ducks. Hunting mortality typically was considered to be compensatory to other forms of mortality (Nichols and others, 1984), but the concept of a threshold of additivity of hunting losses emerged as Anderson and Burnham (1976, p. 41) stressed that "Whatever this point is, it may be easy to exceed it on the breeding grounds or on areas where the birds may be particularly vulnerable (Jessen, 1970). Harvest rates early in the season on adult females and young on breeding and staging areas could be severe."

In 1976, with an increased commitment to developing an understanding of the variables affecting the black duck, Patuxent sent me to Maine to investigate the breeding ecology of the species. At the same time, Patuxent biologist Dr. Ronald Kirby was assigned to investigate aspects of wintering ecology of black ducks along the Atlantic Coast, focusing on Chesapeake Bay and New Jersey. Implications about the role of the mallard in the black duck population decline persisted as Johnsgard and DiSilvestro (1976) suggested that "….the relatively specialized black duck, through increased competition and hybridization with the much more broadly adaptable mallard, will continue to become an increasingly rarer [sic] component of the North American bird fauna." It seemed to some of us field biologists studying the black duck, however, that "There is always an easy solution for every human problem—neat, plausible and wrong" (Mencken, 1917).

1980s

Black duck conservation and management during this decade benefited from establishment of a Black Duck Committee by the Atlantic Flyway Council, which was chaired by H.E. Howard Spencer, Jr. (Spencer, 1980). This committee compiled a Black Duck Management Plan for North America 1980–2000 with data provided by personnel of Provincial, Federal, and State agencies; organizations; and private citizens. Black duck conservation benefited further from formal establishment of the North American Waterfowl Management Plan (NAWMP) (U.S. Fish and Wildlife Service, 1986) and from increased research, including an array of field studies by several Patuxent scientists. The NAWMP was signed by the governments of the United States and Canada in 1986 (Serie, 1997), and the plan identified the black duck as a "species of international concern." Under the plan, the Black Duck Joint Venture (BDJV) was formed and implemented in 1990 to coordinate data gathering for population surveys, banding, and research. A winter population goal was set at 385,000 black ducks. A technical committee established within the BDJV, composed of American and Canadian biologists, reviewed proposed survey, banding, and research projects, thereby improving the quality of data collected.

Patuxent continued its research on exposure to contaminants and their effects on black ducks. A minute amount (3 parts per million, dry weight) of DDE in the diet of black ducks caused loss of shell thickness and mass (Longcore and Stendell, 1982), but by 1978, the thickness of black duck eggshells had recovered to a pre-1946 mean (Haseltine and others, 1980). This discovery lessened the probability that chemicals were decreasing productivity and contributing to the population decline, but monitoring of organochlorine pesticide residues in black duck wings continued (Cain, 1981; Prouty and Bunck, 1986; Hall and others, 1989). Heinz and Haseltine (1981) documented that chromium added to the diet of young black ducks affected their avoidance behavior; similar effects were determined for cadmium (Heinz and others, 1983). Differential susceptibility to lead poisoning between the black duck and the mallard was suggested as a possible cause of declines in the number of black ducks (Chasko and others, 1984). Rattner and others (1989) refuted the hypothesis that the black duck was more sensitive to lead poisoning than the mallard by documenting the absence of any difference in mortality between these species on the same lead pellet dosage and diet.

The effects of acidic deposition on wetland invertebrates raised concern that growth and survival of black duck ducklings could be negatively affected. The role of wetland acidification on captive black ducks was evaluated at Patuxent with constructed ponds that were experimentally acidified by Haramis and Chu (1987) and Rattner and others (1987), whose findings indicated lower invertebrate food production on acidic ponds and possible adverse effects on ducklings. In subsequent field studies, Longcore and others (2006) reported that black duck broods readily used low-pH wetlands with good survival of ducklings.

