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MALLARD POPULATION AND HARVEST DYNAMICS IN WISCONSIN

ABSTRACT

An investigation of mallard duck (*Anas platyrhynchos*) population and harvest dynamics in Wisconsin during 1967-72 had two principal objectives: (1) to summarize the mallard population and harvest information, particularly band recoveries, available in relation to Wisconsin; and (2) to estimate the contributiion of locally-reared mallards to the Wisconsin harvest.

In 1961-72, Wisconsin banded 48,644 mallards in the preseason (July 1-September 30) period. Breeding populations in southeast and central regions were adequately banded, but populations in the remainder of Wisconsin were not.

Productivity of mallards was slightly better in Wisconsin than in North America overall. Class III brood size averaged 6.5 ducklings. Vulnerability of juveniles to shooting resulted in age ratios from the Wisconsin harvest that consistently exceeded 2.0 young:adult. Age ratios of populations contributing to the mallard harvest in Wisconsin averaged 1.0 young:adult.

The majority of mallards banded in Wisconsin were recovered in the Mississippi Flyway; over half the direct recoveries occur in Wisconsin. Forty to 50 percent of the subsequent season recoveries from females occurred in Wisconsin, with 9-15 percent taken in the original 10-minute block of banding.

Seven percent of the adult female and 16-24 percent of the juvenile female preseason population was shot within the first 2 weeks of the Wisconsin duck season; locals were still being recovered during the last week of hunting. Proportions of banded locals shot early in the season were negatively correlated with the proportions of banded migrants taken in the state. Recoveries of migrants banded north of 50° latitude peaked latest in the season. The forested regions of Ontario, northern Manitoba and northern Saskatchewan are suggested as major sources of migrants.

Hunting kill rates on mallards banded in Wisconsin were slightly higher than kill rates for North America overall. Adult and juvenile female mean kill rates were 22 percent and 44-47 percent, respectively. Mean survival rates for adult males (62 percent) and females (58 percent) compared favorably with the continental average. Nonhunting mortality removed 20 percent of the adult females. Juvenile male mortality rate (65 percent) was above the continental average.

Mortality rate for juvenile females banded in Wisconsin (50 percent) was the average mortality rate for North America.

Total rate of hunting kill on mallards banded in Wisconsin was directly related to the rate of kill within the state. A reduced rate of kill in Wisconsin usually resulted in a lowered total kill rate. Moderately restrictive mallard regulations of 60-80 bag-days (mallard daily bag limit x season length) offered the best return of local birds to Wisconsin hunters, and still lessened the impact of hunting on future breeding populations.

Regional distribution of the mallard harvest in Wisconsin did not change significantly between 1938-43 and 1961-72. Annual fluctuations in the 1950-72 harvests resulted primarily from changes in hunter numbers and days of activity which apparently varied in response to annual regulation changes. Restrictive regulations had their greatest impact on harvest by reducing hunter numbers and days afield. Liberal regulations during 1970-72 increased mallard harvests but numbers of mallards bagged per individual per day afield were reduced. More hunters and more days afield probably caused the poorer return.

Twenty-seven percent of the adult mallards and 23-37 percent of the juvenile mallards shot in Wisonsin were locally produced. Local contribution in some seasons exceeded 40 percent for adults and 50 percent for juveniles.

With average 1961-72 productivity and survival, female mallard populations in Wisconsin could have increased an estimated 10-11 percent annually, based on a deterministic model.

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By

James R. March and Richard A. Hunt

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INTRODUCTION

PERSPECTIVE

Mallards are the best known and most numerous wild ducks in North America and probably, also worldwide (Anderson and Henny 1972). North American breeding mallard populations since 1955 have ranged from a high of 14.4 million birds in 1958 to a low of 7.1 million in 1965 (Pospahala et al. 1974). Although less than 2 percent of the continental mallard population nested in Wisconsin, the species was the most abundant breeding duck in the state during recent years (March et al. 1973). Mallards are also the most numerous and widely distributed ducks in Wisconsin during the fall migration (Jahn and Hunt 1964), and hunters in the state shoot more mallards than any other ducks (March 1973). Almost 4 percent of the total mallard harvest in Canada and the United States occurred in Wisconsin (Geis and Cooch 1972). As Anderson and Henny (1972) pointed out, however, hunting statistics alone cannot fully convey the importance of mallards as a natural resource. The nonconsumptive values of the species are equally important. Mallards are a prominent wildlife feature of most wetland communities in Wisconsin and are also common year-round residents of rivers, lakes and park lagoons in urban areas across the state.

Changes in the status of mallard populations in Wisconsin are known to have occurred over a 25-year period. Jahn and Hunt (1964) found mallards were the second most abundant breeding duck in the state; by 1965, the mallard had replaced blue-winged teal (*Anas discors*) as the most abundant species statewide (March et al. 1973). Also, the range of annual breeding populations obtained during 1965-70 indicated a difference of more than 50,000 mallards between the high and low years (March et al. 1973). Considerable variation in survival and productivity would have been necesary to create such fluctuations in numbers. Since hunting regulations on mallards are selected and enacted annually, the effectiveness of these regulations in stabilizing shooting losses was also questionable in light of observed population changes. If overall survival and/or productivity in some years, or over a longer time interval, was not sufficiently high to support current shooting losses, additional measures would be needed to protect local populations. A review of past productivity, harvest and rate of survival, in relation to rates of exploitation and legislated hunting opportunity, was essential to preparation of future management objectives and planning. If locally nesting mallard populations were providing a significant proportion of the annual harvest in Wisconsin, management of these populations independent of, or in conjunction with, continental or regional efforts, would also be of primary concern. Establishing the contribution made by local birds to the Wisconsin mallard harvest also became a priority item. As a result, the Wisconsin Department of Natural Resources, under its charge of managing and perpetuating the wildlife of the state, initiated a study of local mallard populations in Wisconsin. This report represents the culmination of these efforts through 1972.

PREVIOUS INVESTIGATIONS

Grundtvig (1895), Jackson (1927), Schorger (1929), Pirnie (1934) and Buss and Mattison (1955) all considered the mallard to be a "common" or "widespread" breeder in Wisconsin, while Kumlien and Hollister (1903) indicated that the species nested "sparingly" in localities where it was formerly a common breeder.

Pirnie (1934) found mallards and blue-winged teal to be the only "abundant and widespread" species in Wisconsin during the breeding season, with both species "nesting commonly in localities where sufficient food and rearing cover exists, most particularly in the eastern and southeastern portions of the state". Leopold (1931) estimated that 8 lakes and marshes in Winnebago County produced 17,880 ducks, 37 percent of which were mallards. Gates (1965) estimated a mallard density of 3.3 pairs per square mile (1.3 per km^2) on a 7-square mile (1.8 km^2) area in east central Wisconsin. In the same general vicinity, Wheeler (1975) found about 2 pairs per square mile (0.8 per km^2) over a 504 square-mile area (1305 km^2). In 1965-70, highest densities of mallards, 3 to 5 pairs per square mile (1 to 2 pairs per km^2), were found by March et al. (1973) in the southeast-central and northwest regions (Fig. 1).

Although the spring and fall arrival and departure dates for migrating mallard populations are reasonably well-documented in the ornithological literature from Wisconsin, the only comprehensive summary of this information and related numerical indexes are found in Jahn and Hunt (1964). Mallards comprised about 30 percent of the duck occupancy in Wisconsin during the falls of 1954-56 (Jahn and Hunt 1964:66). Green (1963), in a summary of waterfowl use of the Upper Mississippi National Wildlife Refuge (which also included parts of Minnesota, Iowa and Illinois) concluded that mallards represented about 38 percent of the fall use.

Early references to mallard harvest in Wisconsin were largely kill records of hunting clubs or diaries of individual hunters, kept over a period of seasons. In a summary of diaries and club records spanning various years between 1876 and 1939, in eastern and southeastern Wisconsin, Bartonek and Anderson (1966) noted that mallards represented from 2 to 20 percent of the recorded bags. At least three of the areas included, however, were known primarily as excellent diving duck shooting sites, and mallards may not have been generally available. On the other hand, records (1938-62) of a gun club on Winneconne Marsh indicated that mallards made up 41 percent of the bag (Bartonek and Anderson 1966). Ducks bagged by the early shooting clubs on the Horicon Marsh (1883-1920) were primarily blue-winged teal and mallards (Personius 1975). Mallards accounted for only 10 percent of the ducks shot by W. H. Chase on Lake Wingra in 1876-88, but increased to 21 percent of his kill in 1889-94 (from Leopold 1937). Buss

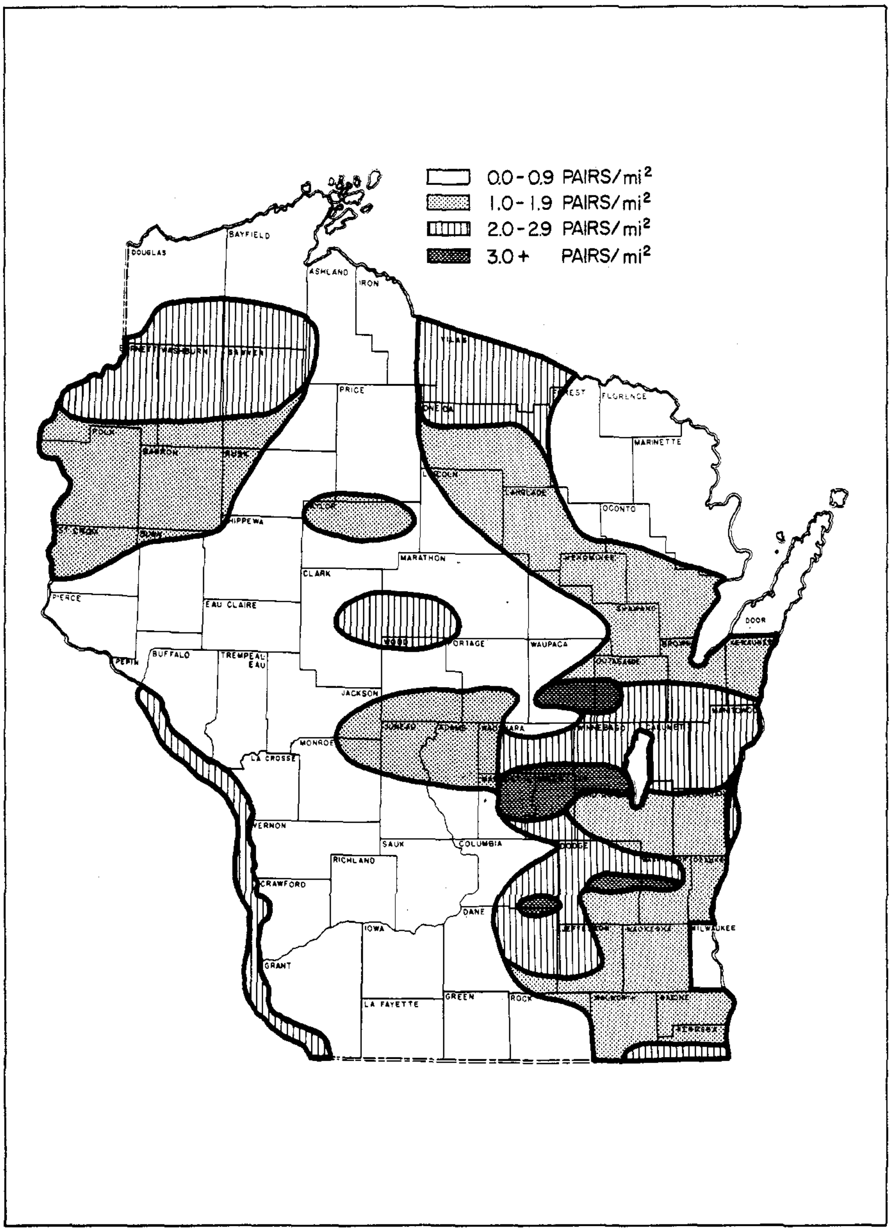


FIGURE 1. *Distribution of breeding mallards in Wisconsin based on 1965-66 and 1968-70 aerial surveys, corrected for birds present on the ground but missed by air. March et al. (1973) describe survey techniques and results in detail.*

and Mattison (1955) reported that 51 percent of the ducks examined on Lake Pepin in 1939-41 were mallards but the species represented only 16 percent of the ducks checked from Dunn County during 1942-48. Green (1963) found that mallards accounted for 40 percent of the ducks shot on the Upper Mississippi River. Jahn and Hunt (1964:61-138) gave considerable information on migration and harvest of mallards in Wisconsin.

Additional contributions to the understanding of mallard populations and breeding ecology in Wisconsin have been made by Labisky (1957), Hunt et al. (1958), Knudsen (1962), Martz (1964), Gates (1965), March (1971a), Bergquist (1972), Pearson (1974) and Smith (1975). Hopkins (1949), Barger (1950), Hickey (1951 and 1956), Hunt et al. (1958) and Jahn and Hunt (1964) variously discussed early mallard bandings and recoveries associated with Wisconsin. March (1969 and 1973) contained brief discussions on results of more recent mallard banding studies. Considerable information on harvest, migration, population surveys and production is available for mallards and other ducks in the quarterly and annual Wisconsin progress reports submitted to the Federal Aid to Wildlife Restoration office under Pittman-Robertson project W-141-R. Some of this information has been summarized by Jahn and Hunt (1964) and March et al. (1973).

Materials pertinent to the studies of mallard populations in Wisconsin are found in Atwood and Wells (1960), Geis and Carney (1961), Anderson and Henny (1972), Schroeder et al. (1974a), Pospahala et al. (1974), Anderson (1975), Anderson and Burnham (1976), and Martin and Carney (1977). The Waterfowl Status Report and Administrative Report series prepared by the U.S. Fish and Wildlife Service also contained essential information.

DATA BASE

Migratory game birds, including mallards, are banded "to obtain information on the characteristics of populations which can be used for management" (Geis 1972). Banding data furnish information on "(1) the distribution (and derivation) of the hunting kill, (2) rate of hunting kill, and (3) estimates of mortality rates from all causes" (Geis 1972). To fulfill these objectives, however, "banding experiments must be developed on a scientific basis if accurate and precise results are to be expected" (Anderson 1972). Therefore an analysis of banded samples and recoveries in 1950-72 is discussed first. Much of the information discussed in subsequent sections depends in some way on the basic banding and recovery data. Without an initial examination of the raw banding results, development of succeeding sections in a logical sequence would be difficult.

DEFINITION OF TERMS

Terms used in discussions of banding and population data are defined as follows (in most instances definitions are similar to those used in Geis 1972, or Volume I of the 1972 Bird Banding Manual).

Local.—A young-of-the-year duck not yet capable of sustained flight when banded. Locals are known to have been hatched in a particular geographic region.

Immature.—A young-of-the-year duck capable of sustained flight when banded. Geographic region of hatching is uncertain. Locals and immatures are collectively referred to as "juveniles" in the text.

Adult.—A sexually mature duck in at least its second calendar year of life when banded; a bird hatched in some previous breeding season. Geographic region of hatching is unknown.

Band Recovery Rate.—The proportion of banded birds that is recovered and reported to the Bird Banding Laboratory.

Band Reporting Rate.—The proportion of bands taken by hunters that is reported to the Bird Banding Laboratory.

Direct or First-Hunting Season Recovery Rate.—Proportion of banded ducks reported killed or found dead during their first hunting season following banding.

Indirect Recovery.—A banded duck reported killed or found dead in any hunting season following the first hunting season after banding.

Harvest.—Retrieved or "bagged" hunting kill. Derived from U.S. Fish and Wildlife Service or Department of Natural Resources mail surveys of hunters.

Degree Block.—The area bounded by consecutive degrees of latitude and longitude within which birds were banded or recovered. In Wisconsin a degree-block measures about 50 x 70 miles (80.5 x 112.6 km) or 3500 square miles (9,065 km^2).

10-Minute Block.—The area by 10-minute intervals of latitude and longitude within which birds were banded or recovered. About 8.3 x 11.7 miles (13.4 x 18.8 km) in Wisconsin, or 97 square miles (251 km^2), the 10-minute block is the smallest geographic unit used to identify recovery sites.

Age Ratio.—Number of young-of-the-year ducks per adult in the annual harvest or banded sample. Harvest age ratios are obtained from U.S. Fish and Wildlife Service annual duck wing collection surveys (Geis and Carney 1961).

Sex Ratio.—Number of male ducks per female in the harvest or banded sample. Harvest sex ratios are from the U.S. Fish and Wildlife Service duck wing collection surveys.

Adjusted Age and Sex Ratios.—Age or sex ratios in the harvest, adjusted for differences in vulnerability to shooting between age or sex cohorts. Obtained by dividing age or sex ratios in the harvest by the relative recovery rate(s) of the two cohorts being compared.

Preseason Population Estimates.—An "indirect" method of estimating population levels that utilizes annual retrieved kill, adjusted age ratios in the kill and harvest rates to measure the numbers of birds present prior to the hunting season. Method of calculation is described further in the section entitled "Prehunting Season Population Estimates".

SOURCES OF BANDING DATA

All records from waterfowl banded in Wisconsin and recovered through 1972, as well as all records of recoveries in Wisconsin of waterfowl banded elsewhere, were supplied by the Bird Banding Laboratory of the U.S. Fish and Wildlife Service. Each recovery was listed by date, species, age, sex, banding date and location, how obtained and reporting source. Mallard recoveries were extracted and sorted by computer. Programs for this analysis were developed by the Department of Natural Resources' Bureau of Data Systems.

In addition to individual recovery records, the number of mallards banded annually in Wisconsin were sorted by date, age, sex, banding site, status and banding permittee. Computer programs developed by the Bureau of Data Systems were also used.

Data used in this report generally represent records on file with the Bird Banding Laboratory through July 15, 1972. All data provided by the Bird Banding Laboratory were subject to an unknown level of clerical mistakes and other errors (Anderson and Henny 1972). Comparison of the federal banding data with information in Department of Natural Resources files did not identify any important errors relating to numbers banded for particular cohorts. A similar check could not be made of the recovery data, however. Anderson and Henny (1972) reported about 7-8 percent of the 1914-69 recovery entries as "erroneous".

Only bandings and recoveries of normal, wild-caught mallards were included in the analyses. Also, only recoveries from birds reported to the Bird Banding Laboratory as "shot" or "found dead" during the hunting period, assumed to be September 1 through February 15, were included. With one important exception, all samples represent mallards captured and marked between July 1 - September 30, the "preseason" banding period. Recoveries from a sample of locals banded beween June 15 and June 30, were also included in the analyses.

The analyses compare results from two general banding periods: 1950-60 and 1961-72. The two periods reflect differences in the level of banding effort carried out in Wisconsin. Limited banding occurred in the first 11 years, while an intensive banding program was conducted throughout the state in the latter 12 years.

NUMBERS BANDED AND RECOVERED

Methods

Capture Techniques. All mallards banded by the Department of Natural Resources were captured by one of the following methods: (1) spotlighting; (2) drive trapping; (3) bait trapping; or (4) cannon net trapping. About 90 percent of the flightless locals, plus a few hundred flying adults and immatures were captured at night using spotlights (March 1969, 1972). Remainder of the locals were captured in drive traps (Kniffin 1964). Wire bait traps with baited funnels were used most frequently during the 1950-60 banding operations. Cannon net traps captured the majority of adults and immatures banded during 1961-72. Net trapping procedures closely followed those suggested by Dill (1969). Cob and shelled corn, wheat or oats were used as bait.

Mallards banded by the three national wildlife refuges (NWR's) in Wisconsin, Horicon, Necedah and the Upper Mississippi River, were captured primarily with cannon nets or bait traps. Samples from Horicon NWR were obtained almost entirely with cannon nets. On the Necedah NWR, both cannon nets and bait traps were used, with the former method used most commonly in 1961-72. Bait traps were the main capture technique employed on the Upper Mississippi NWR; cannon nets received only limited use. Nelson and Green (1962) gave details of these bait trapping operations with reference to wood ducks.

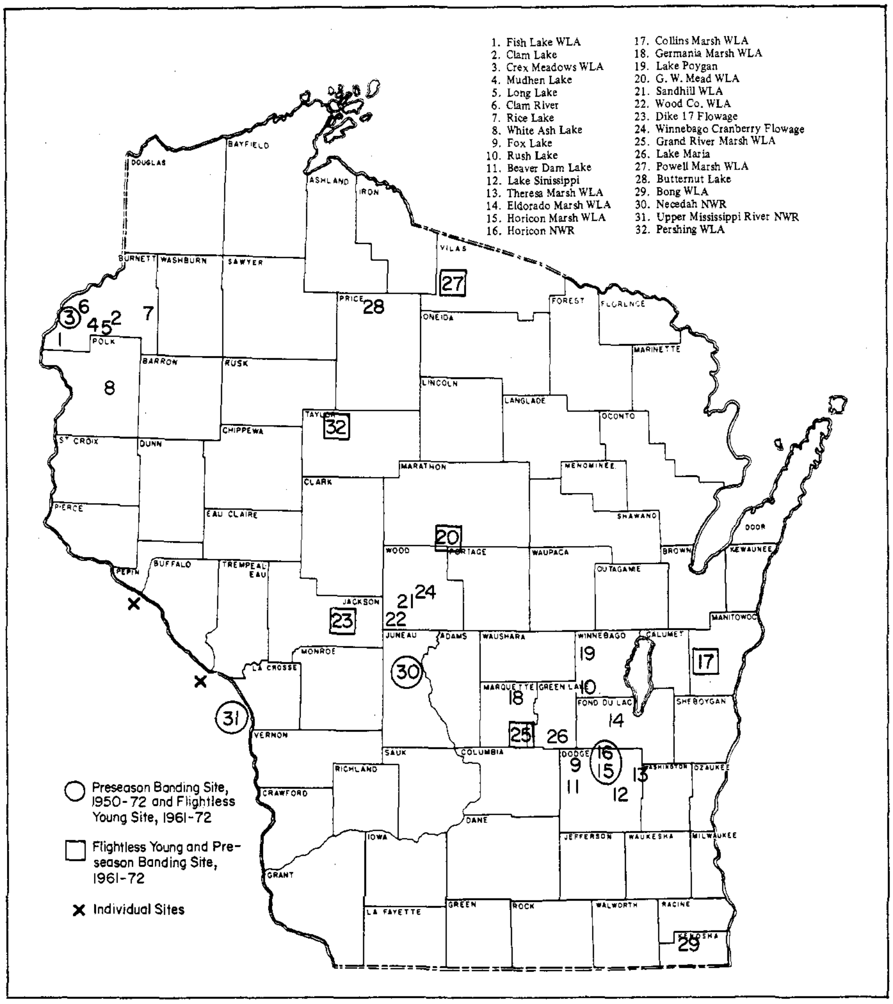


FIGURE 2. *Locations where one or more flightless young mallards were banded in Wisconsin during the summers of 1961-72. Numbers circled or boxed also indicate preseason mallard banding sites used during 1950-72.*

Other than a few flightless locals, all mallard banding considered in this report was done by or under the direction of the Wisconsin Department of Natural Resources, its predecessor the Wisconsin Conservation Department, or the U.S. Fish and Wildlife Service. All birds were marked with standard U.S. Fish and Wildlife Service numbered aluminum leg bands.

