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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The information in this chapter draws on published literature and unpublished reports written by staff members of the U.S. Geological Survey, Patuxent Wildlife Research Center (Patuxent), during its 75-year history.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 non-hunting 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.

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

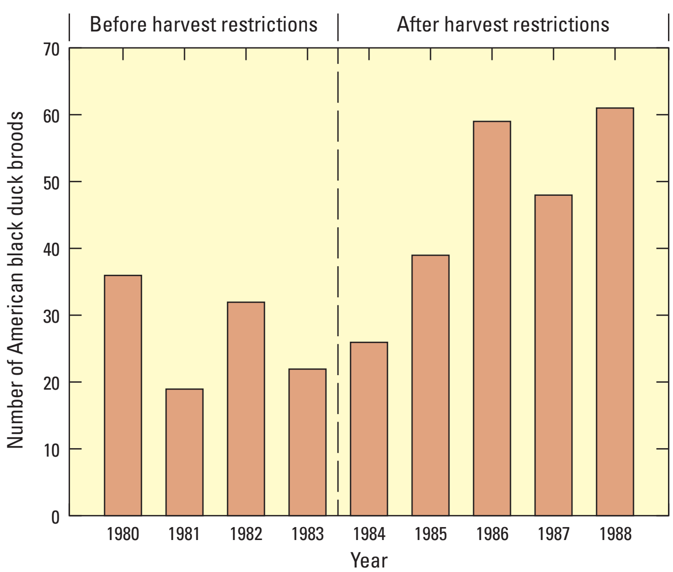

Figure 1. Number of black duck broods on 34 index wetlands in Maine before (1980–83) and after (1984–88) harvest restrictions were applied to protect local breeding pairs. (Data from Maine Department of Inland Fisheries and Wildlife, Bangor, ME)

(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).

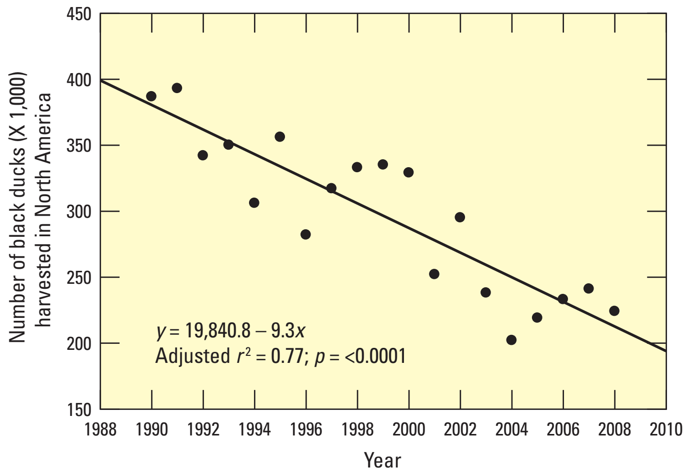

Figure 2. Number of black ducks harvested in North America, 1990–2008. (Data from Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Laurel, MD; <, less than)

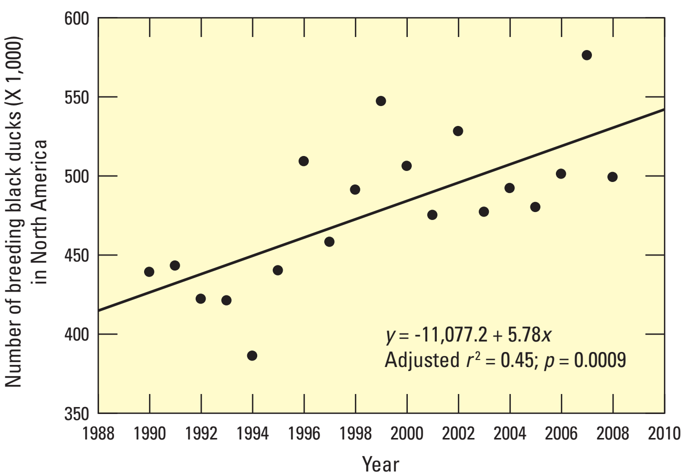

Figure 3. Number of breeding black ducks in North America, 1990–2008. (Data from Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Laurel, MD)

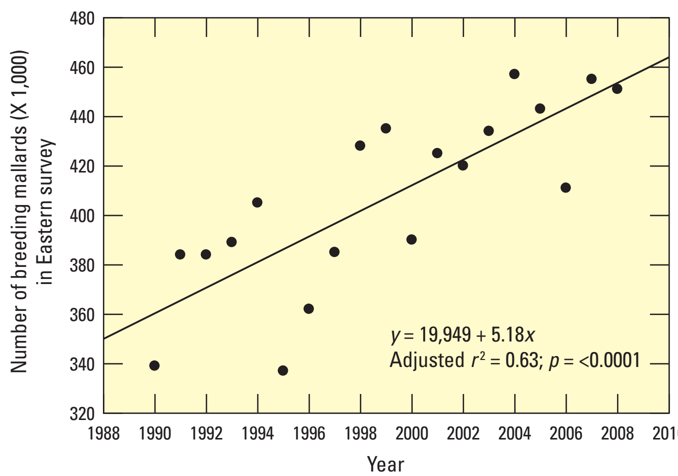

Figure 4. Number of breeding mallards in Eastern Survey, 1990–2008. (Data from Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Laurel, MD; <, less than)

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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