Kirby (1988) reviewed enhancement of black duck breeding habitat in the northeastern United States, and Jorde and others (1989) compiled information on existing tidal and nontidal wetlands of the northern Atlantic States. Results of several studies on breeding ecology and survival of black ducks were published by Patuxent scientists and associated students. Longcore and Ringelman (1980) determined variables affecting breeding densities in the Northeast and developed a black duck population model through use of computer simulations (Ringelman and Longcore, 1980). Results of telemetry used on breeding pairs of black ducks in Maine revealed movements and wetland selection by brood-rearing black ducks (Ringelman and Longcore, 1982a), survival of broods to fledging (Ringelman and Longcore, 1982b), habitat types selected and sizes of home ranges of males and females (Ringelman and others, 1982a), nest and brood attentiveness of females (Ringelman and others, 1982b), and survival of females (Ringelman and Longcore, 1983). Krementz and others (1987) determined sources of variation in survival and recovery rates in black ducks, wherein more adults than hatch-year ducks survived and more adult males than adult females survived. Survival rates were similar for young of both genders, but the recovery rate was greater for young males than for young females. Although recovery rates were time dependent, survival rates were not, which indicates that some variations in mortality caused by hunters may be compensated for by

Dan Stotts and Mike Conroy, U.S. Fish and Wildlife Service, recording weight of black ducks, Atlantic City, NJ, 1982. Photo by Matthew C. Perry, U.S. Fish and Wildlife Service.

other causes. Body mass in winter was not positively related to annual survival (Krementz and others, 1989). In studies of the effects of hunting on black duck survival, Krementz and others (1988) reported that changes in harvest rate under different regulatory schemes resulted in direct effects (that is, an additive effect) on survival of some age or sex classes (such as adult males and juveniles). Rogers and Patterson (1984) reviewed black duck population status and management and noted that average decline in the population was approximately 1.5 percent annually in the 1970s and 1980s.

Grandy (1983) referred to management of the black duck as "a case of 28 years of failure in American wildlife management," and attributed the long-term population decline to excessive harvest of black ducks. Nichols and others (1984) reviewed evidence for compensatory mortality in waterfowl losses, and Anderson and others (1987) advocated the use of experiments to understand black duck population dynamics. Nichols and others (1987) determined that band recovery rates of sympatric black ducks and mallards were similar and results of tests for differences in annual survival rate were equivocal. Conroy and Blandin (1984) identified geographic and temporal differences in band reporting rates for black ducks, but the optimum estimate was a constant 0.43, although this value may overestimate the reporting rate because some reward bands are not reported. Conroy and Krementz (1986) challenged the validity of inferences made by Boyd and Hyslop (1985) regarding effects of hunting on survival rates of black ducks. Conroy and others (1989b) determined mean winter survival rates for female black ducks along the Atlantic Coast as 0.73 for after-hatch-year ducks and 0.60 for hatch-year ducks that had a lower body mass.

Conroy and others (1988) evaluated the aerial transects for the MWI of black ducks and concluded that the survey was a useful index. Diefenbach and others (1988a) identified distributions of wintering populations of black ducks that had a stronger fidelity to coastal wintering sites than inland sites. Young black ducks wintered northeast of young mallards, but no differences in distribution patterns existed between adult birds (Diefenbach and others, 1988b). Longcore and Gibbs (1988) identified critical habitat for black ducks on the Maine coast during the severe winter of 1980–81, when ducks roosted in the lee of islands. Rusch and others (1989) summarized information on the population status and harvest of the black duck. Longcore and others (1987) evaluated black duck-mallard interactions as noted in literature related to Maine and found few records, but numbers of black duck broods were declining substantially statewide on 36 index wetland areas (15,019 acres) in the relative absence of mallard broods (table 1).

Table 1. Numbers of black duck and mallard broods on 36 index wetlands in Maine, 1956–86.

[Modified from Longcore and others, 1987]

Species	Years		
	1956–65	1966–76	1977–86
Black duck	457	328	178
Mallard	2	5	18

Ankney and others (1987) implied that the number of mallards in Ontario and Quebec, Canada, was increasing at the expense of the black duck population, whose numbers were declining in some parts of its range. Data to support this assertion were lacking, however, as noted by Conroy and others (1989a), who commented that no evidence existed for "cause and effect" for the hypothesis of "increasing mallards and decreasing black ducks." Ankney and others (1989) tried to defend their position on the role of the mallard in the black duck decline. The belief that mallards could competitively exclude black ducks from fertile habitats, however, appeared to be losing support.

1990s

The second Black Duck Symposium (Kehoe, 1997) was held at the beginning of this decade. Serie and others (1997) informed on population status and harvest management strategies in the United States, and Serie and Bailey

(1997) discussed implementation of the BDJV. Longcore and Ringelman (1997) reported that, although the area occupied by surface water increased in a 58-square-mile area in south-central Maine, the number of pairs and broods of black ducks decreased from 1958–60 to 1978–80.