Banding Sites. The majority of the 1950-72 preseason mallard banding in Wisconsin was done on three NWR's and eight state wildlife areas (WLA's) shown on Figure 2. Some adult and flying immature mallards were banded at miscellaneous sites during nightlighting operations. The limited preseason banding in 1950-60 was mainly done on four sites (Fig. 2).

Preseason banding sites were usually selected because of geographic location and the availability of mallards. On WLA's, the presence of at least 200 mallards was considered sufficient numbers to begin trapping. A special effort was made after 1966 to locate sites in each quartile of the state in order to sample individuals from all population segments present.

Local mallards were banded on 31 different sites during 1950-72 (Fig. 2). Included were 14 state WLA's, 13 public lakes or rivers, three NWR's and one private flowage (March 1976:307). All but the Necedah NWR and Upper Mississippi NWR bandings were done by the Department of Natural Resources.

Band Recoveries. Band recoveries were summed individually for male and female cohorts of each age class of banded mallards. Within each sex and age cohort, recoveries were summed by hunting season of recovery following banding. Direct recoveries were used as the basis for calculating harvest and kill rates discussed in later sections. Rates of direct recovery were also used to obtain relative recovery rates for measuring differences in vulnerability to shooting between sex and age cohorts. Both direct and indirect recoveries were incorporated into the models used to estimate survival rates.

Differences in the number of direct recoveries obtained for individual age and sex cohorts by banding site, year and groups of years were tested by chi-square. The criterion for statistical significance was considered to be $P < 0.05$. Only sites with samples of at least 50 birds banded for a particular cohort were included in the analysis.

Since band report rates are known to have declined in recent years (Anderson and Henny 1972), comparisons of recovery rates between different banding periods, e.g. between 1950-60 and 1961-72, would not accurately reflect changes in shooting rates.

Results and Discussion

Distribution of Banding. From 1900 through 1949, about 9,300 wild mallards were banded in Wisconsin. Since 1949, summer mallard bandings have totaled 50,095 *normal, wild-caught* birds (Table 1). During 1950-60, a comprehensive banding program for Wisconsin was in its infant stages. Beginning in the early 1960's, preseason-banded samples increased substantially, totalling 48,233 adults and flying immatures during 1961-72 (March 1976:309). At least 2,000 mallards were banded preseason during the 12 consecutive years, but geographic distribution was limited during the first half of that period. The Horicon NWR accounted for at least 70 percent of the preseason bandings during 1961-64. When birds banded at the Crex Meadows WLA were added to the Horicon NWR total, those two sites accounted for at least 75 percent of each annual sample during 1961-66. Starting in 1967, less than 50 percent of the preseason samples were banded on the two sites, with about 25 percent coming from Horicon NWR.

From the standpoint of both total mallards banded and continuous yearly samples in Wisconsin, Horicon Marsh was the most important banding site, largely because of the accelerated preseason program which began in 1961. However, even during 1950-60, mallards banded on the state portion of the marsh represented the only major sample banded in Wisconsin (Table 2, and March 1976:310). For 12 consecutive years, 500 or more mallards were banded on the Horicon NWR. The refuge birds represented over one-half the total 1961-72 preseason sample from Wisconsin.

The second longest sustained banding history—10 consecutive years, starting in 1963—and the second largest total sample was obtained at the Crex Meadows WLA (Table 2). Necedah NWR was an important banding site from 1960 through 1967. Since 1966, four sites (Horicon NWR, Crex Meadows, the G. W. Mead WLA and the Collins Marsh WLA) have provided the largest samples of preseason-banded mallards.

Geographically, the 1961-72 preseason mallard banding was confined mainly to the southeast quartile which accounted for about 70 percent of the total sample (Fig. 3). Four of its nine degree blocks had samples of 500 or more banded mallards. Approximately 22 percent of the mallards were banded in two degree blocks of the northwest quartile (Fig. 3) and about 4 percent each came from the southwest and northeast quartiles. In the southwest, except for the 44°-90° block, most of the banding was done along the Mississippi River. Banding in the northeast was confined almost entirely to the degree block containing Powell Marsh WLA.

About 50 percent of the average 1965-66 and 1968-70 mallard breeding population was found in the Southeast/Central region of Wisconsin (March et al. 1973). That region is roughly approximated by the quartile in Figure 3 south of 45° and east of 90°. Seventeen percent of the breeding mallards were found in the Northwest region which included a large portion of the quartile west of 90° and north of 45°. The remainder of Wisconsin's breeding population was distributed over the regions designated as Low Density (March et al. 1973) and the Driftless Area.

Mallard breeding population segments in southeastern and east central Wisconsin seemed adequately, if not excessively, represented by preseason banded birds during 1961-72 (Figs. 1 and 3). Four major preseason banding sites were within that quartile (Fig. 2). Mallard breeding populations in northwestern Wisconsin should also be adequately represented numerically, but not geographically, by banded samples. Northeastern Wisconsin breeding populations appear to be inadequately represented by banded mallards. Additional banding sites and effort are needed north of 45°, both east and west of 90° (Figs. 2 and 3).

While breeding populations are relatively low in southwestern Wisconsin, the birds which are present were the most poorly represented by banded samples in recent years. Since mallard banding was discontinued on both the Necedah NWR and the Upper Mississippi NWR in 1968, there has been only one preseason banding site active west of 90° and south of 45°. This was the Dike 17 Flowage in the Black River State Forest (Fig. 2).

Table 1. *Total mallards[a] banded in Wisconsin during 1950-72, the number of direct recoveries and direct recovery rates.*

Age and Sex	1950-60 # Banded	1950-60 # Recovered First Year	1950-60 Rate	1961-72 # Banded	1961-72 # Recovered First Year	1961-72 Rate
Males:						
Adults	85	8	.09	6,004	482	.0803
Immatures	600	119	.200	10,696	1,585	.1458
Locals	23	4	.2	914	132	.144
	708	131	.185	17,614	2,199	.1248
Females:						
Adults	109	17	.16	16,788	958	.0571
Immatures	619	100	.160	13,332	1,573	.1180
Locals	15	2	.1	863	96	.111
	743	119	.160	30,983	2,627	.0848
Total	1,451	250	.172	48,644[b]	4,826	.0992

[a]Normal, wild-caught birds banded in June, July, August and September.

[b]Includes an additional 47 locals banded as sex "unknown".

Banding of Flightless Local Mallards. In 1950-60, local mallards were banded in only four degree blocks. The largest sample banded on a single site was 28 locals from Necedah NWR. During 1961-72, including intensified nightlighting efforts in 1965-71, local mallards were banded in 12 degree blocks. Sufficient numbers of locals were banded in three degree blocks (43°-88°, 45°-90° and 45°-92°) to provide 30 or more direct recoveries from each block. Anderson and Henny (1972) indicated that "30 direct recoveries for each degree block" was considered a meaningful sample size for local mallard banding efforts in Canada during the 1950's. Although that objective was met in many places in the southern portions of the prairie provinces, considerable banding was still needed in northern Canada and the United States (Lensink 1964).

Sex and Age Ratios of Banded Samples. The annual immature:adult ratios in the 1950-72 preseason mallard bandings are shown in Table 3. The age ratios for 1967-72 were undoubtedly more representative of the age structure of late summer mallard populations in Wisconsin than were samples obtained in 1961-66 or 1950-60, because banding was more widely distributed in the former period. Immature:adult ratio for the 1967-72 banding was significantly greater (chi-square = 920, 1 df, $P<0.001$) than the 1961-66 ratio. In 1961-66, banding was done primarily at Horicon NWR and Crex Meadows, sites with unique age and sex ratios in relation to other banding sites (Table 4).

The 1961-72 age ratio (0.7 immature:adult) of the combined banded samples from Horicon NWR and Crex Meadows was significantly lower than the age ratio of the total sample banded at all other Wisconsin sites (chi-square = 4854, 1 df, $P<0.001$). Separate age ratios for the Horicon NWR and Crex Meadows banded samples also each were significantly less than the age ratio from the rest of the Wisconsin samples (chi-square values were 4439 and 2774 respectively, for Horicon and Crex, 1 df, $P<0.001$). Combined samples from Horicon NWR and Crex also had significantly lower age ratios ($P<0.001$) than combined samples from all other sites in 1961-66 and 1967-72. Age ratios from Crex Meadows (0.7 immature:adult) and all other sites (3.3 and 3.2 immatures:adult) except Horicon NWR were not different between 1961-66 and 1967-72 at $P=0.05$. The Horicon NWR age ratio in 1967-72 (0.6 immature:adult) was significantly *lower* ($P<0.05$) than the age ratio for 1961-66 (0.7 immature:adult). Immature:adult ratios in the Horicon NWR exceeded 1.0 only four times during

Table 2. *The 1950-72 preseason mallard banding in Wisconsin by individual sites.*[a]

Banding Site	# Banded in Preseason Period[b] 1950-60	1961-72	Total
Wildlife Areas:			
Crex Meadows	109	8,465	8,574
G. W. Mead		4,637	4,637
Collins Marsh		3,543	3,543
Horicon Marsh	948	1,296	2,244
Powell Marsh		804	804
Grand River Marsh		525	525
Dike 17 Flowage		214	214
Pershing		178	178
	1,057	19,662	20,719
National Refuges:			
Horicon	19	24,529	24,548
Necedah	129	1,527	1,656
Upper Mississippi	201	892	1,093
	349	26,948	27,297
Misc. Sites:	7	210	217
Total	1,413	46,820	48,233

[a]Normal, wild-caught mallards, with all age and sex cohorts combined (excluding locals).

[b]Banded between July 1 and September 30 each year.

1961-72; Crex Meadows age ratios exceeded 1.0 immature:adult only twice during 1963-72. In at least two of the years with age ratios above 1.0, special efforts were made to band more immature mallards at the Horicon and Crex sites. After a predetermined number of adults were banded, additional adult females were released unbanded.

Sex ratios for the 1950-60 banded samples were 0.8, 1.0 and 1.5 males:female respectively, for adults, flying immatures and locals. In the 1961-72 banded samples, sex ratios for the same sequence of cohorts were 0.4, 0.8 and 1.1, respectively. Because of their large sample sizes, mallards from Horicon NWR and Crex Meadows also strongly influenced the sex ratio of the preseason banding. Table 4 suggests that both Horicon NWR and Crex Meadows attracted a greater proportion of adult females than were present on a majority of the other banding sites. Two additional sites, Powell Marsh and the Pershing WLA also had adult sex ratios equal to or less than the Horicon NWR ratio. Only 216 adults were banded at Powell and only 39 at Pershing. The 1961-72 adult sex ratios from both Horicon NWR and Crex Meadows were significantly lower (chi-square values of 422 and 207, 1 df, $P < 0.001$) than the combined sex ratio for adults banded at all other sites. Overall, adult sex ratios were less than 1.0 males:female at nine of the eleven sites and immature sex ratios were less than 1.0 at seven (Table 4).

Bellrose et al. (1961) presented evidence that sex ratios at hatching for wild ducks are close to 1.0 males:female. The sex ratio of local mallards banded in Wisconsin during 1950-72 was 1.07 males:female (937:878). The Wisconsin ratio was similar to the 1.06 males:female found for local mallards banded throughout Canada and the United States during 1950-61 (Lensink 1964). The 1961-72 sex ratio for flying immatures in Wisconsin was about 1.0 males:female if samples banded at Horicon NWR are omitted. The Horicon NWR immature sex ratio was significantly lower than the sex ratio for the remainder of the banding sites combined (chi-square = 244, 1 df, $P < 0.001$).

Theoretically, sex and age ratios in preseason-banded samples should reflect the late summer population structure, assuming that all major population segments are included in the banding. Local concentrations of a particular sex or age cohort can bias these estimates however; the high incidences of adult females in samples from Horicon NWR and Crex Meadows are prime examples. Using age ratios from pooled samples of preseason-banded mallards as indexes to annual productivity trends in Wisconsin might be practical if there were three or four sites with long histories of banding. To examine this further, the direction of annual changes in age ratios (ratios indicated either higher or lower, or no change, in productivity from the previous year's sample) were compared between individual sites having at least 3 consecutive years of banding during 1961-72. In the 44 comparisons between sites, 31 (70 percent) showed the same directional changes in productivity between pairs of age ratios. This was not significantly different (chi-square = 3.28, 1 df, $P = 0.05$) from the proportion expected by chance alone (assuming differences would be the same in half the instances due to chance). For comparisons between age ratios from the same pairs of years, Horicon NWR, Crex Meadows, the Mead WLA and Powell Marsh showed the same directional changes in productivity for 25 of 28 instances (89 percent). Agreement between the four areas was significantly greater (chi-square = 7.88, 1 df, $P = 0.005$) than expected by chance. For example, in 1969, age ratios from samples banded at Horicon NWR, Powell Marsh, the Mead WLA and Crex Meadows all were higher than in 1968; age ratios from Collins Marsh and the Horicon Marsh WLA were lower than in 1968. Age ratios from Necedah NWR, Collins Marsh and the Horicon Marsh WLA did not consistently change in the same direction as the other four sites.

In general, there was evidence of some continuity in the direction of annual changes in age ratios from samples banded on several of the major preseason sites; magnitude of these changes varied considerably for individual sites. On this basis, the use (in subsequent sections) of age ratios from the pooled banded sample as one index to annual productivity of mallard populations in Wisconsin is assumed to be justified.

Direct Recovery Rates. Immature male mallards banded during 1950-60 had a higher direct recovery rate than adult males marked in the same years (Table 1; chi-square = 4.69, 1 df, reference value for P = 0.05 is 3.84). Direct recovery rates for all other cohorts were not different at P 0.05 in 1950-60.

During 1961-72, immature males had significantly higher direct recovery rates than either adult cohort and immature females (Table 1). Chi-square values were significant (at $P < 0.001$, 1 df, 163, 646 and 35.9 respectively) for comparisons between immature males-adult males, immature males-adult females and immature males-immature females. On an annual basis, direct rates for immature males were significantly higher (March 1976:313) than for adult females in all years, adult males in 1961 and 1963-70, and immature females in 1967 and 1969-72.

Immature females also had a significantly higher direct recovery rate than adult cohorts in 1961-72 (Table 1). For immature females-adult males, chi-square was 64.6 and for immature females-adult females, 346 (1 df). Annual direct rates for immature females were significantly higher ($P < 0.05$) than all adult female yearly rates and were higher than adult male rates in 1961, 1963, 1966 and 1968-69 (March 1976:313).

Adult male recovery rate for 1961-72 was higher than the rate for adult females (Table 1; chi-square = 40.3, 1 df), and the annual rates for males were greater ($P < 0.05$) in 1962, 1967 and 1970-72.

The 1961-72 local male direct recovery rate was higher than the rate for local females (Table 1; chi-square = 4.34, 1 df). However, only the 1966 and 1969 direct rates for local males were different from the corresponding female rate at P 0.05 (March, 1976:313).

Direct recovery rates for immature and local cohorts of either sex showed no difference by age category at P 0.05. For males there also were no differences in annual rates for immatures and locals. The 1970 and 1972 direct recovery rates (March 1976:313) were significantly different between the two age categories of females at $P < 0.05$.

Recovery Rates in Wisconsin Compared to Other Regions. Comparison of Wisconsin's 1950-60 direct recovery rates for juvenile mallards (rates for flying immatures and locals) with average 1954-60 direct recovery rates from local mallards banded in Alberta, Saskatchewan, Manitoba, North Dakota and South Dakota (in Table 47, from Lensink 1964) indicated that

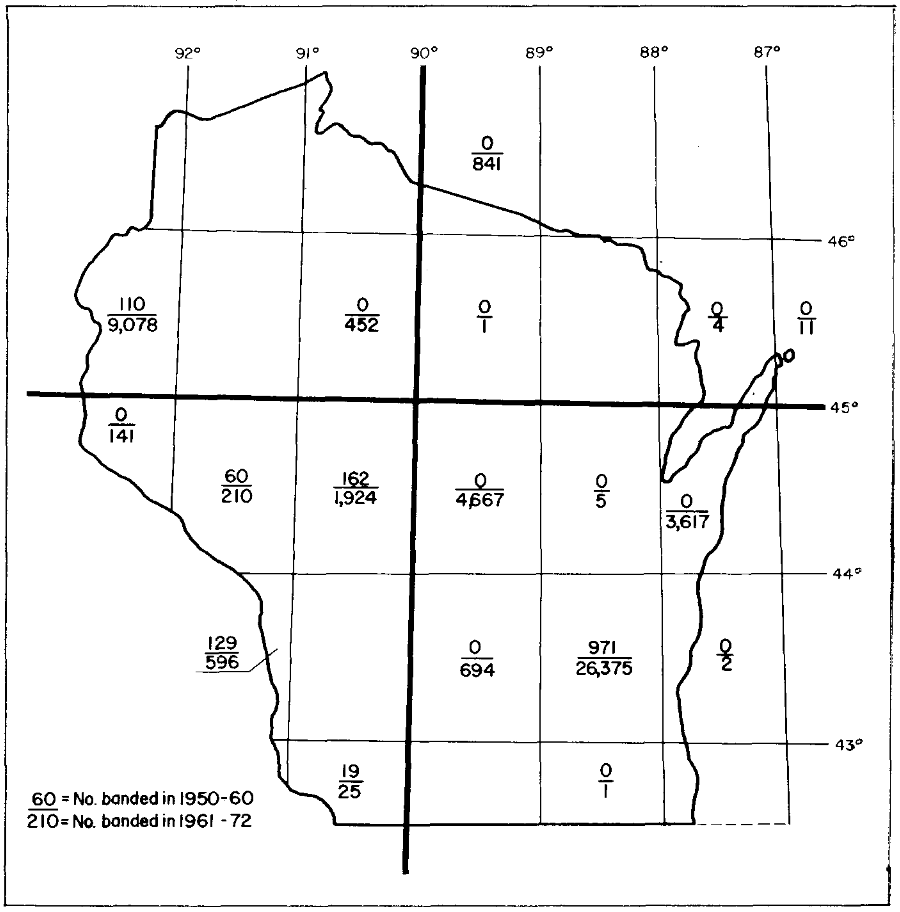


FIGURE 3. *Distribution of preseason mallard banding, including locals, by degree blocks in Wisconsin during 1950-60 and 1961-72.*

rates in Wisconsin were similar to those of both Dakotas and were higher than those for the three provinces.

Direct recovery rate for locals banded in Michigan was about 6 percent (Lensink 1964). For Minnesota, Jessen (1970) concluded that in the 1950's, direct recovery rate for locals was about 19 percent, for flying young, about 17 percent and for "older" (adult?) preseason banded mallards, 10 percent. The level of shooting pressure, especially on locals, was considered excessive. By Minnesota's standards, adult female, immature and local male cohorts banded in Wisconsin were also being overshot in the 1950's (Table 1). Both Lensink (1964) and Jessen (1970) indicated that a major cause of the high rate of recovery on locals in Minnesota was the high recovery rate in the vicinity of banding.

Local mallards banded in Wisconsin during 1961-72, had a direct recovery rate of about 11-14 percent (Table 1). For Minnesota, local mallard direct recovery rates were 12 percent in 1963-67 (Jessen 1970), and also in 1969-72 (Benson 1974). Since the estimated band report rate was lower in Minnesota during the 1960's (0.318 versus 0.388 for Wisconsin; Anderson and Henny 1972), Wisconsin mallards were subjected to a slightly lower rate of direct recovery in recent years. Recovery rates on mallards produced in Minnesota have been emphasized in relation to Wisconsin's local populations because the two states undergo considerable exchange of birds.

Relative Recovery Rates. Since relative recovery rates are not dependent on band report rates, vulnerability to shooting can be compared between sex and age cohorts banded in different sets of years. Local and immature male mallards were 1.8 and 2.1 times as vulnerable to shooting as adult males in 1950-60 and 1.8 times as vulnerable in 1961-72 (using direct recovery rates in Table 1). For females, relative recovery rates suggested some increase in juvenile vulnerability between 1950-60 and 1961-72. Relative recovery rate between local females and adult females was 0.8 in 1950-60, but increased to 1.9 in 1961-72; immature female:adult female relative rates were 1.0 in 1950-60 and 2.1 in 1961-72.