In a study of the effect of acid precipitation on the quality of invertebrate food eaten by the black duck, Sparling (1990) evaluated the effects of dietary aluminum, calcium, and phosphorus on the growth and survival of captive black ducks and mallards. Black ducks seemed more sensitive than mallards to treatments low in calcium and phosphorus and high in aluminum. Effects of these diets on bone and liver characteristics of these species were similar (Sparling, 1991). Frazer and others (1990a, 1990b) evaluated home range, movements, and habitat use of post-fledging black ducks in Maine and New Brunswick. Krementz and others (1991) documented historical changes in egg-laying date, clutch size, and nest success of black ducks in Chesapeake Bay and compared the productivity of the black duck to that of the mallard, which was similar (Krementz and others, 1992).

Black duck breeding ranges have been decreasing across the Bird Conservation Regions of Boreal Hardwood Transition and the Great Lakes/St. Lawrence Plain throughout the second half of the 20th century (Pendleton and Sauer, 1992). Krementz and Pendleton (1991) recorded the movements and survival of black duck and mallard ducklings on Chesapeake Bay with implanted transmitters and found no differences in movements between species, but black duck duckling survival rates were greater than mallard survival rates in 1 of 2 years. Longcore and others (1998) determined that mean sizes of Class II-III broods of black ducks (slightly less than 4 to 4.5 ducklings per brood) equaled or exceeded those of mallards regardless of habitat type; moreover, black duck females with broods were not competitively excluded from inhabiting fertile wetlands in Maine. The period (late August to mid-December 1985–87) survival rate for post-fledging female black ducks equipped with transmitters in Maine was 0.593; survival was 0.694 when losses from hunting were censored (Longcore and others, 1991). This period estimate multiplied by interval rates for hunting, winter, and breeding periods produced an annual survival estimate of 0.262, about 12 percent less than the estimate (0.38) made on the basis of analyses of banding data.

Carney (1992) developed keys to identify species of wings submitted during harvest surveys, which facilitated estimating harvest of black ducks by hunters. Conroy and Krementz (1990) reviewed existing evidence that hunting was affecting the black duck population and discussed the biological basis of compensatory as opposed to additive mortality. Blandin (1992) determined population characteristics of black ducks through simulation modeling. Nichols (1991) presented an in-depth review of science, population ecology, and management of black ducks and reported that the statistical methods used in earlier papers had been inappropriate, thereby invalidating their conclusions. Clugston and others (1994) documented the effect of hunter kills related to habitat use for immature female black ducks at Escoumins, Quebec, in 1991. The sample of radiomarked ducks was divided into three groups on the basis of the percentage of times (that is, telemetry locations) recorded in the St. Lawrence Estuary (table 2).

Most hunting took place in the estuary, so most ducks that avoided the estuary survived. These findings support the concept of additivity of hunting losses on breeding and staging areas described by Anderson and Burnham (1976, p. 41), who concluded the "threshold" of additivity of hunting losses "may be easy to exceed on the breeding grounds," whatever that point might be. Kitchens (1994) determined that opening of hunting seasons disrupted use of prime feeding habitats in Missisquoi Bay in Vermont and Quebec, but use resumed when hunting seasons closed. Francis and others (1998) estimated annual survival during three periods on the basis of changes in harvest regulations. Mean survival rate increased from the first (1950–66) to the second (1967–82) period following initial restrictions on harvest, a finding that is consistent with a model of additivity of hunting mortality. The increase in survival rates following a second round of harvest restrictions revealed some evidence for an increase in survival for immature males between the second (1967–82) and third (1983–93) periods. For adults, however, survival increased less than expected if hunting mortality was additive. These researchers concluded that evidence of additive mortality existed in at least some age-sex classes of black ducks in all periods, but that evidence was weaker in the post-1983 period, perhaps indicating that harvest was falling below the threshold for additivity.

Table 2. Mortality of radiomarked black ducks relative to the percentage of times (that is, telemetry locations) that radiomarked ducks were in the Saint Lawrence Estuary.