Juveniles were 1.4 times as vulnerable as adults to shooting overall in 1950-60 (immature-local direct recovery rate of 0.18 divided by adult recovery rate of 0.13), and 2.1 times as vul-

Table 3. *Age ratios from 1950-72 preseason-banded samples of mallards.*

Year	# Banded Immatures	# Banded Adults	Immature:Adult Ratio
1950	272	64	4.2
1951	540	72	7.5
1957	99	10	9.9
1958	17	7	2.4
1959	58	17	3.4
1960	233	24	9.7
1950-60	1,219	194	6.3
1961	1,788	3,516	0.5
1962	1,524	3,098	0.5
1963	1,741	2,060	0.8
1964	2,343	1,258	1.9
1965	2,194	1,270	1.7
1966	2,426	3,362	0.7
1967	1,937	1,465	1.3
1968	2,333	1,796	1.3
1969	2,946	1,427	2.1
1970	1,763	1,202	1.5
1971	1,342	984	1.4
1972	1,691	1,354	1.2
1961-66	12,016	14,564	0.8
1967-72	12,012	8,228	1.4
1961-72	24,028	22,792	1.05

Table 4. *Age and sex ratios from preseason-banded samples[a] of mallards, 1961-72.*

Banding Location	Immatures:Adult Ratio	Male:Female Ratio Adults	Male:Female Ratio Immatures
Upper Mississippi NWR	19.7	1.9	1.4
Mead Wildlife Area	5.8	0.6	0.8
Pershing Wildlife Area	3.6	0.2	0.8
Grand River Marsh	3.5	0.7	0.8
Powell Marsh	2.7	0.3	0.8
Collins Marsh	2.4	0.8	0.9
Necedah NWR	2.0	0.8	1.2
Horicon Marsh Wildlife Area	1.7	0.8	0.9
Dike 17 Flowage	1.5	1.1	1.3
Crex Meadows Wildlife Area	0.7	0.4	1.0
Horicon NWR	0.7	0.3	0.6
Miscellaneous Sites	2.3	0.4	0.7
Overall	1.05	0.36	0.80
Overall-w/o Crex and Horicon	3.2	0.7	0.9
Mean plus 95% Conf. Limits	3.9 ± 3.3	0.7 ± 0.3	0.9 ± 0.2

[a]See Appendix III for appropriate sample sizes

nerable as adults in 1961-72.

To adjust age and sex ratios of the mallard harvest (duck wing collection data) for differential vulnerability to shooting in Wisconsin, relative recovery rates based on only the direct recovery rate encountered within the state were calculated. Mean immature:adult relative recovery rates in Wisconsin for 1961-72 were 2.6, 2.7, 1.6 and 2.6 respectively, for immature males, immature females, local males and local females. Immature males were more vulnerable to shooting (in comparison to adult males) in Wisconsin than they were elsewhere, while local males were less vulnerable within the state. Both immature and local females were more vulnerable (compared to adult females) to shooting in Wisconsin.

Although the relative recovery rate of 0.7 male:female in 1950-60 (using recovery rates in Table 1) suggested that adult males were less vulnerable to hunting than adult females, adult males banded in 1961-72 were 1.4 times more likely to be shot than females. Relative recovery rates for juvenile cohorts showed little difference in vulnerability between sexes in the two banding periods. Male:female relative recovery rate was 1.2 for immatures and 1.3 for locals in both periods. Based on mallards banded preseason throughout North America in 1967 and 1968, adult males were 1.2-1.6 times more vulnerable than females and immature males were 1.2-1.3 times more vulnerable (data from Example 11, Geis 1972). Mallards associated with Wisconsin were about average in vulnerability between sexes on that basis.

The 1961-72 relative recovery rates for both adults and immatures were 1.2 males:female in Wisconsin. Adult males were not as vulnerable to shooting (as compared to females) in Wisconsin as they were elsewhere. Immature males were equally vulnerable in Wisconsin and elsewhere. For locals, the relative male:female recovery rate was 0.7, indicating males were only about half as vulnerable to shooting in Wisconsin as they were outside the state (when compared to local females).

Differences in Recovery Rates Between Banding Sites. Adult and immature direct recovery rates for individual 1961-72 preseason banding sites are listed in Table 5 and in (March 1976:314). Mallards banded at the Mead Wildlife Area (Fig. 2) had significantly higher rates than cohorts from any other sites with the following exceptions: (1) adult females and immature males banded at Grand River, and (2) immature females banded at Dike 17 and the Upper Mississippi NWR. Other than Dike 17 birds, immature females banded on the Upper

Mississippi NWR had significantly higher direct rates than any other site. Immature males from the Upper Mississippi NWR had higher direct rates than immature males from Dike 17, Pershing, Crex Meadows and Horicon NWR.

The Mead Wildlife Area and the Upper Mississippi NWR, the two sites with generally higher direct recovery rates (Table 5), are considerably different from one another, particularly in the amount of available sanctuary. The 1,200 acre (486 ha) refuge on Mead represents about 5 percent of its area; 26 percent or 22,140 acres (8,964 ha) of the Wisconsin portion of the Upper Mississippi NWR was closed to hunting (Green 1963). Although Mead receives excessive hunting pressure (an average of 10,100 hunter-trips annually for waterfowl in 1967-72, J. Berkhahn pers. comm.) and its direct recovery rate based on voluntary hunter-reported bands is above average (March 1971 b), the overall direct recovery rate for the site is increased further by bands obtained during intensive hunter checks. While about 90 percent of the mallard bands reported to the Bird Banding Laboratory from Wisconsin came directly from hunters or indirectly through hunter mail surveys (Anderson and Henny 1972:61), for Mead mallards in 1966-69, an average of one-third of the direct recoveries represented bands noted in hunter-checks (March 1971 b). About 75 percent of the direct recoveries from mallards banded at Mead came within the degree block of banding. Lensink's (1964) warning that recovery rates in the vicinity of the banding site can have a major influence on total recovery rate is particularly appropriate in this situation.

On the Upper Mississippi NWR, banding was done at more than one site (Fig. 2) and represented several degree blocks. Hunting pressure was also heavy overall (an average of 102,920 man-days of hunting on all units annually during 1953-60, Green 1963). Forty-three percent of the direct recoveries came within the degree blocks of banding. Bag checks probably were not a major contributor to band reporting. However, mallards using the Upper Mississippi were subjected to shooting on both the Wisconsin and Minnesota shores; this undoubtedly was a major influence on the higher recovery rates.

Recovery rates from adult females banded at the Grand River Marsh WLA were significantly higher than the corresponding rates from Collins Marsh WLA and the Horicon NWR and immature male rates from Grand River were higher than rates from Dike 17, Pershing and Crex Meadows (significant at $P < 0.05$). Sixty percent of the direct recoveries for mallards banded on Grand River came within the degree block of banding.

Table 5. *Direct recovery rates from selected 1961-72 preseason banding sites.*[a]

	Age and Sex at Banding			
	Adult		Immature	
Banding Site	Male	Female	Male	Female
Horicon Marsh Wildl. Area	.02	.06	.14	.07
Grand River Wildl. Area	(.1)	.12	.18	.08
Collins Marsh Wildl. Area	.08	.042	.135	.107
Mead Wildlife Area	.18	.14	.223	.178
Powell Marsh Wildl. Area	(.1)	.07	.12	.11
Dike 17 Wildlife Area	(.1)	(.0)	.1	.1
Pershing Wildlife Area	-	(.0)	.1	.1
Crex Meadows Wildl. Area	.067	.055	.125	.100
Horicon NWR	.079	.0541	.130	.1030
Necedah NWR	.07	.07	.132	.11
Upper Mississippi NWR	(.1)	(.3)	.17	.17
Mean Rate	.09	.08	.14	.10

[a]Recovery rates for individual sites represent total # of direct recoveries ÷ total # banded. Rates in parentheses were calculated from a banded sample of less than 50 birds.

Immature males banded on the Pershing WLA had significantly lower direct recovery rates than males banded on Horicon NWR, the Horicon Marsh WLA, Collins, Powell Marsh, Crex Meadows and Necedah NWR (Table 5).

No other banding sites showed consistent overall significant differences in recovery rates when compared with one another. A review of rates for individual sex-age cohorts (Table 5) failed to identify any significant north-south or east-west trends in shooting pressure. Crex Meadows and Powell Marsh rates were not different from those for Horicon NWR. Although individual sites had higher rates for one or more cohorts, these areas (i.e. Mead, Upper Mississippi NWR and Grand River) were located in different regions. Hunting pressure on a particular area or in its immediate vicinity apparently had some influence on the magnitude of direct rates.

Local Recovery Rates. Direct recovery rates for locals were derived for all banding locations having at least 10 first-year recoveries (Table 6). Data for both males and females were combined to enlarge sample sizes. Beaver Dam Lake, Collins Marsh and Clam Lake all had significantly higher overall direct recovery rates than the Wood-Juneau-Jackson counties complex at $P < 0.05$ (chi-square values with 1 df were 6.08, 4.40 and 5.31, respectively). Also, direct recovery rates from Beaver Dam Lake and Clam Lake were significantly greater than the direct rate for Crex Meadows (chi-squares with 1 df were 5.41 and 5.31, respectively). None of the recovery rates for the remaining sites were significantly different from one another at $P < 0.05$.

The overall chi-square tests for differences in local recovery rates within "southeast Wisconsin" (chi-square = 2.70, 4 df) and "northern and central Wisconsin" (chi-square = 7.44, 3 df) were nonsignificant at $P < 0.05$. Overall rates from the two regions also were not different at $P < 0.05$ (chi-square = 2.95, 1 df).

Locals banded on Crex Meadows and Clam Lake (Fig. 2), sites that are within 14-15 air miles (22-24 km) of one another, had different direct rates

Table 6. *Direct recovery rates for mallards banded in 1961-72 as locals on selected sites.*[a]

Banding Site	# Banded	# of Direct Recoveries	Direct Recovery Rate
Fox Lake (Dodge Co.)	142	17	.12
Beaver Dam Lake (Dodge Co.)	71	14	.20
Horicon Marsh & Lake Sinissippi (Dodge Co.)	104	15	.14
Rush Lake (Fond du Lac and Winnebago Cos.)	90	13	.14
Collins Marsh (Manitowoc Co.)	80	14	.18
Southeast Wisconsin	487	73	.15
Butternut Lake (Price Co.)	266	35	.13
Clam Lake (Burnett Co.)	173	29	.17
Crex Meadows (Burnett Co.)	386	39	.10
Wood-Juneau-Jackson Counties Complex[b]	166	14	.08
Northern and Central Wisconsin	991	117	.118

[a]Only those sites having at least 10 direct band recoveries.

[b]Includes Dike 17 Flowage, Necedah NWR, Meadow Valley Wildlife Area, Wood County Wildlife Area, the Sandhill Wildlife Area and the Winnebago Cranberry Flowage bandings and recoveries.

of recovery. The recovery rate in the 10-minute block of banding was less than 1 percent for locals from Crex. By comparison, locals from Clam Lake had a direct recovery rate of 2 percent in the 10-minute block of banding. Apparently the Crex cohort was subjected to some reduction in shooting losses in the vicinity of banding. The 1,600-acre refuge (648 ha) on Crex Meadows may have furnished added protection to local birds. However, it may also be that the band reporting rate in Crex Meadows is lower as a result of the long history of banding on the site. Henny and Burnham (1976) found depressed band-report rates in the vicinity of traditional banding sites.

Summary

Mallards banded on the Horicon NWR and the Crex Meadows WLA comprised 75 percent of the 1961-66 Wisconsin sample; less than 50 percent of the 1967-72 sample came from those same two sites. The banded samples from both Horicon NWR and Crex Meadows included a greater proportion of adult females than the combined sample from all other sites. This disproportionately large number of adult females in the 1961-66 preseason samples biased immature:adult ratios downward. Age ratios from the 1967-72 samples were assumed to be more representative of the actual juvenile:adult composition of Wisconsin's late summer mallard populations. Preseason age ratios from several banding sites, including Horicon NWR, Crex Meadows and Mead, showed similar annual trends in productivity, suggesting that annual changes in the age structure of combined samples from all sites could be used as one index to production in Wisconsin.

Sex ratios indicated that adult males were the least abundant sex and age cohort in Wisconsin's late summer mallard populations. Also, the immature sex ratio, based on samples banded in August and September, was only 0.8 males per female. Some juvenile males may leave the state soon after fledging since banded samples of flightless young had a sex ratio of about 1.1 males:female.

Immature males had higher 1961-72 direct recovery rates than either adults (both sexes) or immature females. Adult males and immature females also were recovered at a higher direct rate than adult females. Direct recovery rates for flying immatures were not different from rates obtained for birds banded as flightless young.

One or more age-sex cohort of mallards banded on the Mead WLA, the Grand River Marsh WLA and the Upper Mississippi River NWR had higher direct recovery rates than the rates obtained for the same cohort of birds banded on all other sites. Locals banded on Beaver Dam Lake (Dodge County), Clam Lake (Burnett County) and Collins Marsh had higher direct recovery rates than several other sites with banded samples of locals.

Based on 1961-72 overall relative recovery rates, juvenile mallards were about twice as vulnerable to shooting as adults. Within Wisconsin, however, immatures (both sexes) and local females were 2.6-2.7 times as vulnerable to shooting as adults; local males were 1.6 times as vulnerable as adults.

REPRODUCTION

Reproduction of young is essential to the maintenance of a species. If annual productivity is unable to offset deaths within a population, the breeding adult cohort will decline the following year, assuming no additional influx of individuals from other sources occurs.

There was no single reliable index to the annual productivity of mallards breeding in Wisconsin. March et al. (1973) could detect no significant relationships between breeding duck densities, occupancy of wetlands by pairs and habitat abundance. The direct relationship between pond numbers in May and breeding populations and between pond numbers in July and annual production characteristic of the Canadian prairies (Crissey 1969, Geis et al. 1969) apparently either is absent or is not as important in Wisconsin. However, both Jahn and Hunt (1964) and Gates (1965) suggested that productivity was lowered by a lack of summer brood habitat.

Anderson and Henny (1972) explain how duck wing survey data and preseason banding are used to check the predictability of multiple regression techniques for estimating annual productivity of North American mallard populations. A similar regression model was not tested for Wisconsin because of a lack of appropriate information. Instead, each of three indirect estimates of annual productivity available was considered as a separate index to reproduction of young mallards.

PRODUCTIVITY INDEXES

Methods

Sex and Age Ratios. Sex and age ratios of the 1959-72 Wisconsin mallard harvest were obtained from results of the annual U.S. Fish and Wildlife Service's mail duck wing collections as presented in Geis and Carney (1961) and Martin and Carney (1977). Relative recovery rates from preseason banded mallards were used to adjust these ratios for differences in vulnerability to shooting between adults and immatures, or between males and females. The adjusted wing survey ratios were considered as representative of the sex and age composition of Wisconsin mallard populations during the hunting period and were used as one index to annual productivity of local populations. As indexes to productivity, the adjusted age ratios were biased to an unknown degree by the presence of migrant mallards in the Wisconsin harvest.

Age ratios from preseason-banded samples were used as a second index to mallard productivity in Wisconsin. Immature:adult ratios from the same banding sites were compared between years. Post-nesting season movements of adult breeders and post-fledging dispersal of locally-produced young, both intra- and inter-state or province, plus the potential presence of early migrants from other breeding grounds, also bias these age ratios as indexes to productivity.

Sex and age ratios for 1950-56 were obtained from bag checks of Wisconsin hunters. Checks were made on state waterfowl projects and other public boat landings and represented various dates. Jahn (1953) summarized procedures used in these surveys.

Proportion of Successful Females. Two estimates of the proportion of female mallards successfully rearing a brood to fledging were used to calculate mallard production in Wisconsin. The first, which assumed that 30 percent of the females ultimately reared broods, represented a conservative approach which approximated results of the most recent evaluation of mallard production in Wisconsin (Wheeler 1975) and was closest to the continental average from Dzubin and Gollop (1972). The second, and more liberal, estimate of 46 percent success was supported by the greatest amount of Wisconsin data (from Jahn and Hunt 1964) even though the information was gathered 10-15 years prior to the current study. Both methods used a less optimistic choice of reproductive success for determining local production than the 50 percent estimated by Jahn and Hunt (1964) and March et al. (1973).

Brood Size. Number of ducklings in Class I, II and III (Gollop and Marshall 1954) mallard broods, as determined from observations submitted by Department of Natural Resources and other field personnel, were available for 1962-72. The 1950-56 mallard brood data for Wisconsin were previously reported by Jahn and Hunt (1964). The 1962-72 data were gathered throughout the state and represented records obtained incidental to other field activities, results of formal brood surveys, especially on the Crex Meadows Wildlife Area, and broods observed during the June-August banding activities. Samples of "aged" broods with "complete" counts of ducklings were less than 50 broods in some years (e.g. 1962-65), particularly when the data were separated into individual age classes. Average Class I, II, III and all-age brood size and percent loss of ducklings between classes were calculated annually and overall.

Annual Production. Mallard breeding populations in Wisconsin for 1965-66 and 1968-70 were available from March et al. (1973). Spring sex ratio was assumed to be 1.0 male:female and all females were assumed to nest at least once. Productivity was estimated separately for 30 percent and 46 percent of the females successfully fledging broods. Number of young was obtained by multiplying number of successful females by the average Class III mallard brood size for Wisconsin.

In order to allow productivity rates to fluctuate annually, the number of young mallards was also estimated by substituting age ratios from the adjusted wing survey data and from the preseason banding for the two fixed rates of reproductive success and average brood size. Annual production was obtained by multiplying the fall preseason adult population of local breeders by the appropriate age ratios. The adult segment of the local population present each fall was assumed to equal the May breeding population minus birds dying between May 15 and October 1. Geis et al. (1969) used a 5 percent loss of adults between spring and fall; the May breeding population for Wisconsin was similarly reduced by 5 percent. No adjustments were made to account for ingress or egress of mallards, either adults or juveniles, between May and October. Losses to emigration are assumed to equal the replacement by immigration from outside Wisconsin.

Table 7. *Average mallard brood sizes[a], and adjusted mallard wing collection age ratios for Wisconsin.*

Year	Mean Brood Size Class III	All Ages[b]	Adjusted I:A Ratio[c]	"Production" Index[d]
1962	9.0 (1)	8.4 (8)	1.4	9.8
1963	7.2 (4)	7.0 (32)	1.0	7.9
1964	5.0 (12)	6.2 (47)	1.0	7.2
1965	6.7 (25)	7.0 (45)	1.4	8.4
1966	6.8 (44)	6.8 (165)	0.9	7.6
1967	6.8 (32)	6.8 (89)	0.9	7.6
1968	6.9 (17)	6.1 (70)	0.6	6.7
1969	6.6 (34)	7.0 (126)	1.0	8.0
1970	5.8 (30)	6.6 (164)	1.0	7.6
1971	6.7 (38)	6.4 (99)	0.7	7.1
1972	6.5 (18)	7.0 (75)	1.2	8.2
Average of 1962-72 Means	6.7	6.8	1.0	7.8
Overall Mean	6.5	6.7	-	-
95% C.L.	±0.3 (255)	±0.2 (920)		

[a]Observations reported by state and federal agency and university personnel throughout Wisconsin each year. Sample sizes are shown in parentheses.

[b]Mean Class I brood size = 7.2 ± 0.3 ducklings (n = 253)
Mean Class II brood size = 6.5 ± 0.3 ducklings (n = 361)
Mean Unknown Age brood size = 6.3 ± 0.8 ducklings (n = 51)

[c]Obtained by adjusting harvest age ratios in Martin and Carney 1977 for differential vulnerability of immature birds.

Results and Discussion

Mallard Brood Size. Based on samples of 109 broods in 1950-56 (Jahn and Hunt 1964) and 255 broods in 1962-72 (Table 7), the mean size of Class III mallard broods in Wisconsin was 6.5 ducklings. The 95 percent confidence intervals in 1950-56 were 6.3-6.7 ducklings (Jahn and Hunt 1964:45) and in 1962-72, 6.2-6.8 ducklings. Dzubin and Gollop (1972) listed an unweighted average Class III brood size of 6.4 ducklings for United States and Canadian mallard investigations in the 1940's and 1950's. Jahn and Hunt (1964) in their review of past studies, arrived at the slightly lower North American average of 6.3 ducklings. Twelve of the studies listed by Dzubin and Gollop (1972) had mean brood sizes smaller than 6.5 young, and six studies found greater mean sizes. Studies in Saskatchewan, Idaho, Washington, Alberta, Manitoba, Minnesota and Colorado obtained smaller Class III sizes than Wisconsin; North Dakota, south Dakota and Oregon studies found larger mean Class III broods (Dzubin and Gollop 1972). Apparently the number of ducklings fledged per successful female in Wisconsin equaled or exceeded values reported from other production areas.

Combining the 1962-72 observations for mallard broods of all ages gave an overall mean brood size of 6.7 ± 0.2 ducklings (n = 920; P = 0.05). There was no significant difference (P = 0.05) in brood size between Class III and all-age broods. Mean size of Class III broods exceeded the mean size of all-age broods in 4 years (Table 7). If those 4 years were omitted, all-age broods averaged 6.8 ducklings compared to 6.3 ducklings for Class III broods, or about a 7 percent difference.

In 1950-56, there was a 12 percent loss of ducklings between Class I and Class II broods and a 16 percent loss between Class I and Class III broods (Jahn and Hunt 1964). The mean 1962-72 Class II brood size was about 10 percent less than the size of the average Class I brood. Class II and III broods had similar mean sizes in those years. Dzubin and Gollop (1972) listed 11 percent as the average loss of ducklings between Class I-III broods and suggested that a major part of those losses occurred between Class I and II. Duckling losses based on average brood size do not, however, account for losses of entire broods (Dzubin and Gollop 1972), which are known to occur. If losses of entire broods were also accounted for, an average of 36 percent of the mallard brood would be lost between hatching and Class III stages (Dzubin and Gollop 1972).