[Modified from Clugston and others, 1994]

Percentage of telemetry locations recorded in the estuary	Mortality			Total ducks
	Natural	Unknown cause	Shot / probably shot	
Less than 5	2	1	0 / 0	10
35–65	0	1	1 / 0	13
Greater than 95	0	0	10 / 2	15

Sauer and Droege (1997) reported that black ducks were more likely to be declining on Breeding Bird Survey routes on which mallards were observed than on routes without mallards. Krementz and others (1990) responded to criticisms of Dufour and Ankney (1990) about analytical methods used to test for a positive relation between body mass and annual survival of black ducks and determined that the criticisms were unfounded. Merendino and others (1993) speculated that "competitive exclusion" of black ducks from fertile wetlands was the primary cause for the long-term decline of the black duck population in many parts of Ontario. Hoysak and Ankney (1996), however, observing captive ducks, reported that mallards generally were not dominant over black ducks. Later in Maine, McAuley and others (1998) observed aggressive interactions of black ducks and mallards in the field during breeding. They found that male black ducks that instigated an interaction with male mallards did not lose any interactions and displaced mallards 87.2 percent of the time, whereas no change occurred during 12.8 percent of the interactions. In contrast, male mallards that initiated an interaction displaced black ducks during 63.3 percent of the encounters, but were displaced by the black duck during 15.0 percent of the encounters; the remaining 21.7 percent of the encounters resulted in no change. As objective fieldwork replaced conjecture, it became evident that "Science is nothing but organized common sense. The great tragedy of science [is] the slaying of a beautiful hypothesis by an ugly fact…." (Huxley, 1870, p. 6).

2000s

Although Patuxent scientists continued work on various studies during this decade, little attention was focused on contaminants. Field work in Maine (Longcore and others, 2006), however, revealed that low- (< 5.51) pH wetlands, although associated with reduced numbers of acid-intolerant macroinvertebrates, had large numbers of Insecta and supported a greater percentage of broods (78.6 percent), including black duck broods, than wetlands with a pH > 5.51, which supported 21.4 percent of the broods. Longcore and others (2000b) compiled pertinent historical and more recent literature to prepare the Birds of North America series account for the American black duck. Haramis and others (2002, p. 22) evaluated productivity on Smith Island, MD, with radiomarked female black ducks and found that storm tides and predators kept nest success and productivity low.

Earlier, Francis and others (1998) reported that the threshold of additivity for black ducks, especially immature ducks, was exceeded in some years, which supported the caution of Anderson and Burnham (1976) that the "threshold" may be easily exceeded for adult females and young on breeding and staging areas. Therefore, the location and timing of mortality seem to determine whether hunting losses are additive. The time was early in the hunting season, and the location was on the breeding grounds and staging areas. It seems clear, then, how the geographic position of the northern United States and the Canadian provinces with respect to hunting regulations is crucial to the fate of the black duck population. Telemetry data from Nova Scotia, Quebec, and Vermont (Longcore and others, 2000a) further validated the contention of Anderson and Burnham (1976) that harvest on the breeding and staging areas could be severe, as 85 percent of all mortality in those northern study areas was associated with hunting. These data indicate that black ducks that are not shot on breeding and staging areas may have a high survival rate. Survival of immature female black ducks was determined on two adjacent study areas—one in New Brunswick (Parker, 1991), with an early October 1 hunting season opening, and one in Maine (Longcore and others, 1991), with opening delayed until November 15. Kaplan-Meier (Kaplan and Meier, 1958) survival rates for New Brunswick (0.945) and Maine (0.986) were similar in the 1- to 2-month period before hunting began, but declined sharply for marked ducks in New Brunswick when the hunting season opened (table 3).

Most ducks in Maine that were not exposed to hunters in this period did not die. The decrease in survival rate in New Brunswick from 0.945 to 0.348 can be attributed mostly to hunter harvest. The next question, then, was whether black ducks respond if harvest is restricted.

The third Black Duck Symposium was held in 2002 (Perry, 2002). Serie (2002, p. 2) discussed the black duck as a "species of international concern" and noted that the more restrictive harvest regulations beginning in 1984 may have stabilized the MWI for the black duck in the Atlantic Flyway. Another example of a response to harvest restrictions was the stabilization of the results of the breeding black duck survey in Quebec. Even after a sharp decline in numbers (from 27.5 to 16.8 per 100 square kilometers [km^2] [71.2 to 43.5 per 100 square miles (mi^2)]) from 1990 to 1993, where the band recovery rate remained high, the count stabilized from 1994 to 1995 (15.9 to 16.5 per 100 km^2 [41.2 to 42.7 per 100 mi^2] (Dickson, 1995) after retrieved kill declined substantially in Canada.