Age and Sex Composition of the Mallard Harvest. Bag checks from the 1950-56 Wisconsin seasons indicated an overall immature:adult ratio for mallards of 2.6 and a mean of 3.6 (Jahn and Hunt 1964:80). Range of annual ratios was 1.4-6.9 immatures:adult. The mean age ratio for mallard wings submitted in parts collections from the 1959-72 Wisconsin seasons was 2.6 immatures:adult (Table 8) with a range of 1.8-3.3 (Geis and Carney 1961; Martin and Carney 1977). Age ratios for mallard wing collections from Wisconsin were less than 2.0 immatures:adult only in 1961 and 1971 and were 3.0 or higher in 5 years (Martin and Carney 1977).

Both the overall and mean sex ratios for mallards examined in the 1950-56 bag checks were 0.7 male:female for adults and 1.0 male:female for immatures (Jahn and Hunt 1964:80). Overall sex ratio for the total sample of 7,180 mallards was 0.9 males:female. Sex ratios for mallard wings submitted in the 1959-72 parts collections by Wisconsin hunters were higher to males, with a mean of 1.0 males:female for adults and 1.1 males:female for immatures (Table 8, Geis and Carney 1961; Martin and Carney 1977).

Age and Sex Ratios of Preseason Mallard Populations. Age ratios for preseason-banded samples were higher than age ratios derived from wing survey results, corrected for differences in vulnerability, in eight of the 1961-72 seasons (March 1976:319). However, the number of years with higher ratios was not significantly different than expected assuming a chance occurrence of ratios in half the years being higher and half being lower (chi-square = 0.37, 1 df, P = 0.05). Differences between means for the two ratios in 1961-66 and 1961-72 also were not significant at P = 0.05 (Table 8). In 1967-72, when banding was better distributed geographically in Wisconsin, mean age ratio from the preseason banding (1.5 immatures:adult) was significantly higher (P < 0.05) than the mean for adjusted wing results (0.9 immatues:adult).

Assuming that the age ratios of the 1967-72 August and September banded samples actually represented the age structure of a majority of the populations present in Wisconsin, then differential ingress or egress of mallards was needed to obtain the lower age ratios in the populations furnish-

Table 8. *Mean mallard age and sex ratios from adjusted duck wing collections and preseason bandings in Wisconsin.*

Source and Hunting Seasons	Immature:Adult Ratio		Male:Female Ratio			
			Adult		Immature	
	Mean	95% C.L.	Mean	95% C.L.	Mean	95% C.L.
Mallard Harvest[a]						
1959-72	2.6	±0.3	1.0	±0.2	1.1	±0.1
1961-72	2.6	±0.3	1.0	±0.2	1.1	±0.1
Adj. Wing Survey[b]						
1961-66	1.0	±0.4	0.9	±0.3	1.0	±0.1
1967-72	0.9	±0.2	0.8	±0.2	0.9	±0.1
1961-72	1.0	±0.2	0.9	±0.1	1.0	±0.1
Preseason Banding[c]						
1961-66	1.0	±0.6	0.3	±0.1	0.8	±0.2
1967-72	1.5	±0.3	0.4	±0.1	0.9	±0.1
1961-72	1.2	±0.3	0.4	±0.1	0.8	±0.1

[a]Age and sex ratios taken from Geis and Carney 1961, and Martin and Carney 1977.

[b]Age and sex ratios are adjusted for differences in vulnerability to shooting between age and sex cohorts, using relative recovery rates, based on recoveries in Wisconsin only, from preseason banding in the state.

[c]Sample sizes are from March (1976:309).

ing the state's harvest. The change in age structure within the population must have taken place prior to or during the hunting season. On the average, a 40 percent reduction in the number of immatures per adult mallard available to hunters in Wisconsin, a 40 percent increase in the number of adults available, or some combination of fewer immatures and more adults was needed to have reduced the age ratio from 1.5 in August-September to 0.9 during the hunting period. Differences between the mean age ratios would seem to suggest that migrant mallard flights entering Wisconsin after mid-September had lower age ratios than the mallards present earlier in the month. With a hypothetical average Wisconsin September 15 population of 150,000 immature and 100,000 adult mallards, an additional 300,000 adult mallards and 210,000 more juveniles were needed to attain the prehunt age ratio, assuming no prior departure of immatures from the state. Those estimates assumed a migrant age ratio of 0.7 immature:adult which is exceptionally low. If the migrant age ratio was 0.8 immatures:adult, the additional fall flight needed would have included 600,000 adults and 480,000 immatures.

Preseason-banded samples of mallards had significantly lower 1961-66 and 1961-72 ($P < 0.05$) mean adult male:female ratios than were obtained using adjusted wing survey results (Table 8). The 1967-72 adjusted wing survey ratios, assuming again that the banded samples reflected the actual sex ratio of the majority of mallards present in Wisconsin during August and early September, suggested that migrants entering the state after about September 15, had a higher incidence of adult males than populations already present. Sex ratios of migrant immatures probably were not greatly different from those of mallards already present. An alternative explanation in regard to immatures was that: (1) at least some of the preseason-banded immatures already represented transients from other areas and therefore had about the same general proportions of males and females as subsequent migrants; or (2) very few juvenile mallards, other than those which were locally produced, are present in Wisconsin during the hunting period.

Using the same hypothetical populations mentioned before for age ratios, the 300,000 migrant adults would have needed about 1.0 male:female to increase the preseason population sex ratios to the 0.8 male:female estimated as contributing to the 1967-72 harvest.

Age and sex ratios obtained from the 1961-72 preseason banding (March 1976:319) and from adjusting the wing data in Martin and Carney (1977) did not show similar trends in annual productivity and were not correlated ($P < 0.10$).

Class III and all age brood sizes were compared with the annual immature:adult ratios obtained from preseason banding and from adjusted wing survey results. Only the annual mean brood sizes for all age broods were correlated with the annual adjusted duck wing survey age ratios at $P < 0.05$ (Fig. 4). This relationship suggested that the two estimates were indexes to similar trends in annual productivity of Wisconsin mallards. These indexes indicated that 1962, 1965, 1969 and 1972 were years of above-average productivity for Wisconsin mallards and that 1964, 1968 and 1971 were poor years. The remain-

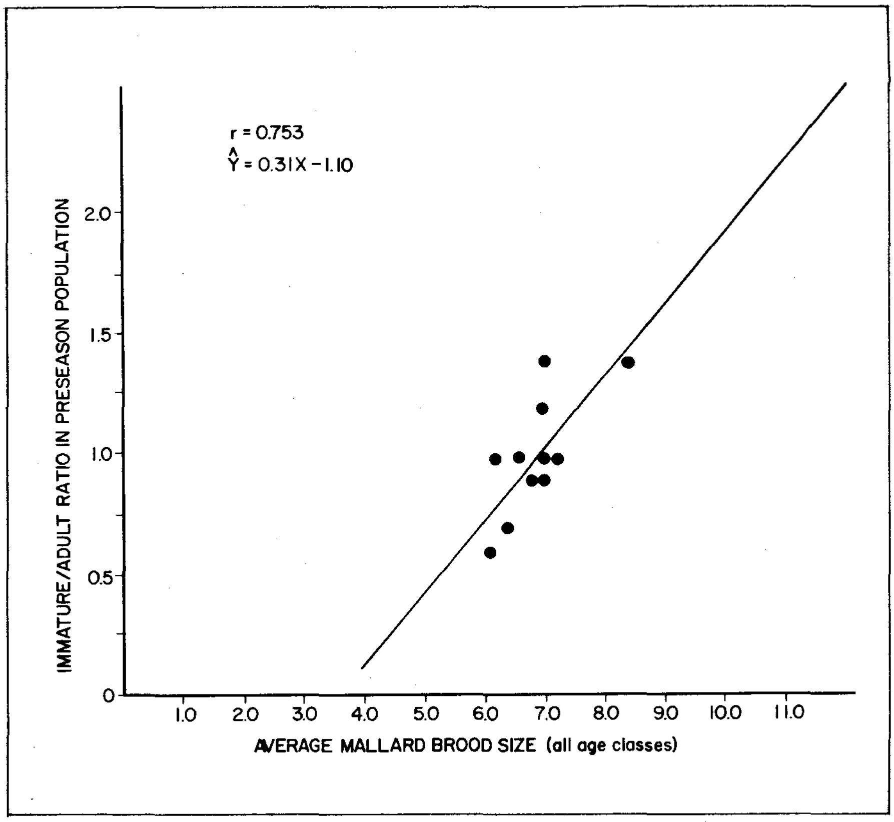


FIGURE 4. *Relationship between the 1962-72 preseason mallard age ratios, based on adjusted wing collection results, and average mallard brood size for all age classes combined.*

ing 4 years were considered as "average" in productivity. Although concurrent brood data were not available to prepare productivity indexes for 1959-61, adjusted age ratios (7.0 and 1.8 respectively) suggested that both 1959 and 1960 were years of good productivity and that 1961 was a poor year (age ratio was 0.4 immatures:adult).

Age Ratios of Mallard Populations Outside Wisconsin. Jahn and Hunt (1964) suggested that since Wisconsin received greater annual precipitation, its breeding habitat was not necessarily affected by drought conditions in the prairie pothole regions of Canada and the United States. As a result, Wisconsin mallard age ratios could be relatively high even in years when severe droughts were occurring in the major breeding grounds in those regions. Also, Jahn and Hunt (1964) suggested that the most probable sources of mallards from outside Wisconsin were the forested regions in northern Saskatchewan, northern Manitoba and Ontario (similar to Bellrose 1972). They concluded (Jahn and Hunt 1964) from the age ratios of mallards shot in Wisconsin during 1950-56 (2.6 young:adult) that the state was deriving only a relatively small volume of birds from the prairie and parkland habitats of Saskatchewan and Manitoba. Mallard production in Wisconsin was thought to strongly influence age ratios obtained in the harvest. Since these age ratios were uncorrected for differential vulnerability, they were only general indexes to production trends. Age ratios in Wisconsin's 1961-70 mallard harvest, which averaged 2.7 immatures:adult, were consistently higher than mallard age ratios in the Mississippi Flyway harvest overall (March et al. 1973). Also, Wisconsin mallard age ratios compared favorably with those obtained from the harvest in other breeding ground states or provinces. Bellrose (1972) concluded that the reason for the higher age ratios in the hunting kill from Wisconsin, and also Michigan and Ohio, was a flight of migrant mallards that originated in eastern Manitoba and western Ontario. The remainder of the states in the Mississippi Flyway, which apparently received the majority of their mallards from the prairie-parklands, had more uniform but lower age ratios in their harvest each year. Most of the evidence has tended to support Bellrose's (1972) suggested origin of the mallards migrating through Wisconsin, but his interpretation that they caused the high age ratio in the harvest is questionable.

The 1955-60 production rates for North American mallard populations averaged 1.2 immatures:adult in the fall population (calculated from Geis et al. 1969). The average 1950-56 mallard age ratio in Wisconsin, based on hunter-checks (Jahn and Hunt 1964:80) adjusted for differential vulnerability, was 1.8 immatures:adult or considerably above the continental average.

North American fall mallard age ratios averaged 1.1 immatures:adult during both 1961-66 and 1967-72 (1961-67 age ratios calculated from Geis et al. 1969, and 1968-72 age ratios taken from Sorenson et al. 1973). In 1961-66 and 1967-72, Wisconsin's fall age ratio, based on adjusted duck wing data, averaged 1.0 and 0.9 immatures:adult respectively, or slightly lower than the continental average. In six of 11 comparisons between years, the 1961-72 adjusted wing survey age ratios for Wisconsin showed the same sign (±) changes (although of different magnitude) in productivity as continental age ratios. This was not different than expected, assuming that sign changes would be the same in half the comparisons on the basis of chance alone (chi-square = 0.0, 1 df, $P > 0.75$). With the small sample size involved, the chi-square test is likely to produce a significant result only if the null hypothesis is very badly wrong (Snedecor and Cochran 1967). North American age ratios were higher (an average of 36 percent) to immatures than the ratios from Wisconsin in 7 of the 12 seasons. Again, with the small sample sizes involved, this is not different from a chance ratio of 50:50 (chi-square = 0.3, 1 df, $P > 0.50$). Since adjusted age ratios from the duck wing collections in Wisconsin reflected productivity rates of both resident and migrant mallards contributing to the harvest, they did not necessarily indicate the true productivity rate of local populations in a given year. The strong correlation between prehunting season age ratios and the average annual all-age mallard brood size in Wisconsin (Fig. 4) did suggest, however, that trends in local production were related to the preseason age ratio each year, making the latter value useful as an index to productivity.

The mean preseason banding age ratio in 1961-66 for Wisconsin was 1.0 immatures:adult, or also just below the North American average for the same period. In 1967-72, when preseason banded samples were thought to be better distributed geographically, the mean banding age ratio of 1.5 immatures:adult was greater than the North American average of 1.1. The mean preseason banding age ratio for 1961-72 (Table 8) was also slightly higher than the continental average.

When the 1961-72 continental production rates (from Geis et al. 1969 and Sorenson et al. 1973) were compared with the age ratios from the Wisconsin preseason banding, the two estimates showed the same direction in changes in productivity between years in only four of 11 comparisons. This was also not significantly different from a chance occurrence of 50:50 (chi-square = 0.18, 1 df, $P > 0.75$) for samples of this size.

Banding age ratios were less than the estimate for North America in only 4 years during 1961-72, and averaged 18 percent higher than the continental ratio. During 1967-72, banding age ratios exceeded continental values in all years and averaged 39 percent greater to immatures. For the latter 6-year period, despite the small sample, banding age ratios were higher in more years than expected on the basis of a 50:50 chance occurrence at $P < 0.25$ (chi-square = 2.1, 1 df). Using the age ratio from the preseason banding, mallard populations present in Wisconsin during August and September which were thought to represent primarily locally breeding adults and their offspring, apparently had productivity rates slightly greater than the 1961-72 average for North America.

July pond numbers in the prairie-parkland regions of Canada were significantly correlated with the number of young mallards produced each year (Geis et al. 1969; Anderson and Henny 1972). In July of 1961, 1962 and 1968, less than 1 million ponds remained in these regions (U.S. Fish and Wildlife Service 1974). Continental production ratios were 0.6, 1.0 and 0.8 immatures:adult respectively (from Geis et al. 1969 and Sorenson et al. 1973), in those years reflecting the poor habitat conditions. Age ratios in Wisconsin, from both the adjusted wing data (0.4 young:adult) and the preseason-banded sample (0.5 young:adult), in 1961 were less than the continental value of 0.6 young:adult. Age ratio from adjusted wing survey data was 0.6 in 1968 and the banding age ratio was 0.5 in 1962. At least one of the Wisconsin productivity indexes did, therefore, drop to a lower level in each of the years with poor productivity in Canada.

Continental age ratios also dropped below 1.0 young:adult in 1964, 1970 and 1972; pond numbers were below the 1960-72 average in 1964 and 1972. However, age ratios from Wisconsin (both adjusted duck wing data and preseason banding) were 1.0 immature:adult or higher in those years (Martin and Carney 1977; Table 3), suggesting better productivity within the state than was found in the prairie-parklands.

In addition to the years already mentioned, Wisconsin age ratios were less than 1.0 immature:adult in 1963 (preseason banding only), 1966, 1967 and 1971 (adjusted wing survey data only, in the latter 2 years). Continental production ratios were either 1.0 or 1.2 in those 4 years and pond numbers were at or above the 1960-72 average for the prairie-parklands, indicating good habitat conditions.

Evidence that age ratios of preseason mallard populations in Wisconsin fluctuate independently from production rates in the prairie-parklands is conflicting. In two extremely dry years within the prairie-parklands (1961 and 1968) adjusted age ratios from the harvest in Wisconsin did suggest a corresponding decline in productivity of mallards associated with the state. However, since the preseason banding age ratio in 1961 was also reduced, productivity in Wisconsin may also have been affected by dry conditions. Except for 1961 and 1968, Wisconsin age ratios appeared to fluctuate independent of conditions on the major Canadian breeding grounds. In addition, adjusted age ratios from Wisconsin were not correlated with either the July pond index from the prairie-parklands ($r = 0.377$, 11 df, $P > 0.05$) or the continental production ratios ($r = 0.512$, 11 df, $P > 0.05$). These inconsistencies between productivity in Wisconsin and on the Canadian breeding grounds suggested that Jahn and Hunt's (1964) original conclusions regarding age structure of mallard populations contributing to the Wisconsin harvest and stability of habitat conditions within the state, with some modifications, are still valid. Overall, it appeared that productivity in any given year was slightly higher in North American populations than in all segments specifically associated with the Wisconsin harvest. High age ratios in the Wisconsin harvest did not entirely result from a fall flight that was largely immature birds (as suggested by Jahn and Hunt 1964, and implied later by Bellrose 1972) but instead reflected the relatively excessive vulnerability of young mallards to shooting while present in the state. The "actual" age ratio of mallard populations providing the Wisconsin harvest was less than 1.0 immature:adult in five of the 1961-72 hunting seasons and averaged only 0.9 immature:adult over the 12 seasons (Table 8). Populations present in Wisconsin during late August and early September, as reflected by 1967-72 preseason bandings, did have higher productivity than continental populations in the same years. The question of where does Wisconsin derive these migrant mallards having lowered productivity, must then be considered.

Since about 52 percent of the continental mallard population breeds in the "Prairie-Parkland Area" of south-central Canada (Pospahala et al. 1974), productivity rates from that region should generally approach the North American average of 1.1 immatures:adult. Age ratios obtained from adjusted wing data in Wisconsin, which reflect age structure of the harvested population, were less than 1.1, suggesting that the state must receive its migrant mallards from areas with lower productivity than the Prairie-Parkland Area overall, or that migrants are coming from segments of the prairie-parklands having lower productivity. Breeding population estimates from Pospahala et al. (1974:58-61) show that mallard populations in southeast Saskatchewan (Reference Area 05) and southwest Manitoba (Reference Area 06) underwent declines during 1955-59 and 1970-73. Populations in southwest Alberta and southwest Saskatchewan, the remaining two components of the prairie-parkland area (Reference Areas 03 and 04) have not shown this decrease in numbers (Pospahala et al. 1974:58-61). Sellers (1973) reported that mallards in the Minnedosa pothole region of southwest Manitoba had declined 50 percent between the 1950's and 1970. Mallard production was too low to sustain even a stable population. Low productivity was thought to result from insufficient nesting cover combined with severe nest predation (Sellers 1973). Minnesota production ratios for 1970-71 should have been 0.6 and 0.3 young:adult in the fall, assuming a 5 percent adult mortality between spring and fall (calculated from data in Table 6 of Sellers 1973:21). On the Redvers Study Area in southeast Saskatchewan, production ratios for the post-drought years of 1964-65 would have been 0.7 and 0.6 immature:adult respectively, again assuming 5 percent spring-fall adult mortality (data from Tables 27 and 29 of Stoudt 1971:45-47). Based on age ratios in preseason banded samples and age ratios from adjusted wing data, productivity in Wisconsin was higher than found in at least part of the Prairie-Parklands. Again, this conclusion agrees with Jahn and Hunt's (1964) hypothesis relating habitat stability in Wisconsin and its effect on productivity of local birds.

Jahn and Hunt (1964) had previously suggested that Wisconsin derived many of its migrant mallards from the forested regions of northern Canada, and Bellrose (1972) narrowed the origin of these birds to eastern Manitoba and Ontario. Wellein and Lumsden (1964) noted that waterfowl densities in the vast regions north and

Table 9. *Estimated production of young mallards in Wisconsin during 1965-66 and 1968-70, using 5 different methods of reproductive success.*

Year	# of Adult Breeders[a]	Reproductive Success[b] 30 Percent	46 Percent	Immature:Adult Ratio[c] Adjusted Wing Data	Preseason Banded Samples
1965	123,700	120,600	184,900	164,500 (1.4)	199,800 (1.7)
1966	103,400	100,800	154,600	88,400 (0.9)	68,800 (0.7)
1968	104,400	101,800	156,100	59,500 (0.6)	128,900 (1.3)
1969	127,600	124,200	190,800	121,200 (1.0)	254,600 (2.1)
1970	170,300	165,300	254,600	161,800 (1.0)	242,700 (1.5)
Mean	125,900	122,600	188,200	119,100	179,000

[a]Number of adult breeders present on May 1 with an assumed sex ratio of 1.0 males:female. Data from March et al. 1973.

[b]Number of females successfully fledging broods multiplied by an average brood size of 6.5 young.

[c]Number of adult breeders less 5 percent mortality (May 15 through October 1), multiplied by appropriate annual age ratio in parentheses (from Tables 3 and 7).

east of the fertile parklands and prairies were comparatively low (1-5 pairs per square mile), with mallards being the main breeding dabbling ducks. Dennis (1974) reported mallard breeding densities of 0.4-1.2 mallards per square mile respectively, for the Precambrian shield and clay belt regions of north-central Ontario. Although there were currently no "concrete" estimates of mallard productivity rates for northern Canada, Pospahala et al. (1974) presumed productivity was lower there than in "southern" Canada. Based on data in Sellers (1973) and, to some extent, in Stoudt (1971), productivity is also low in southwest Manitoba and southeast Saskatchewan. The limited available information suggests that Wisconsin is deriving its migrant mallards from populations with lower productivity; prime candidates would seem to be mallards from southwest Manitoba, southeast Saskatchewan and/or the northern forested regions of Ontario, Manitoba and Saskatchewan.

Differential Harvest in Wisconsin. Regardless of the geographical origins of their quarry, Wisconsin hunters have been differentially shooting immature and male mallards in proportion to their abundance in preseason populations. The age ratios of the Wisconsin mallard kill were always higher than the proportion of immatures in the preseason populations or in the preseason bandings. This was expected because of the greater vulnerability of young-of-the-year birds to shooting.

Sex ratios in the 1961-72 Wisconsin mallard harvest averaged 1.0 male:female for adults and 1.1 males:female for immatures (Table 8). In eight of the 1961-72 seasons (March 1976:318-319), adult males were shot in greater proportions than their representation in the preseason population (as based on adjusted wing data). When compared to the adult sex ratio in the preseason banding, adult males were shot in greater proportions in all of the 1961-72 seasons (March 1976:318-319). For immatures, males were shot in greater proportions than expected on the basis of the 1961-72 adjusted wing survey sex ratios, during 9 of the 12 seasons and greater than expected on the basis of the sex ratios from the preseason banding in all years (March 1976:318-319).

Brood Size and Preseason Age Ratios. Brood size should represent an index to annual variations in duckling survival. The survival of young would generally be a function of local weather and habitat conditions. In dryer years, the available habitat shrinks and losses to predation and other prefledging mortality should increase. Local contribution to the preseason population would be reduced accordingly. All-age brood size and adjusted wing survey age ratios were directly related (Fig. 4), suggesting that such a relationship did exist in Wisconsin.

Using the adult sex ratio from adjusted wing survey results (March 1976:319), the average 1961-66 fall age ratio was 1.9 immatures:adult female; the 1967-72 fall ratio was 1.5 immatures:adult female. Based on sex and age ratios taken from preseason banding (March 1976:319), the 1967-72 late summer age ratio should have been 2.1 immatures:adult female. Assuming that a minimum of 30 percent of the mallard pairs successfully rear broods to flying, at 6.5 ducklings fledged per brood, 2.1 immatures would be produced per adult female alive in the fall (with a 5 percent spring-fall loss of adults). This is identical to the late summer age ratio obtained in 1967-72, using preseason-banded samples. Jessen (1970) gave the higher ratio of 3.0 young per adult female for mallard populations in Minnesota. If 46 percent of the pairs in Wisconsin successfully fledged broods, 3.1 immatures per adult female would be the expected late summer age ratio. Comparable estimates of productivity are not available for continental mallard populations since the sex ratios of the spring breeding populations have not been established (Anderson and Henny 1972). In Wisconsin the spring sex ratio is assumed to be 1.0 male:female.

Number of Young Produced. Numbers of adult mallards in the 1965-66 and 1968-70 spring breeding populations, plus their associated production of Class III ducklings under 30 percent and 46 percent reproductive success are listed in Table 9. Average production was 122,600 and 188,300 young mallards respectively, for the 30 percent and 46 percent success rates (Table 9). These juveniles represented the estimated numbers of locally produced mallards available to hunters on the opening date.

When the reproductive rate was allowed to vary annually, using adjusted wing survey age ratios, the average mallard production in Wisconsin was only 3,500 fewer young than estimated with a fixed reproductive success of 30 percent and a brood size of 6.5 ducklings (Table 9). When age ratios from the preseason-banded samples were substituted as annual reproduction rates, the results most closely resembled values obtained using a fixed rate of 46 percent female success (Table 9). Average production of young was about 9,200 birds less than when the 46 percent rate was used.

Relationship of Productivity to Breeding Population. The 1965-66 and 1968-70 May breeding population estimates for mallards from March et al. (1973:9) were negatively correlated with Class III sizes of 6.7, 6.8, 6.9, 6.6 and 5.8 in those same years at $P < 0.05$ ($r = -0.956$, 3 df). All-age brood sizes, age ratios from preseason banding and age ratios from adjusted wing survey data were not correlated with the 1965-66 and 1968-70 breeding populations at $P = 0.05$.

A strong negative correlation between Class III brood size and breeding populations during 5 years suggests an inverse relationship between annual productivity and spring population size. Errington's (1945) principle of "inversity", where rates of summer population gain in bobwhite quail (*Colinus virginianus*) were lower when spring populations were higher, has not generally been attributed to waterfowl populations. However, Crissey (1969) indicated that when the number of breeding mallards per unit of breeding habitat was considered, inversity was important in affecting production ratios. Pospahala et al. (1974) suggest that production rates of many ducks, including mallards, breeding in North America appear to be regulated by both density-dependent and density-independent factors. Spacing mechanisms, in conjunction with habitat conditions, influence some ducks to overfly the primary prairie-parklands breeding grounds into less favorable habitats to the north and northwest where production rates may be suppressed. Production rate in the prairie-parklands, once this emigration has occurred, seems independent of density because the production rate appears to be a linear function of the number of breeding birds in the area (Pospahala et al. 1974). Production rate in northern Saskatchewan and northern Manitoba also appeared independent of density. While the long-term population and productivity indexes needed to examine inversity associated with Wisconsin birds are unavailable, Class III brood size was negatively related to the numbers of spring breeding adults during 5 years of survey.

Summary

Class III mallard broods averaged 6.5 ducklings in both 1950-56 and 1962-72, and were equal to or larger than average brood sizes reported from a majority of North American Production areas.

Age ratios from the 1967-72 preseason banding were slightly higher to immatures than the average North American production ratio. Although mallard age ratios obtained from the Wisconsin harvest were above average for the Mississippi Flyway, when these ratios were adjusted for the greater vulnerability of immatures in Wisconsin, the age ratio of populations furnishing the total Wisconsin harvest was less than the average production ratio for North America.

Mallard populations banded in Wisconsin during August and September apparently have higher immature:adult ratios than the overall population providing the state's harvest in October and November. An influx of migrant mallards, just prior to or during the hunting season, with an ratio of less than 1.0 immature:adult, would explain these differences in age structure.

If this is true, Wisconsin derives a majority of its migrant mallards from regions that are below the North American average in productivity. The alternative explanations would be: (1) a major exodus of immature mallards from Wisconsin during late September, or (2) a banded sample which was biased toward young birds.

A majority of the age ratio data from Wisconsin seemed to support the hypothesis that productivity in the state fluctuates independently from production in the prairie-parklands of Canada.

MOVEMENTS

Hickey (1951; 1956) considered band recoveries to be only crude indexes to the routes taken by migratory waterfowl, because ducks banded at a given location were more likely to be shot in that same general region in subsequent years than they would in other regions. Also, recoveries by hunters were only indicative of birds that came in contact with shooting and were therefore not representative of non-stop flights at "moderately" high altitudes (Hickey 1956). Clerical errors in reporting recoveries also influenced the distributions obtained. Both the spatial and chronological distributions of fall mallard populations associated with Wisconsin have important influences on the hunting losses incurred by birds reared in the state and also on the contribution made to the state's harvest by migrants.

GEOGRAPHIC DISTRIBUTION OF BAND RECOVERIES

Methods

All recovery locations from Wisconsin-banded mallards were summarized by computer into 10-minute blocks of latitude and longitude. The number of recoveries within 10-minute blocks were then summed by their respective degree-blocks and plotted on maps of North America provided by the U.S. Fish and Wildlife Service. Separate maps were plotted for each age and sex cohort and for direct and indirect recoveries (Append. A).

Results and Discussion

Distribution of Recoveries by Flyway. Over 70 percent of the recoveries from mallards banded in Wisconsin during 1950-72 occurred either within the state or in other states of the Mississippi Flyway (Figs. 5 and 6). The exact proportion coming from the Mississippi Flyway varied by period of banding, sex and age cohort, region of banding and the hunting season of recovery.

All direct recoveries from bandings in eastern Wisconsin during 1950-60 were in the Mississippi Flyway (Fig. 5). Over 90 percent of the direct recoveries from mallards banded in western Wisconsin during 1950-60 also came from the Mississippi Flyway.

In 1961-72, the Atlantic Flyway and Canada were the only regions outside the Mississippi Flyway that accounted for at least 1 percent of the direct recoveries from mallards banded in eastern Wisconsin (Fig. 5). Distribution of direct recovery for mallards banded in western Wisconsin was similar except in regard to the Central Flyway. From 1-2 percent of the direct recoveries from western bandings came in the Central Flyway, while less than 1 percent of the eastern-banded mallards was recovered there (Fig. 5). Also a smaller percentage of the direct recoveries from western bandings came in Canada.

About 20 percent of the 1961-72 indirect recoveries from mallards banded in eastern Wisconsin occurred outside the Mississippi Flyway; increases were primarily in the proportions coming from the Central Flyway and Canada (Fig. 6). Distribution of indirect recoveries from western bandings was similar to the indirect distribution for eastern cohorts. None of the locals banded in western Wisconsin were reported from the Atlantic Flyway, however (Fig. 6).

Distribution of indirect recoveries for mallards banded at two eastern Wisconsin sites during 1927-40 was: Mississippi Flyway 87.8 percent, Canada 8.6 percent (6.6 percent in Ontario and Manitoba), Atlantic Flyway 2.0 percent, Central Flyway 1.3 percent and Pacific Flyway 0.3 percent (Hickey 1956). In 1950-60, using recoveries from all regions of Wisconsin, about 70-90 percent of the indirects came in the Mississippi Flyway, 4-20 percent from Canada, 2-5 percent from the Atlantic Flyway, 0-4 percent from the Central and none from the Pacific (Figs. 5 and 6). More recently, 73-81 percent of the 1961-72 indirect recoveries came from the Mississippi Flyway, 6-8 percent from Canada and 3-12 percent, 2-18 percent and less than 1 percent, respectively, from the Atlantic, Central and Pacific flyways. Ranges of values represented percentages for the various sex and age cohorts at banding. Comparing the 1950-72 distributions to that of Hickey (1956), suggested a greater proportion of recovery in the Atlantic and Central flyways in recent years, with a slightly smaller percent occurring in the Mississippi Flyway.

Distribution of Recovery Within the Mississippi Flyway. Wisconsin represented *the single most important recovery area* for its banded mallards in 1950-72—importance of Wisconsin as a recovery site is considered later in this section.

Minnesota, Illinois, Michigan, Iowa, Ohio and Indiana accounted for 33-72 percent of the Mississippi Flyway's non-Wisconsin direct recoveries from Wisconsin-banded mallards in 1950-60 and 65-80 percent in 1961-72 (Table 10). Also, 49-50 percent of the 1950-60 non-Wisconsin indirect recoveries from the Mississippi Flyway came in these same six states. In 1961-72, the six states had 39-62 percent of the indirect recoveries from the Mississippi Flyway outside of Wisconsin. The percentages of indirect recoveries occurring in the six northern states from bandings in eastern and western Wisconsin were 15-28 percent and 20-33 percent, respectively. Thirty to 40 percent of the direct recoveries from western bandings came from the six states, compared to 10-19 percent from eastern bandings. Differences were mainly the result of a larger proportion of the western birds being recovered in Minnesota (March 1976:321).

In the southern Mississippi Flyway,

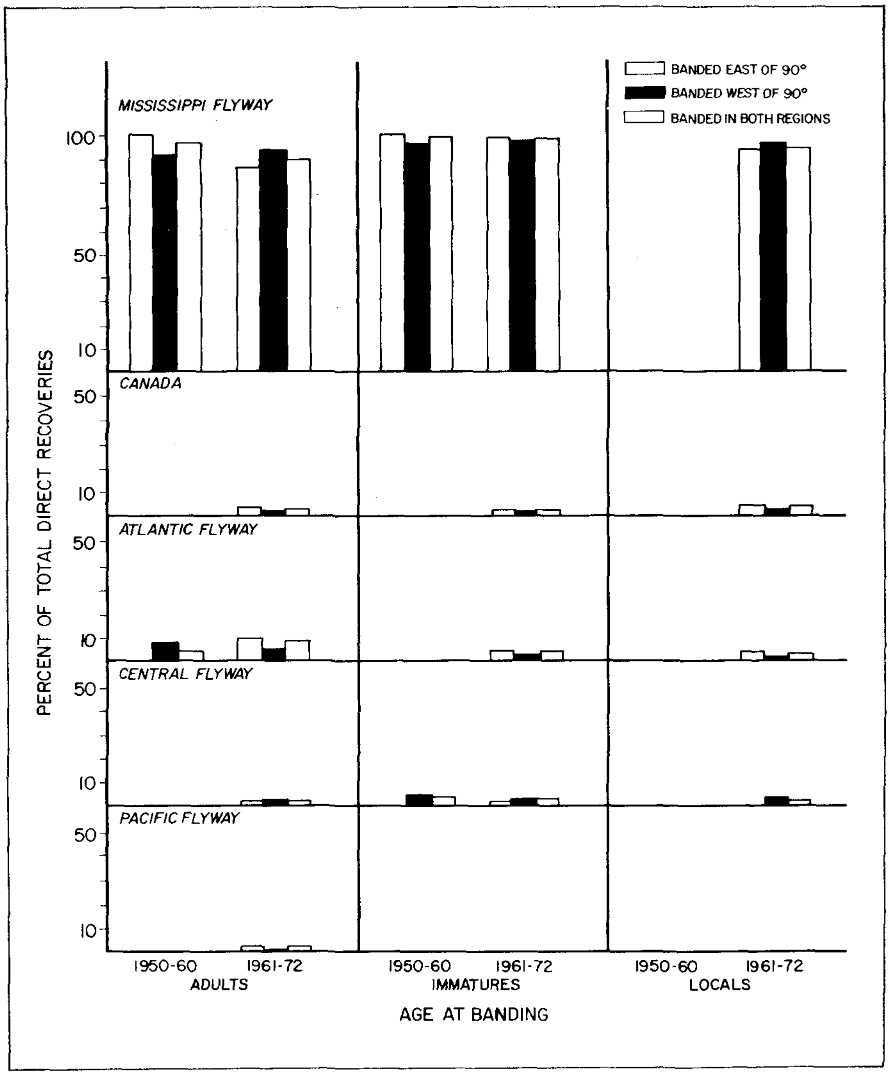


FIGURE 5. *Distribution of direct recoveries from mallards banded in two regions of Wisconsin during 1950-60 and 1961-72.*

Tennessee and Missouri were the only states that accounted for 3 percent or more of the total 1950-60 recoveries, including recoveries in Wisconsin (Table 10 and 11). In 1961-72, Tennessee, Arkansas and Louisiana were the only southern states in the Flyway that consistently had at least 3 percent of the total recoveries from more than one age cohort.

Outside Wisconsin, the major indirect recovery sites shown by Hickey (1956) for the northern Mississippi Flyway were Illinois with 26.9 percent of the total recovered and Minnesota with 15 percent; in the southern half, Louisiana, with 6.3 percent, and Arkansas, with 4.3 percent, were the two more important recovery areas. Only 1 percent of the 1927-40 mallards were recovered in Tennessee.

Throughout 1950-72, Illinois and Minnesota remained the most important northern, and overall, indirect recovery sites outside Wisconsin. Arkansas and Louisiana were also important southern indirect recovery areas, but Tennessee accounted for a greater proportion of the indirect recoveries for most cohorts than either of those two states (Table 11).

Major Recovery Areas Outside the Mississippi Flyway. The 4 non-Mississippi Flyway direct recoveries obtained in 1950-60 came from North Dakota, Maryland and Texas. Indirect recoveries came primarily from Manitoba, Ontario, North Dakota and South Dakota (Table 11). Scattered individual recoveries occurred in seven other states.

In the 1961-72 period, direct recoveries represented mainly potential wintering areas in the Atlantic Flyway (Table 10). The only other important direct recovery region was Ontario. For indirect recoveries, Atlantic Flyway states, North and South Dakota in the Central Flyway and the provinces of Ontario, Manitoba and Saskatchewan were the more important areas of recovery (Table 11). Indirect recoveries also were received from six other Central Flyway states and the province of Alberta. A few Pacific Flyway recoveries were obtained.

While the distribution of recoveries from Wisconsin-banded mallards should be fairly representative of the relative proportions of the hunting kill on these birds occurring in the various harvest areas, it gives no indication of the importance of the kill of Wisconsin mallards to the total kill in each harvest area. To estimate the importance of Wisconsin birds, recoveries must be weighted in relation to size of individual breeding populations and must be compared with the proportion of weighted recoveries occurring in a given harvest area that are derived from other breeding grounds. Geis (1971), using weighted direct recoveries, listed Wisconsin-banded mallards as the source of 5 percent or more of the 1966-68 hunting kill in the following states: Florida (13.7 percent), South Carolina (10.5 percent), Illinois (9.2 percent), Kentucky (6.8 percent), Michigan (6.6 percent), Virginia (6.5 percent), Ohio and Alabama (6.2 percent), Georgia and North Carolina (6.0 percent each) and Indiana (5.8 percent). Only 2 percent of the total juvenile and 8 percent of the total adult direct recoveries from mallards banded in Wisconsin occurred in the Atlantic Flyway during 1961-72, yet at least in the 1966-68 seasons, these birds made up important segments of the harvest in five of the 17 states in that flyway. Lensink (1964) concluded that Mississippi Flyway and Central Flyway mallards in general may contribute more to the kill of states from Chesapeake Bay on south, than did Atlantic Flyway mallards. By comparison, for Wisconsin bandings, 89-96 percent of the total direct recoveries came from the Mississippi Flyway but still only represented 5 percent or more of the 1966-68 harvest in six of its 13 states besides Wisconsin. The differences, of course, reflect the total numbers of mallards available in the two flyways. An average of approximately 3.3 million mallards wintered in the Mississippi Flyway during 1966-68, compared to only 196,000 in the Atlantic Flyway in those same years (from Geis 1971). On a relative basis, once they leave Wisconsin, mallards banded in the state would become more important to the Atlantic Flyway harvest areas than they would to those in the Mississippi Flyway.

No attempt was made to delineate the actual migration routes followed by mallards banded in Wisconsin. Recovery distributions did suggest however, that mallards banded in eastern Wisconsin had a greater tendency to be recovered in areas further east than those banded in western Wisconsin (Figs. 5 and 6, March 1976:321). The eastern birds apparently followed a

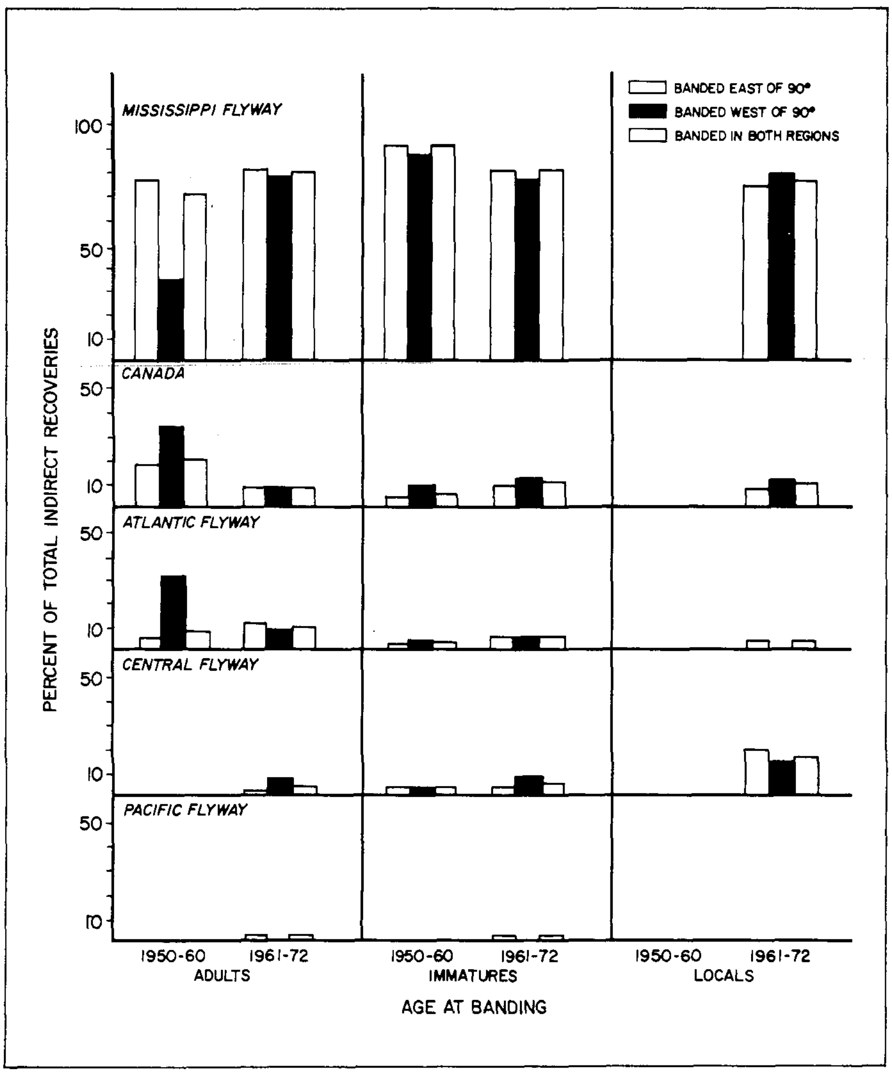


FIGURE 6. *Distribution of indirect recoveries from mallards banded in two regions of Wisconsin during 1950-60 and 1961-72.*

more easterly or southeasterly course after leaving Wisconsin. Mallards banded in western Wisconsin had a greater proportion of their recoveries occur within the Mississippi Flyway west of Wisconsin and also in the Central Flyway. These birds seemed to take either a more westerly or a more direct southern route after departing from Wisconsin (March 1976:321). The western cohorts appeared more closely associated with Bellrose's (1968) "Mississippi migration corridor" than mallards banded in eastern Wisconsin. Eastern birds showed some indication that a portion of their flights followed the Great Lakes and then turned south along the Atlantic coast, in addition to the "classic" route down the Mississippi River Valley. Lensink (1964) suggested that a flight reaches the Atlantic Coast by moving primarily through the Tennessee Valley. This path would further explain the importance of Tennessee as a recovery area for mallards banded in Wisconsin.