Table 3. Survival rate of radiomarked hatching-year female black ducks in Maine and New Brunswick, Canada, as a function of waterfowl hunting season opening date.

[Modified from Longcore and others (1991) for Maine and Parker (1991) for New Brunswick, Canada; waterfowl hunting season in New Brunswick, Canada, opened October 1; waterfowl hunting season in Maine opened November 15]

Time interval studied	Location (years studied)	
	Survival rate in Maine (1985–87)	Survival rate in New Brunswick, Canada (1987–88)
Before September 30	0.986	0.945
October 1–15	0.965	0.500
October 16–31	0.885	0.465
November 1–15	0.834	0.348

In Maine, the Department of Inland Fisheries and Wildlife (P.O. Corr, Maine Department of Inland Fisheries and Wildlife, oral commun., 1983) monitored numbers of waterfowl broods, including black ducks, on 34 wetland brood-rearing reference areas. During 1980–83, most duck seasons were 50 days long, with split seasons in the southern hunting zone that opened October 1st in the early or late season. The black duck daily bag limit was either one or two in 3 of 4 years. In following years (1984–88), the season opening was usually delayed in the early split season to about October 15th in the north zone and about November 16th in the south zone. The daily bag limit was either zero or one in all split seasons except 1988, when it reverted to two black ducks per day with no delayed openings in any split season. Numbers of black duck broods on these 34 reference areas by year are shown in figure 1.

Delaying opening date, reducing season length, and reducing daily bag in this northern state positively affected the number of broods counted in years following protection of local breeding pairs. Reed and Boyd (1974) documented the high mortality of local black ducks breeding in the St. Lawrence Estuary during the opening weekend of hunting. Jorde and Stotts (2002, p. 31) dissected the Federal and State MWI data into geographic areas and showed that trends in the number of black ducks varied with geographic region.

Conroy and others (2002) assembled data on an array of variables affecting the black duck population and, with synthetic modeling, evaluated the relative importance of those variables. Longcore (2002, p. 7) contrasted the effects of variables in the summer and winter ranges of black ducks and concluded that the proximate cause of the long-term decline of the black duck population was unlikely to be related to mallard distribution. Link and others (2006) examined black duck Christmas Bird Count (CBC) data on a regional basis and found decreasing populations in the southern and central parts of the wintering range, but more stable populations in the northeastern parts of the range. In addition, the CBC and the MWI showed similar patterns of population change at the scale of the United States, which lends credibility to the long-term MWI data. Zimpfer and Conroy (2006), in their attempt to model production rates in black duck populations, discovered that they could not include habitat variables as predictors and that multicollinearity among some predictors affected results, which indicated that the predictive ability of the models was limited.

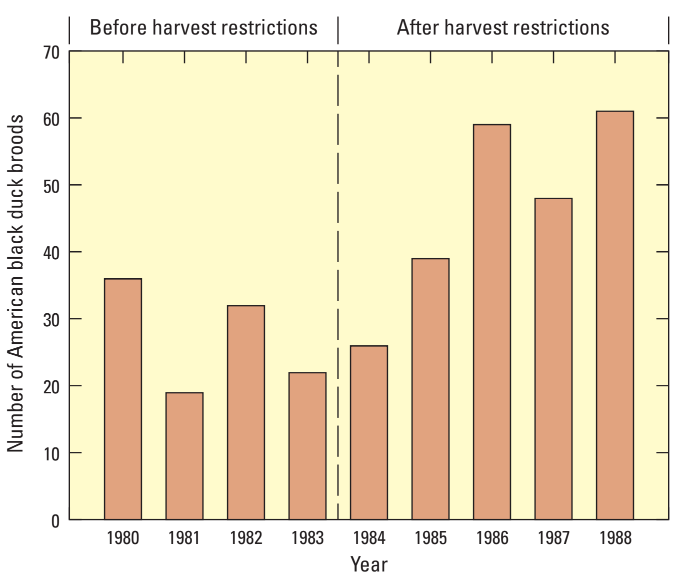

Figure 1. Number of black duck broods on 34 index wetlands in Maine before (1980–83) and after (1984–88) harvest restrictions were applied to protect local breeding pairs. (Data from Maine Department of Inland Fisheries and Wildlife, Bangor, ME)

Kirby and others (2000) published keys of wings to identify mallard, black duck, and hybrids of these species. Petrie and others (2000) found no differences in clutch size, nest success, hen success, duckling survival, or hen survival between black ducks and mallards in New Brunswick, but purported that the difference in population status of the two species was related to differences in breeding propensity arising from competition for breeding resources. In contrast, McAuley and others (2004) documented in nearby Maine that competitive exclusion of black duck pairs from fertile wetlands by mallards was unsupported by field observations, wherein 53 of 65 (81.5 percent) wetlands visited for 2 hours or more were used by both black ducks and mallards. Increasing knowledge of black duck ecology and the positive effects of reduced harvest on the black duck population indicated that "In all science, error precedes the truth, and it is better it should go first than last" (Walpole, 1876, p. 128).

The emerging facts seemed to indicate that hybridization was not a likely cause of the black duck decline (Morton, 1998; Bolen and others, 2002). Furthermore, competitive exclusion was not plausible in light of increasing beaver-created habitat (Longcore and Ringelman, 1980; Seymour and Mitchell, 2006), fewer breeding pairs (Longcore and others, 1987), dynamic use of wetlands by both species (McAuley and others, 2004), the fact that the black duck is as aggressive as the mallard in defending territory and females, and the fact that the black duck is not dominated by the mallard (McAuley and others, 1998). Past studies also determined that black duck brood females are not excluded from fertile wetlands and black duck brood sizes are not different from those of mallards on fertile or infertile wetlands (Longcore and others, 1998), and that mortality of black ducks caused by hunters can be additive to natural mortality (Francis and others, 1998).

So, if not the mallard, what was causing the black duck population to decline? Bolen and others (2002) make a case that sensitivity (that is, wariness or neophobia) of black ducks toward humans may have contributed to the black duck population decline. Without question, the prime Chesapeake Bay wintering area for black ducks has been encroached on by humans around the bay, with a 38-percent increase (from 2.0 to about 2.8 million) in the human population since 1970

(Longcore, 2002). From the 1800s to the 1930s and 1940s, a consensus existed that excessive harvest was the cause of the decline in the black duck population. Even in the late 1960s, biologists and administrators agreed that harvest had to be reduced to stop the decline in black duck numbers (Barske, 1968). The key question was, "What evidence exists to support a conclusion that the black duck population either has, or has not, been affected by harvest regulations?"

Population ecologists typically viewed hunting losses as compensatory—that is, no duck shot in fall or late winter will affect the spring breeding population. In other words, we believed that hunter kill never exceeded a threshold of additivity, whatever that threshold might have been. Francis and others (1998), however, reported that hunter harvest could exceed the threshold and be additive to natural mortality.

Because restrictions on the breeding grounds (mostly in Canada) were not effective until about 1990, the reductions in the United States harvest could only stabilize the MWI in the Atlantic Flyway (Serie, 2002, p. 3). Because few black ducks now breed in the United States (as opposed to Canada), a substantial response in population growth probably cannot be expected until the number of breeders that return to the major breeding grounds increases.

Restrictions on harvest in the United States and Canada since 1992 have reversed the downward population trend (Longcore and others, 2000b). Breeding ground pair surveys initiated in the 1990s indicated that as harvest has been reduced (fig. 2), the number of black ducks has increased substantially (fig. 3) while the mallard population also increased substantially (fig. 4).

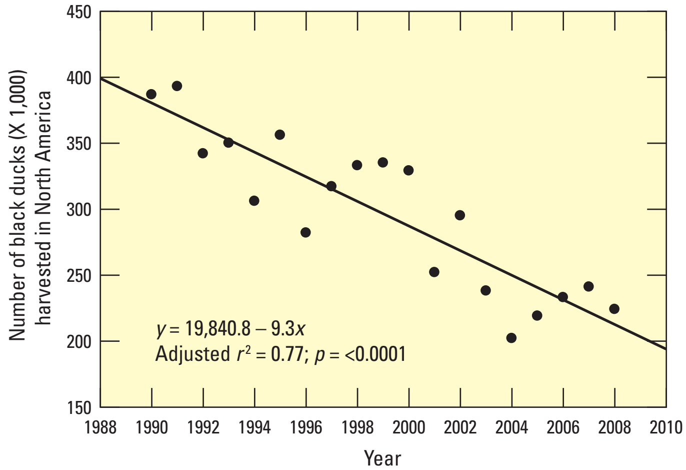

Figure 2. Number of black ducks harvested in North America, 1990–2008. (Data from Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Laurel, MD; <, less than)