Table 10. *Distribution of direct recoveries from mallards banded in Wisconsin during 1950-72.*

Recovery Location	% of Total Direct Recoveries				
	1950-60		1961-72		
	Adults	Immatures	Adults	Immatures	Locals
Wisconsin	58.3	62.3	53.7	72.9	56.3
Minnesota		11.4	3.9	5.8	16.4
Michigan		1.4	3.7	1.0	3.0
Illinois	8.3	10.4	10.0	6.2	6.1
Iowa		1.4	1.0	2.7	3.5
Indiana	4.2	0.9	2.1	7.7	0.4
Ohio		0.4	2.1	0.4	0.4
Kentucky		1.8	1.4	0.7	0.9
Missouri		1.8	0.8	0.8	1.3
Tennessee	8.3	3.2	3.6	0.8	2.2
Arkansas		2.7	2.2	2.0	1.7
Mississippi		0.4	1.9	0.8	0.4
Alabama	4.2		1.1	0.6	0.4
Louisiana			1.3	0.8	0.4
	95.8	98.2	88.7	96.2	93.5
North Dakota		1.4	0.1	0.1	1.3
South Dakota			0.1	0.1	
Texas		0.4	0.2	0.2	
Oklahoma				Tr.	
	0.0	1.8	0.4	0.4	1.3
New York			0.6	0.2	0.4
Connecticut			0.1		
Delaware			0.1	0.1	0.4
New Jersey			0.1		
Pennsylvania			0.3	Tr.	
Virginia			1.0	0.3	
West Virginia			0.1	Tr.	
Maryland	4.2		1.0	0.2	
North Carolina			0.7	0.2	
South Carolina			3.0	0.8	0.9
Georgia			0.7	0.7	0.4
Florida			0.1	0.2	
	4.2	0.0	9.5	2.2	2.2
Ontario			2.4	2.1	2.6
Manitoba			0.1	2.1	0.4
	0.0	0.0	2.4	4.1	3.0
Other[a]	0.0	0.2	0.0	0.2	0.0
N =	24	1,433	220	3,120	228

[a]Pacific Flyway and "unknown" locations.

Wintering Areas of Wisconsin-Banded Mallards. Jahn and Hunt (1964) concluded that mallards present in Wisconsin during the fall spent the winter in the Mississippi Flyway, from Illinois on south, with some birds wintering on the south Atlantic coast. Hickey (1956) thought that mallards from eastern Wisconsin wintered mainly in Arkansas and Louisiana, with scattered birds reaching the Atlantic coast from Virginia to Florida. eastern Arkansas, western Tennessee, western Mississippi and northern Louisiana have since been considered the major wintering grounds for the main stream of mallards migrating through the Midwest (Bellrose and Crompton 1970). An analysis of the distribution of 1961-72 recoveries, using both direct and indirect recoveries weighted for differences in band report rates between states, of Wisconsin mallards in known wintering area states (March unpubl.), indicated that 19-27 percent occurred in Illinois, 12-15 per cent in Tennessee, 10-11 percent in Arkansas, 4-10 percent in Iowa, 6-7 percent in Ohio, 5-8 percent in Louisiana and 5 percent each in Mississippi and Alabama. The Atlantic Flyway accounted for 12-13 percent and the Central, 1-4 percent. These percentages still do not, however, reflect actual proportions of wintering birds, since they only showed that Wisconsin-banded mallards were present in an area long enough to be shot. Using weighted recoveries of mallards banded on various wintering areas, Geis (1971) estimated that Wisconsin derived 25 percent of its 1966-68 kill from mallards that wintered in Tennessee, 21 percent from Arkansas birds, 14 percent from those associated with Illinois, 11 percent from Missouri and 8 percent from Mississippi. Mallards wintering in Ohio, Alabama, Michigan and Kentucky accounted for an additional 6 percent, Atlantic Flyway wintering areas, 6 percent (4.5 percent collectively from North and South Carolina, Georgia and Florida) and Central Flyway states, 3 percent.

The five most important wintering grounds for Wisconsin mallards, based on Geis (1971), were Tennessee, Arkansas, Illinois, Missouri and Mississippi. These states also represented important harvest areas for Wisconsin birds since in 1950-60, 44-52 percent of the non-Wisconsin direct recoveries in the Mississippi Flyway came in the five states. In 1961-72, 37-53 percent of the non-Wisconsin recoveries came from those same states. The lowest values in 1950-60 were for adults and in 1961-72, for juveniles. In subsequent seasons, 45-67 percent of the non-Wisconsin 1950-60 Mississippi Flyway recoveries and 47 percent of those from 1961-72, were in the five states. Overall, just slightly less than one-half the Mississippi Flyway recoveries from Wisconsin-banded mallards, after they left the state, were obtained on the major wintering areas. These recoveries did not, however, necessarily all represent mallards that would actually have wintered in the state where they were recovered. Since the percentages of recoveries occurring in the wintering ground states did not change much between 1950-60 and 1961-72, the wintering area distribution of these birds apparently was not greatly different between periods.

Proportion of Recoveries Within Wisconsin. Wisconsin was the major recovery area for mallards banded in the state, with 53 percent of *all* recoveries reported during 1950-72 coming

Table 11. *Distribution of indirect recoveries from mallards banded in Wisconsin during 1950-72.*

Recovery Location	% of Total Indirect Recoveries 1950-60 Adults	Immatures	1961-72 Adults	Immatures	Locals
Wisconsin	40.0	41.2	32.3	34.4	30.4
Minnesota		7.2	7.0	6.3	5.1
Michigan		4.1	5.0	2.6	2.5
Illinois	5.0	4.1	9.8	10.6	3.8
Iowa		4.1	1.4	2.7	1.3
Indiana	5.0	1.0	3.1	1.8	1.3
Ohio	5.0	3.1	2.7	1.1	3.8
Kentucky		1.0	1.0	1.6	2.5
Missouri	5.0	5.2	1.1	1.6	1.3
Tennessee	10.0	5.2	4.8	3.9	7.6
Arkansas		3.1	3.9	5.0	3.8
Mississippi		4.1	2.3	2.6	2.5
Alabama		3.1	1.6	1.5	1.3
Louisiana		3.1	2.9	3.5	8.9
	70.0	89.7	79.1	79.5	75.9
North Dakota		2.1	1.8	2.5	7.6
South Dakota		2.1	0.5	1.8	5.1
Texas			0.1	0.6	
Kansas			0.1	0.1	1.3
Montana			0.1	0.1	
Oklahoma			0.1	0.4	
Nebraska			0.3	0.2	1.3
Wyoming				0.1	
	0.0	4.1	3.0	5.8	15.2
New York			0.6	0.2	
Connecticut				0.1	
Delaware			0.4	0.3	
New Jersey			0.2		
Pennsylvania			1.6	0.5	
Virginia			1.4	0.6	1.3
West Virginia			0.2	0.1	
Maryland			0.7	0.3	
North Carolina			1.0	0.8	
South Carolina	5.0	1.0	3.9	2.3	
Georgia		1.0	0.6	0.4	
Florida			0.4	0.1	
	5.0	2.1	11.2	5.6	1.3
Ontario	5.0	2.1	4.0	2.1	2.5
Manitoba	15.0	2.1	1.9	3.8	5.1
Saskatchewan			0.7	2.4	
Alberta			0.1	0.5	
	20.0	4.1	6.7	8.8	7.6
Other[a]	0.0	0.0	0.2	0.2	0.0
N =	20	97	1,755	1,438	78

[a]Pacific Flyway and "unknown" locations.

from within the state; 59-66 percent of the direct recoveries and 33-41 percent of indirect recoveries occurred in the state (Table 12). Direct recoveries of immatures and locals were responsible for a greater proportion of recoveries in Wisconsin during 1961-72 than found in 1950-60. A greater proportion of the 1950-60 indirect recoveries occurred in Wisconsin (Table 12).

Female mallards had a greater tendency to be recovered in Wisconsin than males during 1950-72 (Table 12). This was true for mallards recovered in both their first and subsequent hunting seasons and for all age cohorts. Percentages of females recovered in Wisconsin also declined in subsequent seasons.

Indirect recoveries probably represent the more reliable estimate of the geographic distribution of adult hunting kill as heavy shooting pressure in the immediate vicinity of the banding site is minimized after the first season. Using only indirect recoveries, about 41-56 percent of the hunting kill associated with the banded adult female cohort occurred in Wisconsin (Table 12). This percentage was slightly higher for 1950-60 than for 1961-72. For adult males, about 27 percent of the hunting kill in 1950-60 and about 17 percent in the 1961-72 came in Wisconsin.

By necessity, distribution of the hunting kill for juvenile mallards has to be estimated from direct recoveries. During the 1950's, 53 percent of the direct recoveries for immature males and 64 percent of those for immature females were in Wisconsin. Locals banded in 1961-72 also had 51 percent (males) to 65 percent (females) of their direct recoveries in Wisconsin. The proportion of 1961-72 direct recoveries occurring in Wisconsin from mallards banded as flying immatures increased for both males and females, however (Table 12).

Differences in hunting kill distribution between sex and age cohorts were examined further by comparing the mean annual percentages of recovery in Wisconsin during 1961-72 (Table 13). There were highly significant differences (P 0.01) between the mean proportions of recoveries in Wisconsin for adult males and females, immature males and females, adult and immature males (direct recoveries only) and adult and immature females. The overall test for differences showed that the mean percent of direct recovery in Wisconsin was significantly greater than the mean percent of indirect recovery.

The 1961-72 mean data also indicated that about 20 percent, 40-50 percent and 60-75 percent of the reported band recoveries for adult males, adult

Table 12. *Percent of total recoveries of Wisconsin-banded mallards that occurred within the state.*

Years Banded	Adults Male	Adults Female	Adults All	Immatures Male	Immatures Female	Immatures All	Locals Male	Locals Female	Locals All	Overall
Direct:										
1950-60	50.0	58.8	56.0	52.9	64.0	58.0	-	-	100.0	58.8
1961-72	44.5	58.2	53.6	70.9	74.9	72.9	50.8	64.6	56.3	66.3
Indirect:										
1950-60	27.3	55.6	40.0	33.3	51.1	41.8	-	-	-	40.8
1961-72	16.6	41.3	32.3	19.1	49.0	34.4	17.1	43.2	30.4	33.3

(Age and Sex at Banding)

females and juveniles, respectively, came from Wisconsin (Table 13).

Recovery Within the 10-Minute Block of Banding. Overall, about 20 percent of the 1950-72 recoveries of mallards banded in Wisconsin were reported from the same 10-minute block of latitude and longitude as their original banding site. The percent of adult recoveries in the 10-minute block was over twice as great in 1950-60 as in 1961-72 (Table 14). For immatures and locals, a slightly greater proportion of recoveries was obtained in the 10-minute block during 1961-72. In most instances, highest levels of recovery within the 10-minute block were obtained during the first hunting season after banding. These higher values reflect the heavy shooting pressure associated with several of the banding locations. In the first season, there was less difference between sexes in the percent recovered within the 10-minute block than during subsequent seasons (Table 14). Adults banded in 1950-60 had the greatest differences.

In subsequent hunting seasons, females were from two to six times more likely than males to be recovered back within the original 10-minute block of banding (Table 14). Between 25-35 percent of *all* female recoveries from 1950-60 bandings and 13-27 percent of those from 1961-72 occurred within that block. The highest rate of "return" in subsequent seasons, judged by indirect recoveries, to the 10-minute block of banding was 56 percent of the adult females banded in 1950-60. During 1961-72, 9 percent of the adult females and 14-15 percent of the juvenile females, now also adults, were recov-

Table 13. *Mean proportions of annual recoveries of Wisconsin-banded mallards that occurred within the state during 1961-72.*[a]

Age and Sex at Banding	Direct Recoveries	Indirect Recoveries
	Mean Proportion of Annual Recoveries Occurring in Wisconsin	
Adult Male	.458	.170
Adult Female	.549	.386
Immature Male	.695	.198
Immature Female	.747	.486
Locals	.605	-
	Differences Between Mean Values	
Ad. Male - Ad. Female	**	**
Ad. Male - Im. Male	**	NS
Ad. Female - Im. Female	**	**
Im. Male - Im. Female	**	**
All Cohorts	**	**

[a]Represents only recoveries from mallards banded in Wisconsin during 1961-72.

* = significantly different at $P \leq 0.05$

** = significantly different at $P \leq 0.01$

NS = non-significant at $P \leq 0.05$

Table 14. *Percent of total recoveries of Wisconsin-banded mallards that occurred within the original 10-minute block of banding.*

Years Banded	Age and Sex at Banding									
	Adults			Immatures			Locals			
	Male	Female	All	Male	Female	All	Male	Female	All	Overall
Direct:										
1950-60	36.5	23.5	28.0	21.8	25.0	23.3	-	-	-	23.6
1961-72	17.9	17.7	17.8	31.7	32.4	32.1	13.6	15.7	14.5	26.9
Indirect:										
1950-60	9.1	55.6	30.0	11.8	25.5	18.4	-	-	-	20.0
1961-72	4.1	8.7	7.0	3.8	14.5	9.2	2.6	15.4	9.0	8.0

ered within the 10-minute block in subsequent seasons (Table 14).

Recovery Within the Degree Block of Banding. The degree block of banding, next to the 10-minute block, was the smallest geographic unit of interest when considering recovery distributions. About one-third of *all* recoveries occurred within the degree block of banding. Again, females tended to be recovered in greater proportions than males (Table 15). The percent of direct recoveries coming within the degree block of banding was most similar for males and females banded as flying immatures.

During subsequent seasons, females were recovered in the degree block two to ten times more frequently than males (Table 15). In subsequent seasons, about one-fifth to one-third of the indirect female recoveries came from the degree block. The exception was adult females in 1950-60 when over 50 percent of their recoveries occurred in the degree block of banding (Table 15). Approximately 17-27 percent of all indirect recoveries came from the degree block of banding.

The portion of the adult kill associated with Wisconsin, as reflected by the percent indirect recovery in Wisconsin, declined between 1950-60 and 1961-72 bandings (Table 16). For the adult male segment of the population, the percent recovered in Wisconsin went from about 30 percent to less than 20 percent. Similarly, over 50 percent of recoveries from adult females, the cohort assumed to represent the mainstay of the Wisconsin breeding population, banded in 1950-60, came in Wisconsin. Since 1960, less than 50 percent of the indirect adult female recoveries were obtained in the state.

The percentages of juveniles recovered in Wisconsin have remained approximately equal or have increased since 1960 (Table 16). At least half the juvenile recoveries were reported from Wisconsin in both banding periods.

Table 15. *Percent of total recoveries of Wisconsin-banded mallards that occurred within the original degree block of banding.*

Years Banded	Age and Sex at Banding									
	Adults			Immatures			Locals			
	Male	Female	All	Male	Female	All	Male	Female	All	Overall
Direct:										
1950-60	36.5	52.9	48.0	42.0	41.0	41.6	-	-	-	42.0
1961-72	28.9	35.2	33.1	48.6	50.8	49.7	28.0	43.8	34.6	44.0
Indirect:										
1950-60	9.1	55.6	30.0	19.6	34.0	26.5	-	-	-	26.7
1961-72	9.4	21.6	17.2	8.4	26.9	17.7	2.6	28.2	15.4	17.4

Table 16. *Distribution of recoveries of Wisconsin-banded mallards within the state.*

	Adults[a]				Juveniles[b]	
	Males		Females			
	1950-60	1961-72	1950-60	1961-72	1950-60	1961-72
% of Total Recoveries Occurring in Wisconsin	27-33	17-19	51-56	41-49	53-64	51-75
% of Total Wisconsin Recoveries Occurring in the Degree Block of Banding	34-59	15-57	66-100	52-65	64-79	55-68
% of Recoveries Within the Degree Block of Banding that Come From the 10-Minute Block of Banding	60-97	44-100	75-100	40-55	52-61	36-65

[a]% of indirect recoveries for mallards banded as adults, flying immatures and locals. Combines data from Tables 13, 14 and 15.

[b]% of direct recoveries for mallards banded as immatures and locals, both sexes combined. Combines data from Tables 13, 14 and 15.

Distribution of the Harvest Within Wisconsin. Because of their greater vulnerability to shooting, young ducks showed an inflated kill rate within their home state or province (Hickey 1951). In the 1927-40 period, 27-51 percent of the direct mallard recoveries from eastern Wisconsin occurred within a 50-mile radius of the banding site (Hickey 1956). Immature mallards banded at Horicon during 1949-51, had 43 percent of their recoveries come from within 0-20 miles of the banding site (Hunt et al. 1958). The proportion from within the 20-mile radius was over twice as high in the first year after banding. Wisconsin accounted for 79 percent of the direct recoveries and 45 percent of the indirect of these mallards. In Hickey's (1956) study, 27 percent of the indirect recoveries (both sexes combined) occurred in Wisconsin. Since 1950, over one-half of all recoveries reported for Wisconsin-banded mallards have been from the state. The proportion recovered in the first year was always greater than in subsequent years and was significantly higher for juvenile birds. The 58-59 percent of direct juvenile recoveries occurring in Wisconsin during 1950-60 was less than the 79 percent reported by Hunt et al. (1958), but in 1961-72, 73 percent of the immature direct recoveries were reported from Wisconsin.

Neither the 10-minute block of banding or the degree block of banding conformed to Hunt et al.'s (1958) 20-mile radius, or Hickey's (1956) 50-mile circle. However, in 1950-60 and 1961-72, the 35-50 percent of direct recoveries of immatures and locals falling within the degree block of banding was similar to levels of recovery within the vicinity of banding that were reported in the two earlier studies.

Anderson and Henny (1972:57) list the percentages of direct and indirect band recoveries of local mallards that occurred within the state or province of banding during 1950-69. Percentages of direct recoveries for males within individual "reference areas" of banding ranged from a low of 38.7 percent of those from southeastern Saskatchewan to a high of 72.5 percent of the males banded in eastern Minnesota and eastern Iowa, averaging 52 percent. For local females the low and high percentages of direct recoveries within the reference area of banding were 41.2 percent in southeastern Saskatchewan and 68.8 percent in eastern Minnesota and eastern Iowa, averaging 55 percent overall. The proportion of Wisconsin local females recovered within the state, 64.6 percent, was higher than the average for the eight reference areas, but Wisconsin males were recovered at a lower rate, 50.8 percent.

The original intent of Anderson and Henny's (1972:57) Table 7 was to compare the percent of recovery within the reference area of banding between cohorts banded as locals and as flying immatures. Similar proportions within the reference area were considered as indicative that the samples of flying immatures were also mallards which had been produced in that reference area. In Wisconsin, for the 1950-60 banding, 58 percent of the direct immature recoveries came from Wisconsin and 100 percent of the banded locals were recovered there. For indirect recoveries, proportions occurring in Wisconsin were 42 percent for flying young and 75 percent for locals. During 1961-72, immature females banded preseason had 8.3 percent more of their direct recoveries in Wisconsin than did local females (Table 12). Twenty percent more immature male recoveries than local male recoveries occurred in Wisconsin. Indirect recoveries were very similar in their occurrence in Wisconsin between immature and local cohorts. Less than 1 percent more of the immature males and 1.9 percent more of the immature females were recovered in Wisconsin. Proportions of adult and local direct and indirect recoveries in Wisconsin were very similar also (Table 12). Locals had about 6 percent more direct recoveries in Wisconsin and about 0.5-1.9 percent more of their indirect recoveries occurred there. Average differences in the percent recovery in Wisconsin were +9.5 percent between locals and flying immatures and -3.8 percent between locals and adults. Comparing overall recovery distributions (Figs. 5 and 6), both locals and immatures had similar proportions of their recoveries in the Mississippi Flyway, 94 and 96 percent, and were both slightly more likely to occur there than adults. Judging the differences in recovery distribution by Anderson and Henny's (1972) criteria, at least part of the immatures banded in Wisconsin would probably not represent local production, but instead entered the state during the preseason banding period. Flying immatures banded in North and South Dakota and in Minnesota also were not all locally produced mallards as judged by their recovery distributions (Anderson and Henny 1972).

An alternative explanation for differences in the proportion of local and immature recoveries that were reported in Wisconsin would be that heavy shooting pressure in the vicinity of the preseason banding site was responsible for the greater proportion of recovery in the state noted for immatures. Table 14 showed that the percent of the 1961-72 immature direct recoveries occurring within the 10-minute block of banding was almost twice as great as the percent of local recoveries occurring there. Percentages of adult direct recoveries occurring in the 10-minute block also were not similar to those for locals—18 percent for adult males and females compared to 14 percent for local males and 16 percent for local females. In subsequent seasons, adult males and juvenile males had similar proportions of their recoveries in the 10-minute block, but adult females were recovered there only one-half as frequently as juvenile females.

Comparison of percents recovered in the degree block of banding (Table 15) gave a different series of relationships. Immatures had 7-21 percent more of their direct recoveries come from the degree block of banding than did locals. But in subsequent seasons, 27 percent of the indirect immature female recoveries were in the degree block of banding and 28 percent of indirects from females banded as locals also occurred there. Only 3 percent of the local male indirect recoveries were in the degree block of banding compared to 8 percent for those banded as immatures. Adult females were still not recovered in proportions as great as immatures and locals, and adult males had about the same percent in the degree block as immature males.

Higher first-season shooting rates in the vicinity of banding, rather than differences in breeding ground origin, seemed to be capable of producing the differences in recovery distribution within Wisconsin for cohorts banded as flying immatures and locals. Immature samples are apparently still primarily Wisconsin-reared mallards. Although the proportion of adult female and local female indirect recoveries occurring in Wisconsin are quite similar, the distribution of harvest within the state was different. While the preseason-banded cohort of adult females seemed to represent at least 50 percent hens that nested in Wisconsin, intrastate preseason movements were suggested. The large concentrations of adult female mallards found at the Horicon and Crex Meadows banding sites were probably good indications of post-nesting movements into large wetland complexes. A logical reason for these movements would be to spend the molt period in a more secure habitat. Because of the wandering behavior of males, and the tendency for males to select breeding grounds of their mates, it is actually of little significance whether preseason-banded drakes are Wisconsin's local birds or not. Although there is some suggestion of homing by yearling males (Lensink 1964), indirect recoveries of males in Wisconsin did not show it to be very strong here.

Anderson and Henny (1972) summarized evidence for movements by mallards between reference areas during the preseason banding period and there seems to be little doubt that such interchange does occur. Mallards banded in Wisconsin as flightless locals during June and July have been recaptured at August and September preseason banding sites both within and outside the state. A local male mallard banded on July 14, 1969, at 44°20'-90°10', was accidentally killed in preseason trapping operations at Collins Marsh, 44°00'-87°50', on September 9, 1969, or a distance of about 120 miles (74.5 km) almost straight east. Another local male, banded on Butternut Lake, 45°50'-90°30', on July 16, 1970, was retrapped on September 2, 1970 at Horicon, over 180 air miles (112 km) to the southeast. Not all movements covered as long a distance however. A second Butternut Lake local, a female banded August 8, 1972, was recaptured at the Pershing Wildlife Area, 45°10'-90°50', on September 28, 1972.

A local female mallard banded July 31, 1968 on Clam Lake, 45°40'-92°10', was captured 37 days later along the Mississippi River on the Iowa shore somewhere near Cassville, Wisconsin at 43°20'-91°10', or over 200 miles (124 km) farther south. A Butternut Lake male, banded July 15, 1970, was trapped again in Michigan on September 24 at 43°40'-83°30'. It may be just coincidental, but all of the retrapped locals were mallards hatched on marshes in central or northwestern Wisconsin and all were recaptured farther south or east in September.

Additional movement information suggested that larger waterfowl management projects in Wisconsin attracted mallards produced in other regions of the state. These movements into the major projects took place sometime between fledging and the opening of the hunting season. Three female mallards banded as locals in the summer of 1970 at Grand River, Horicon and Butternut Lake were all shot on the Mead Wildlife Area during the October 3, 1970, opening. The Horicon and Grand River birds had to travel northwest about 80-100 miles (50-62 km) from their natal marshes to reach Mead. The Butternut Lake female had traveled about the same distance southeast. Also in 1970, mallards banded as locals on Grand River and Rush Lake were shot the same fall at Horicon. These birds had to travel only about 20-25 air miles (12-15 km) however. Other examples of local mallards moving into the larger projects during the first fall after banding included: (1) a local male banded at Germania Marsh on July 22, 1969, which was shot at Horicon on October 5, 1969; (2) a Collins Marsh local banded July 28, 1971, and shot at Horicon on November 7, 1971; and (3) two locals from Butternut Lake, banded August 3 and August 8, 1972 respectively, the first of which was recovered at Collins Marsh the same fall (date unknown) and the second at Mead on October 7, 1972. It is also of interest that three locals, all banded on Butternut Lake, either on August 3 or August 8, were shot or recaptured the same year on three different state waterfowl projects, each being further southeast or east of the other.

Relationship Between Overall Recovery Rate and Recovery Rate in the Vicinity of Banding. The potential effect on locals by heavy shooting pressure at or near the natal marsh was tested by comparing direct recovery rates with proportions of first-season recoveries obtained from the 10-minute and degree blocks of banding. Overall direct local recovery rates from nine degree blocks, 43°-88°, 43°-89°, 44°-87°, 44°-89°, 44°-90°, 44°-91°, 45°-90° and 45°-92°, were compared with the proportion of direct recoveries within each degree block and within the 10-minute block of banding. None of the "r" values were significant at $P < 0.05$. Direct recovery rates for the five easternmost degree blocks were significantly correlated with the percent recovered in each degree block at $P < 0.10$ however. Similar comparisons, using direct recovery rates from individual local banding sites listed in Table 6, did not yield any additional relationships at $P < 0.10$.

Summary

Depending on the sex and age cohort of interest, 89-96 percent of the direct recoveries and 76-80 percent of the indirect recoveries from Wisconsin-banded mallards occurred in the Mississippi Flyway. Fifty-four to 73 percent and 30-34 percent of all direct and indirect recoveries, respectively, came within Wisconsin. Mallards banded in western Wisconsin tended to be recovered in more westerly locations than birds banded in eastern Wisconsin.

Minnesota, Illinois, Michigan, Indiana and Ontario were the more important non-Wisconsin recovery areas in the upper Mississippi Flyway. Tennessee, Arkansas and Louisiana were the more important recovery states in the lower Mississippi Flyway. The latter 3 states, plus Illinois, Missouri, Mississippi and South Carolina, appear to be the major wintering areas for mallards associated with Wisconsin.

Within individual age cohorts, female mallards were recovered in Wisconsin with greater frequency than males. Based on indirect recoveries which are less biased by heavy first-year shooting pressure in the vicinity of banding sites, 40-50 percent of the adult female hunting losses (recoveries) came in Wisconsin. Within Wisconsin, 50-65 percent of the adult and 55-70 percent of the juvenile female recoveries came from the degree-block of banding. About half of these degree-block recoveries came near the original banding site (10-minute block of banding).

August-September recaptures of flying mallards, banded as flightless young in June, July or August, suggest both intra- and inter-state movements of young birds during the preseason banding period. Also, at least a small segment of locals were attracted to major waterfowl management projects (Mead, Horicon Marsh, Collins Marsh) after fledging on other marshes.

WISCONSIN RECOVERIES OF MALLARDS BANDED ON THE MAJOR BREEDING GROUNDS OF CANADA AND THE UNITED STATES

Methods

Recoveries from mallards banded on breeding grounds outside Wisconsin but recovered within the state were summarized by both degree block of banding and degree block of recovery. The original degree block of banding was used to identify production areas contributing mallards to the Wisconsin harvest. Only hunting season recoveries of normal, wild-caught mallards, banded between June 1 and September 30, were included. Direct and indirect recoveries for both sexes were combined by age-at-banding cohorts.

To further delineate production areas from outside Wisconsin, degree blocks of banding in the regions north of 42°00' latitude that contributed one or more hunting season recoveries to the state were identified. Distribution of preseason and local banding efforts within these outside breeding grounds was obtained from maps in Anderson and Henny (1972:25-27) and is shown on Figure 7. Although our data covered the years 1950 through 1972, the maps from Anderson and Henny (1972) only included bandings accomplished during 1950-69. The addition of new degree blocks of banding after 1969 was assumed to be minimal. Also, Anderson and Henny (1972) did not show male and female degree blocks of banding on separate maps. Only recoveries from female mallards banded between June 1 and September 30, or males banded as flightless young and recovered in their first hunting season are presented numericaly on Figure 7. We considered the female data to be more representative of the breeding ground origins of recovered birds. Wisconsin data and investigations elsewhere (e.g. Anderson and Henny 1972) have indicated that males have a greater tendency to wander from one region to another, especially after becoming adults. Maps in Anderson and Henny (1972) should, however, be representative of the banding effort within the designated degree blocks despite their combined data for both sexes. Most degree blocks should have banded samples of both males and females of a particular age cohort.

A more precise delineation of the breeding ground derivation of non-local mallards recovered in Wisconsin would require that the recovery data also be weighted for both differences in population size and the proportion of the population banded. Data used to prepare recovery maps and distribution tables in this section were not weighted accordingly. Geis (1971) did this for continental mallard populations, using banding and population data from 1966-68. His data for Wisconsin were re-calculated to include only the major breeding grounds furnishing banded mallards to the state and excluding Wisconsin recoveries of mallards banded in the state. Although Pospahala et al. (1974) lists weighting factors for adult mallards during the 1955-73 preseason periods, corresponding information on the numbers of mallards banded each year were not available from the literature.

Results and Discussion

Distribution of Unweighted Recoveries. Table 17 lists the number and unweighted percentages of recoveries in Wisconsin from mallards banded on the major breeding grounds of Canada and the United States during 1950-72. Manitoba, Minnesota and Saskatchewan, in order of decreasing percent of total recoveries, furnished the largest proportion of adults, and Minnesota, Michigan, Ontario and Manitoba, the largest proportions of juveniles.

Distribution of Weighted Recoveries. Proportions of weighted band recoveries, re-calculated from data in Geis (1971) but using an average 1966-68 Wisconsin breeding population of 104,000 mallards, showed that locally produced birds furnished 67 percent of the recoveries in the state (Table 17). Ontario, Minnesota and Manitoba, followed by South Dakota and Michigan, were the more important non-Wisconsin sources of banded mallards. Almost 26 percent of the recoveries (excluding Wisconsin-banded birds) were from mallards banded in Ontario. Minnesota and Manitoba furnished 18 percent and 17 percent, respectively.

Breeding Ground Origins of Banded Migrants. During 1950-72, mallards banded in two Ontario degree blocks southwest of James Bay were recovered in Wisconsin (Fig. 7). All other recoveries from degree blocks east of Wisconsin originated from bandings in Michigan and Ohio, or from along Lake Erie, Lake Ontario and the St. Lawrence River. Wisconsin recoveries of mallards banded in western United States breeding grounds all originated from degree blocks east of 103° latitude. Mallards banded in western Canada and recovered in Wisconsin came mainly from the region lying between 50° and 53° latitude and 95° and 110° longitude (Fig. 7). Although mallards were also banded as far north as Great Slave Lake, no females or local males (first season recoveries) were reported shot in Wisconsin. Only three of 36 banding degree blocks in Alberta yielded recoveries in Wisconsin. Mallards were banded in 11 additional degree blocks lying north of 60° latitude that were not included in Figure 7. None of these blocks provided female or local male recoveries in Wisconsin during 1950-72.

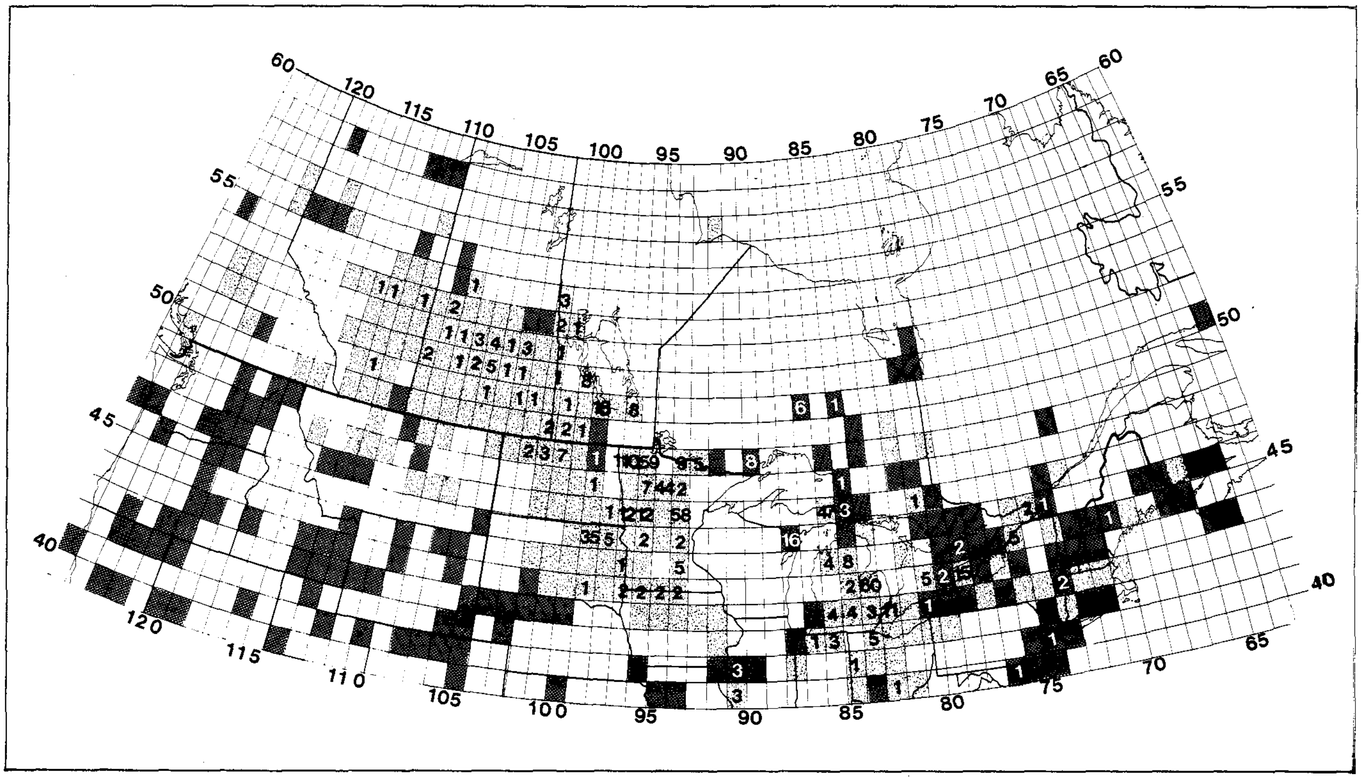


FIGURE 7. *Degree blocks of banding in the major breeding grounds of North America that contributed one or more mallard band recoveries to Wisconsin during 1950-72. Numbers indicate total recoveries of females in Wisconsin (birds banded between June 1 and September 30) from bandings within that block, plus any direct recoveries of males banded as flightless young. Light-shaded blocks had one or more mallards banded in them as flightless young during 1950-69 (Anderson and Henny 1972:25-27); dark shaded blocks had one or more flying mallards banded in them during the preseason periods of 1950-69 (Anderson and Henny 1972:25-27).*

Table 17 *Origins of mallards banded on the major breeding grounds of Canada and the United States and recovered in Wisconsin.*[a]

Location of Banding	% of Total Recoveries: Adults 1950-60	Adults 1961-72	Juveniles 1950-60	Juveniles 1961-72	% of 1966-68 Weighted Recoveries[b]: Wisconsin Recoveries Included	Without Wisconsin
Wisconsin	-	-	-	-	66.9	-
Quebec				1.1		
Ontario	1.0	4.8	3.6	18.3	8.5	25.8
Michigan	8.6	7.4	24.8	26.5	3.1	9.4
Minnesota	32.4	44.8	39.6	42.6	5.8	17.7
Manitoba	35.2	10.1	12.8	4.0	5.7	17.1
South Dakota	4.8	12.0	3.6	1.8	3.8	11.6
North Dakota	2.8	11.5	3.2	1.4	2.3	7.0
Saskatchewan	13.3	7.9	9.6	3.7	2.3	7.1
Alberta	1.0	1.2	1.6	0.6	1.4	4.3
Northwest Terr.	1.0	0.2	1.2			
	100.1	99.9	100.0	100.0	99.8	100.0
N =	105	417	250	727	1,066	172

[a]All recoveries are from hunter-shot, wild-caught mallards banded between June 1 and September 30.

[b]Calculated from data in Geis (1971), pages 13, 14, 16, 17, 47 and 55.

Jahn and Hunt (1964), from information available through 1961, concluded that Wisconsin lay northeast of the main flight of mallards originating in eastern Alberta, Saskatchewan and southwest Manitoba. The eastern fringe of that flight crossed southwest Wisconsin, but only minor flights passed through other regions of the state.

Lensink (1964) concluded that along any given longitude, ducks produced further north tended to be harvested farther to the east than ducks produced farther south. Banding locations in Figure 7 tend to support such a conclusion although the relationship is not clearly demonstrated. Recoveries (in Lensink 1964) from the extensive 1950-61 local mallard banding efforts in the prairie-parkland regions and other major breeding grounds of Canada and the United States showed little evidence of any major influx of mallards to Wisconsin. Percentages of total direct recoveries occurring in Wisconsin ranged from zero for MacKenzie N.W.T. and southwest Alberta mallards; 0.1-0.9 percent for southeast Alberta, southwest and southeast Saskatchewan, southwest Manitoba birds; and 1.0-3.9 percent of the total Manitoba, North Dakota, South Dakota and Minnesota recoveries. No recoveries were recorded from Ontario-banded locals (Lensink 1964) although Table 17 and Figure 7 suggest otherwise. Northern Saskatchewan, northern and eastern Manitoba and much of Ontario have previously been identified as the most logical sources of migrant mallards coming to Wisconsin. Although those particular regions represented 56 percent of the 1961 North American mallard breeding population index, they were represented by only 0.1 percent of the total local mallard recoveries reported in Lensink (1964). The lack of mallard banding in the northern regions of Saskatchewan and Manitoba and western Ontario which support 15-25 percent of the continental breeding population is a serious gap in the study of the species in North America (Anderson and Henny 1972).

Tables A-1 and A-2 of Anderson and Henny (1972: 129-164) listed the following Canadian reference areas as having at least 3 percent of their 1950-69 mallard recoveries, both direct and indirect, occur in Wisconsin: northern Saskatchewan-MacKenzie N.W.T. (2-3 percent); northern Manitoba-southwest Keewatin N.W.T. (14-15 percent); and western Ontario (10-12 percent). All of these areas were included in the region that was poorly represented by banded mallards. United States areas having at least 3 percent of their recoveries from Wisconsin were: western Minnesota (5-6 percent); western Iowa (3-5 percent); eastern Minnesota-eastern Iowa (11-13 percent); and Michigan-northern Ohio-Indiana (6-8 percent).

Although the recovery data in Table 17 suggested that North and South Dakota were among the more important sources of mallards harvested in Wisconsin, only 1.3 percent of the North Dakota and 1.7 percent of the South Dakota recoveries reported by Lensink (1964) and 1-2 percent of those North Dakota and 2-3 percent of those for South Dakota listed in Anderson and Henny (1972) occurred in Wisconsin. Kuck (1974) credited Wisconsin as the recovery state for 2.5 percent of the adult mallards banded at Sand Lake NWR in eastern South Dakota, 0.5 percent of those banded at Lake Andes NWR in southeast South Dakota and none from bandings in the "High Plains" region of South Dakota.

The "main stream of mallards migrating to the Midwest arises in central Saskatchewan and assumes a southeasterly course primarily to the Mississippi River, secondarily to the Illinois River" (Bellrose and Crompton 1970). These birds winter largely in eastern Arkansas, western Tennessee, western Mississippi and northern Louisiana. Seven of the mean lines of indirect mallard recoveries for the Mississippi migration corridor crossed the extreme southwest corner of Wisconsin, coming from southeast Minnesota and northeast Iowa (Bellrose and Crompton 1970). Although the deviations from several of the mean lines extended into southeast Wisconsin, only two sites, Delta Marsh and McGinnes Slough, had their deviation lines extended as far east as 43°-88°, the degree block which included the greatest numbers of recoveries in Wisconsin (Figs. 4 and 5 of Anderson and Henny 1972:23-24).

An additional means of determining the origins of mallards coming into Wisconsin was by comparison with recovery distributions from breeding ground bandings in each of the four neighboring states. Minnesota, Iowa and Illinois had greater percentages than Wisconsin of the local mallard recoveries from all Canadian and "tri-state" (North Dakota, South Dakota and Minnesota) banding areas listed in Lensink (1964). Michigan, conversely, accounted for either a smaller percentage of the recoveries from each region or had about the same percent as Wisconsin. With the exception of southwest Alberta and northern Saskatchewan-southeast MacKenzie, N.W.T., Minnesota, Iowa and Illinois all had greater percentages of the recoveries from female mallards banded in western Canadian reference areas listed in Table A-2 of Anderson and Henny (1972). Wisconsin received a greater percentage than either Iowa or Illinois recoveries from western Ontario and eastern Ontario-western Quebec reference areas. Percentages occurring in Michigan were generally lower than or equal to those for Wisconsin. For United States breeding grounds, Wisconsin obtained smaller percentages of recoveries than Minnesota, Iowa and Illinois from all reference areas in Montana, the Dakotas and other western states (Anderson and Henny 1972:148-164). Wisconsin recovered a larger proportion than Iowa of the females banded in western Minnesota. Also, more eastern Iowa band recoveries came in Wisconsin than in Illinois and more eastern Minnesota-eastern Iowa recoveries occurred in Wisconsin than in either Iowa or Illinois. For mallards banded in reference areas east of Wisconsin, the percent recovered in the state was generally higher than the percent from Iowa or Illinois and equalled or exceeded the percent taken in Minnesota. Michigan had a smaller percentage of recoveries from reference areas west of Wisconsin but a greater proportion of those coming from eastern reference areas. These data seem to indicate that the origins of migrant mallards to Wisconsin are more similar to those for Michigan and more easterly states than to areas contributing migrants to Minnesota, Iowa and Illinois.

Changes in Origins of Banded Migrants. Percentages of recoveries in Wisconsin from various outside breeding grounds were somewhat different in 1961-72 than in 1950-60 (Table 17). When considering differences in recovery distributions, however, the potential effect of changes in banding sites or effort must be recognized. Shifts in locations of banding, changes in numbers banded at a location and the addition of banding in new areas with no previous samples, could all effect the sources of mallards recovered in Wisconsin. None of these changes would represent actual changes in population status or migratory patterns.

The scarcity of recoveries from Ontario and northeastern Manitoba probably resulted from only a few mallards being banded in those areas in comparison to other locations, rather than a less significant flight of birds into Wisconsin. The absence of banded samples in the region west from James and Hudson Bays to Lake Winnipeg and further northwest is obvious from Figure 7.