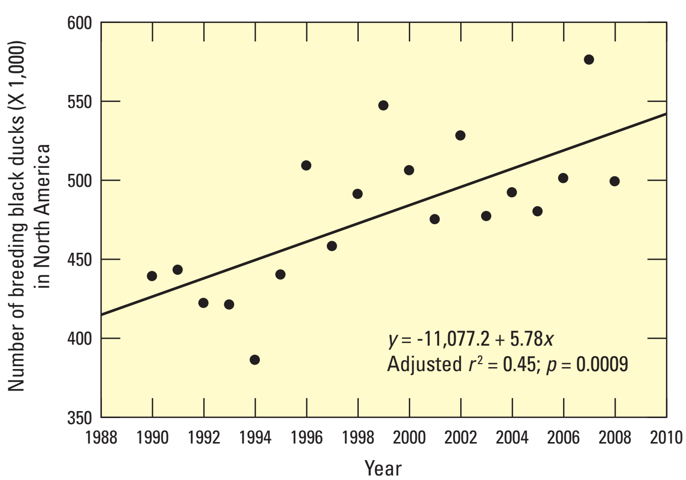

Figure 3. Number of breeding black ducks in North America, 1990–2008. (Data from Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Laurel, MD)

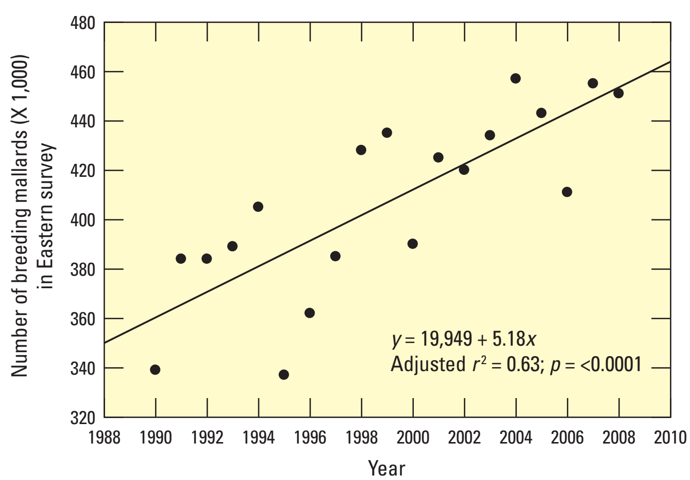

Figure 4. Number of breeding mallards in Eastern Survey, 1990–2008. (Data from Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Laurel, MD; <, less than)

Future Challenges

The original goal of the Black Duck Management Plan for North America, 1980–2000 (Spencer, 1980), was to "…reverse the apparent downward population trend…" as expressed in the MWI. As indicated by data from the improved waterfowl breeding pair survey, that goal has been achieved; however, this success resulted largely from reducing harvest by applying restrictions in areas where opportunity for exceeding the threshold of additivity was small—that is, south of the primary breeding and staging areas. Conjecture about the role of the mallard in the black duck decline was not supported by objective field studies of sympatric populations of these species. Additive effects of hunting were exposed as the black duck population began to recover following substantial reductions in harvest. Even after 80 years of research, an expanding human population, which will increase human disturbance and neophobia (Bolen and others, 2002), and energy development across Canada may affect where black ducks can breed or winter, thereby affecting productivity. For example, some wintering populations of black ducks are shifting northward (Brook and others, 2007), which may affect breeding success or survival, but the outcome is unknown. Over the long term (1955–2007) in Maine, size of waterfowl broods, including those of black ducks, seems to be declining (Schummer and others, 2011); this decline may indicate contaminant effects on egg hatchability or increased duckling mortality. Changes in brood survey methods, however, may have affected these results. For the early brood counts, broods of one or two ducklings were considered "incomplete broods" and were not included in calculating average brood size (H.E. Spencer, Jr., Maine Department of Inland Fisheries and Wildlife, oral commun., 1983), thus biasing the means higher than they would have been if broods of all sizes had been included. The next generation of black duck biologists will undoubtedly be vexed by some of the old issues and faced with new challenges to sustain the North American black duck population.

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