Minnesota and Michigan were both important sources of *banded* mallards in both 1950-60 and 1961-72 (Table 17). Since these states are Wisconsin's immediate neighbors and both have extensive banding programs, considerable exchange of banded mallards between all three states would be expected.

The 1966-68 weighted recoveries indictated a greater importance to mallards from Ontario, Manitoba, South Dakota, Alberta, North Dakota and Saskatchewan than suggested by the raw percentages of 1961-72 total recoveries. Lesser importance was accorded by weighted recoveries to Minnesota and Michigan birds. Those two states both have relatively large banded samples, as does Wisconsin, in relation to the sizes of their breeding mallard populations. No recoveries of mallards banded in Quebec or the Northwest Territories apparently were reported in Wisconsin during 1966-68 (Table 17).

Summary

A review of the available banding information, some dating back to the 1930's and 1940's (in Bellrose and Crompton 1970), suggested that Wisconsin almost certainly gets a much smaller volume of mallards coming out of the prairie-parkland areas of Canada and from the prairie nesting areas of the United States, than do neighboring states to the west and south. There was no published evidence that Wisconsin ever did receive a larger proportion of these prairie-reared mallards than has occurred in recent years. Although supporting banding data are very limited, the "major" flight of migrants coming into Wisconsin each fall apparently originates in the northern forested regions of eastern Saskatchewan, Manitoba and from Ontario, plus additional birds which enter the state from southwest Manitoba, southeast Saskatchewan, Minnesota, Iowa and Michigan. A few birds also originate in breeding areas east and southeast of Wisconsin. The one exception to this general pattern would be the southwest corner of Wisconsin which apparently does intercept at least a segment of the Mississippi migration corridor. Birds using that flight line probably are restricted primarily to the Mississippi River.

CHRONOLOGY OF HUNTING SEASON BAND RECOVERIES

Methods

All 1950-72 hunting season recoveries of mallards banded and recovered in Wisconsin were summarized by the year, month and day recovered. The 1961-72 data were combined into 5- and 7-day periods of the Wisconsin duck hunting season.

The distribution and chronology of hunting season recoveries for mallards banded as locals in Wisconsin during 1961-72 were determined by 7-day periods during September 15 - January 13. Locals were the only cohort considered in the analyses of temporal and geographic distribution of harvest in order to reduce biases created by the high recovery rates associated with the immediate vicinity of preseason banding sites. Locals, which were banded from late June through early August (before August 15), had 50 to 60 days in most instances to disperse prior to the Wisconsin hunting season opening. Also, locals were banded at least one month or more before the first seasons opened in southern Canada.

The 1950-72 Wisconsin recoveries of mallards banded north of 43°00' latitude and west of 80°00' longitude or banded north of 50°00' latitude at all longitudes, were summarized by year, month and day. Wisconsin-banded birds were excluded from these data. The 1961-72 data were also combined into 7-day periods of the Wisconsin duck hunting season.

Results and Discussion

Recovery Chronology of Mallards Banded in Wisconsin. Twenty-five percent of the mallards banded and recovered in Wisconsin during 1961-72 were reported taken on the opening day; 35 percent occurred within the first 2 days and 52 percent came within the first 7 days (Table 18). Percentages of recoveries from within that period were generally higher for juvenile cohorts. Except for the cohort banded as locals, recovery percentages within the first 7 days of hunting were similar between sexes, with females being taken at a slightly higher level than males. Over 90 percent of the recoveries from all cohorts

Table 18. *Chronology of hunting season band recoveries for mallards banded and recovered in Wisconsin.*

Period of the Duck Season	% of Total Recoveries in Wisconsin — Age and Sex at Banding: Males Adult	Males Imm.	Males Local	Females Adult	Females Imm.	Females Local	All Cohorts
Opening Day	18.6	28.7	33.3	15.3	28.7	24.6	24.9
1st 2 days	25.7	40.1	46.7	25.3	39.5	36.2	35.4
1st 7 days	41.4	55.8	61.7	43.7	56.6	59.4	52.4
1st 14 days	56.8	71.6	75.0	63.4	73.7	78.3	69.6
1st 21 days	71.8	82.8	83.3	78.6	85.0	87.0	81.9
1st 28 days	85.0	90.9	91.7	89.0	92.7	94.2	90.7
1st 35 days	92.1	97.4	95.0	95.7	97.3	97.1	96.5
1st 42 days	97.8	99.3	98.3	98.9	99.6	100.0	99.2
1st 49 days	99.6	99.9	100.0	99.9	99.9	100.0	99.9
1st 56 days	100.0	100.0	100.0	100.0	100.0	100.0	100.0
# Recovered	280	1,096	60	829	1,314	69	3,650[a]

[a] Includes 2 locals, sex unknown.

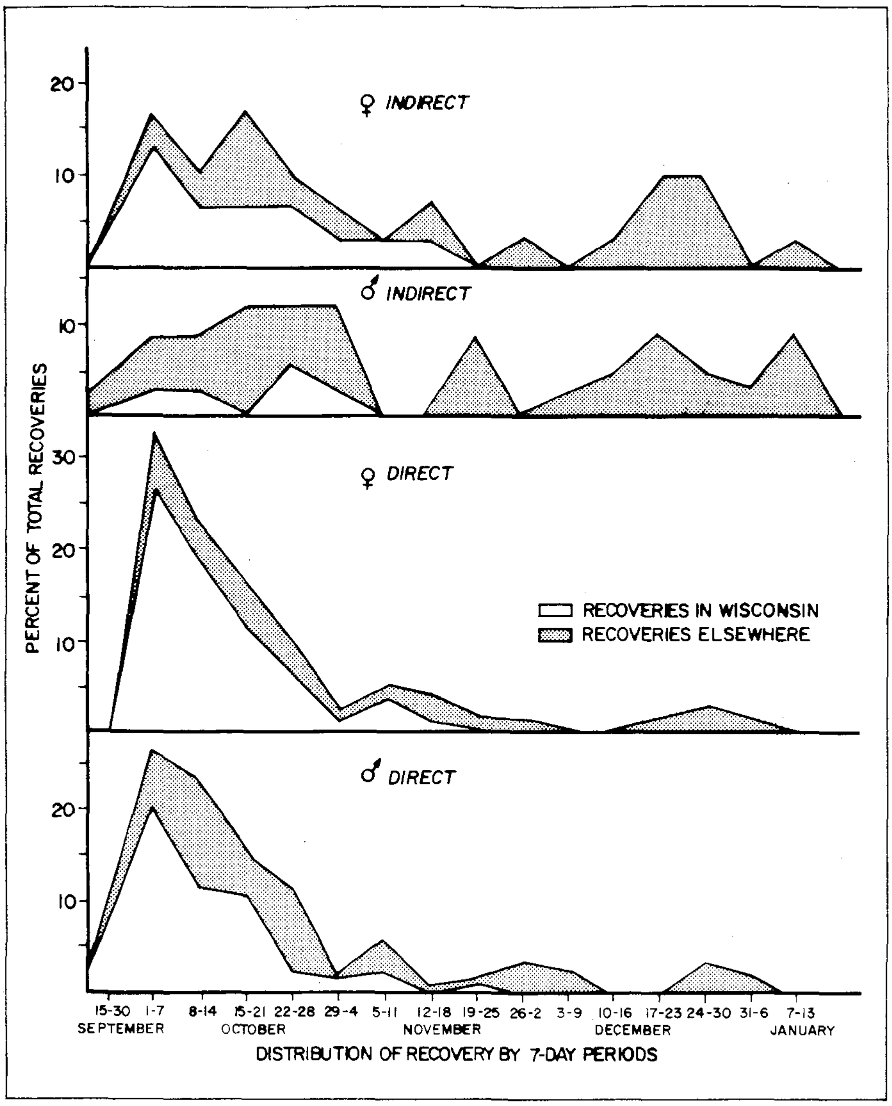


FIGURE 8. *Chronology of recoveries from mallards banded as flightless locals in Wisconsin during 1961-72.*

were reported within the first 35 days of the season. The 1961-72 season length averaged about 40 days.

For locals, a larger proportion of female direct recoveries occurred earlier in October than males, and a smaller percentage of the females were recovered outside Wisconsin (Fig. 8). Fifty-five percent of all local females were recovered prior to October 15, as compared to 50 percent of all males. Only 18 percent of the females recovered before October 15 were taken outside Wisconsin. Prior to October 15, thirty-two percent of the males were taken elsewhere. No females were reported recovered before October 1, but a few males were recovered in Canada during late September, suggesting northward emigration from Wisconsin after fledging.

Non-Wisconsin recoveries for a given 7-day period represented their greatest proportion of the season totals for both males and females during October, even though after November 25, all recoveries came from outside the state (Fig. 8). The maximum proportion of the total season recoveries occurring outside Wisconsin in a single 7-day period was 9.9 percent for local males between October 8-14. For both sexes there was a slight increase in non-Wisconsin recoveries in late December and early January. This peak undoubtedly represented the later opening dates in states of the deep south. These peaks were more pronounced for indirect recoveries.

Indirect recoveries of locals, now all adults, showed that only about 5 percent or less of the total season recoveries for males occurred in Wisconsin during any 7-day period (Fig. 8). A greater proportion of total male recoveries was taken outside Wisconsin during all periods. Females, conversely, had an indirect recovery distribution and chronology similar to that during the first year (Fig. 8). Fifty-three percent of indirect female recoveries are reported prior to October 29, and 63 percent of these occurred in Wisconsin. For males, only 44 percent of the total indirect recoveries came before October 29, with about one-fourth coming from Wisconsin. Also, no male recoveries were reported from the state after November 11, but females were still being taken until the end of the season. The non-Wisconsin recovery distributions in December and January were quite similar between sexes (Fig. 8). Except for the small peak in late December or early January, patterns for both males and females were somewhat different than suggested by direct recoveries.

Jahn and Hunt (1964:113) found that one-fifth to one-half of the seasonal duck kill on many areas in Wisconsin took place the first 7 days of hunting, with an average of 32 percent occurring in the first 2 days. Mallard wing receipts from Wisconsin indicated that 40-60 percent of the harvest occurred by October 15, with about 30 percent coming in the first 2 days (Smith 1975). Jessen (1970) reported that over 60 percent of the band recoveries from local mallards in Minnesota came before October 15, and only a few were taken after November 1 because most marshes in the state were frozen or had frozen at least once by that date. Local mallards were still recovered in Wisconsin during late November (Fig. 8) even though freezeup over much of the state usually came prior to November 15 and the bulk of the ducks have left by that date (Jahn and Hunt 1964).

Longer seasons did not seem to reduce the proportion of mallards shot early in the season. The 1961-72 percentages of banded mallards recovered on opening weekend in Wisconsin or within the first 7 days (Table 18) were not correlated with duck season length at $P < 0.05$ (r values were 0.372 and 0.376, respectively). Seasons in excess of 50-55 days would seem to contribute little hunting opportunity in most years to the majority of Wisconsin duck hunters. Although Jahn and Hunt (1964) found hunting pressure on opening weekend and early in the season was less in years with 70 days of hunting opportunity, only a small part of the total hunting effort occurred in the latter days of the season. Less than 5 percent of the total duck bag came after 50 days of hunting (Jahn and Hunt 1964:113).

Chronology of Wisconsin Recoveries of Mallards Banded Elsewhere. Mallards banded outside Wisconsin tended to be recovered in smaller proportions within the first 7 days of hunting than birds banded in the state (Table 19). The proportion of non-Wisconsin, i.e. "foreign" mallards recovered early in the season was lowest for bandings from 50° latitude and further north. After the first 7 days of hunting, the proportions of recoveries occurring within a given period were similar for both foreign and Wis-

Table 19 *Percent of mallard band recoveries during weekly periods of the 1961-72 Wisconsin hunting seasons by region of banding.*

Days of the Duck Season	Adults			Juveniles		
	Wisconsin[a]	50°[b]	50°[c]	Wisconsin[a]	50°[b]	50°[c]
Opening Day	16.1	9.1	8.4	28.7	11.4	11.8
Days 1 - 2	25.4	15.7	14.1	39.8	20.8	17.6
Days 1 - 7	43.1	29.2	19.7	56.3	35.9	23.5
Days 8 - 14	18.7	20.1	22.5	16.5	20.5	25.0
Days 15 - 21	15.1	19.0	18.3	11.3	14.1	13.2
Days 22 - 28	11.1	14.6	11.3	7.8	13.9	11.8
Days 29 - 35	6.8	10.2	16.9	5.5	7.9	10.3
Days 36 - 42	3.8	5.1	8.4	2.1	4.7	13.2
Days 43 - 49	1.2	1.8	2.8	0.5	2.2	2.9
Days 50 - 56	0.2	0.0	0.0	0.1	0.7	0.0
	100.0	100.0	100.0	100.0	100.0	100.0
# Recovered	1,109	274	71	2,410	404	68

[a]Mallards banded in Wisconsin.

[b]Mallards banded outside Wisconsin, south of 50° latitude but north of 43° latitude and west of 80° longitude.

[c]Mallards banded outside Wisconsin, from 50° latitude, and further north.

consin-banded mallards until the fourth through the sixth week. During the fourth through the sixth week, juveniles banded outside Wisconsin were recovered in 1.3 to 6.5 times greater proportions than state birds (Table 19). Also, foreign adults were recovered in 1.2-2.4 times greater proportions than Wisconsin birds during the fifth and sixth weeks. Cumulative proportions of total recoveries from both Wisconsin and foreign bandings were about equal after 42 days of hunting.

Within the first 14 days of the season, between 62-73 percent, depending on age cohort, of the total recoveries in the state of Wisconsin-banded mallards had occurred. Only 49-56 percent of the foreign mallards banded south of 50° and 42-48 percent of those banded at 50° or further north, were recovered in the state within that same period (Table 19). Fourteen to 21 percent of the foreign recoveries came during the first 2 days of the season as compared to 25-40 percent of the recoveries of Wisconsin-banded mallards (Table 19). Figure 9 also suggested that during 1961-72, foreign-banded mallards were not present, or at least were not recovered, in Wisconsin to any great extent until about the October 6-10 period. Over 17 percent of the Wisconsin-banded cohort had already been shot within the October 1-5 period. After the first 5 days of October, trends in the 1961-72 recovery chronology were similar between Wisconsin- and foreign-banded mallards (Fig. 9).

Jessen (1970) suggested that since mallards reared in Minnesota, which were the last to leave that state in the fall, had a tendency to remain close to their natal area, they became especially vulnerable to hunters. Mallards banded as flying immatures in northern Minnesota, which may have included migrant birds from Canada, usually left the state before locally-reared birds did. Although Wisconsin's local mallards remained in the state throughout the duck season as evidenced by recoveries in Wisconsin until the end of the season, over 80 percent of the Wisconsin kill of banded birds had already taken place before the season was barely half over, assuming an average of 40 days of hunting during the 1961-72. Only about 60-70 percent of the migrant recoveries had occurred by that time. The late-season mallard harvest in Wisconsin apparently includes a larger proportion of birds that originated from other breeding grounds than the early-season harvest. Whether this resulted because most of the locals still alive had already left Wisconsin (Fig. 8 did not particularly suggest that this occurred) or because those surviving had become less vulnerable to shooting is not known. In any case, the popular "concept" that a majority of local birds are burned out early in the season and that hunters must then rely on whatever flight of migrants comes along, may be realistic in Wisconsin.

Chronology of Recovery In Different Banding Periods. The hunting season chronologies of all mallards banded and recovered in Wisconsin during 1950-60 and 1961-72, are compared in Fig. 9. Insufficient recoveries were available from 1950-60 for comparison of separate sex and age cohorts. The peak 5-day recovery period during 1961-72 was about 5 days earlier than in 1950-60, even though the mean opening date was 3 days earlier in the latter period. Only 22 percent of the 1950-60 recoveries came during October 1-10, even though the opening date fell within that period in 9 of the 11 years considered. During 1961-72, 9 of 12 opening days came between October 1-10 and 38 percent of the total recoveries (Fig. 9) also occurred in those 10 days.

Effect of Opening Date on Chronology. In 1961-72, the percentages of total recoveries from Wisconsin-banded mallards that occurred in the state on opening day, and the percentages of the total Wisconsin recoveries of foreign-banded mallards occurring on opening day, were negatively correlated ($r = -0.708$, $P < 0.05$). A negative correlation, significant at $P < 0.05$, was also obtained between the two variables for the first 2 days of hunting

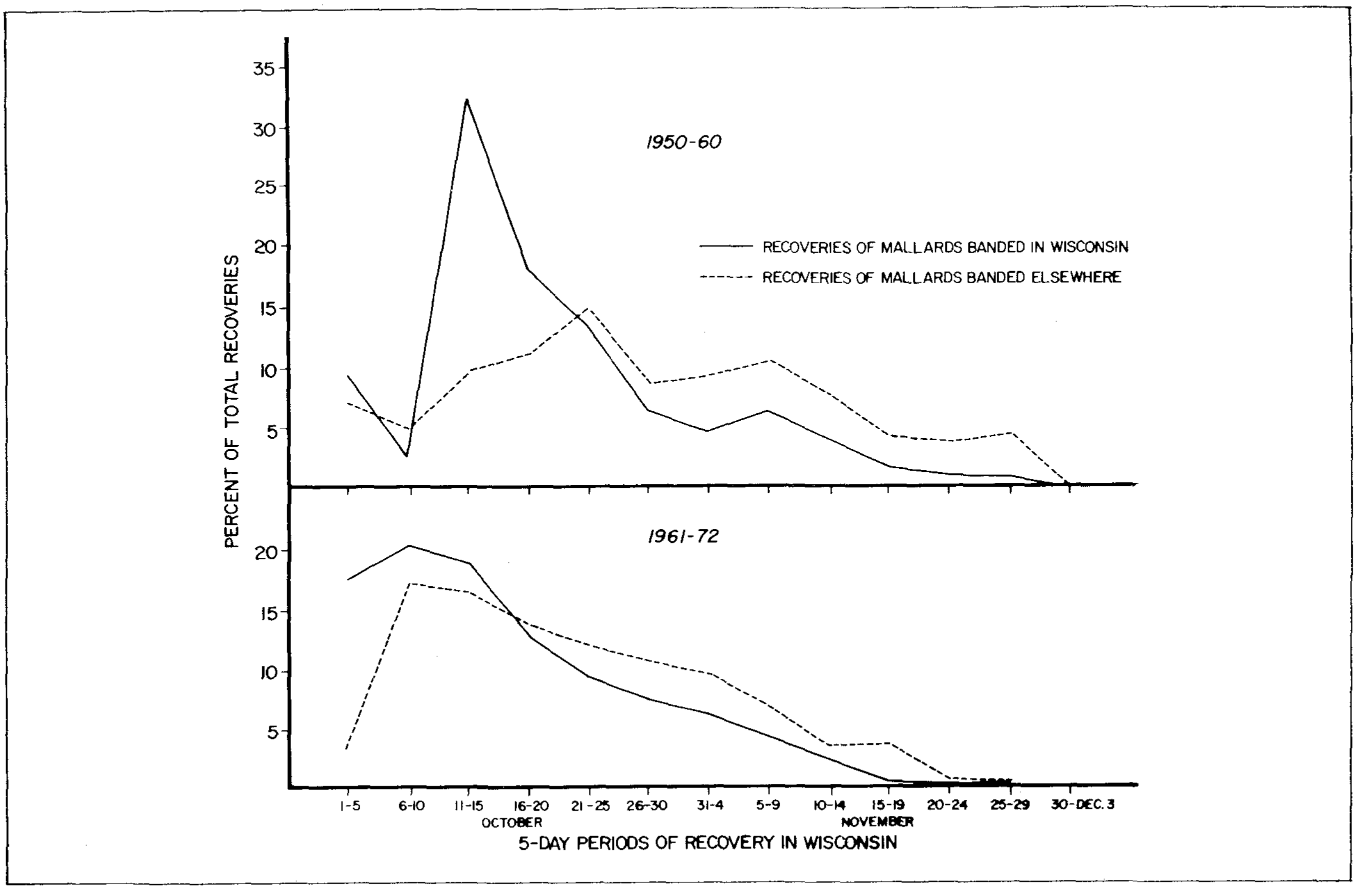


FIGURE 9. *Comparison of recovery chronologies in Wisconsin from mallards banded in the state and on the major outside breeding grounds during 1950-60 and 1961-72.*

(r = -0.705) but not after 7 days, (r = 0.437) or the remainder of the season. A greater harvest of migrant mallards, based on chronology of band recoveries, during the first 2 days of hunting apparently was associated with a reduced proportion of Wisconsin-banded birds being shot. However, the percentages of foreign recoveries in the state that occurred on opening day and thereafter were not correlated with the 1961-72 calendar opening dates at $P < 0.10$. The annual 1961-72 percentages of mallards banded and recovered in Wisconsin, excluding samples and recoveries associated with the Horicon NWR, on the opening day of the duck season also were not significantly correlated with the calendar opening dates in the state ($r = .384$, $P > 0.05$). Despite the apparent absence of a direct relationship between calendar date of opening and the proportions of migrants or state-banded mallards recovered in Wisconsin on that day, if the state's opening was designed to specifically take greater advantage of migrant mallard populations, openings should be delayed at least until after October 5. Harvest of other species, e.g. wood ducks and teal, may have a greater impact on selection of opening date, however.

Peak recovery periods for foreign-banded mallards were between October 6-15 in 1961-72, after which time the percentage of recoveries within a 5-day period was only slightly greater than the percentage of Wisconsin-banded birds being recovered (Fig. 9). The percentage of recoveries from mallards banded in northern Canada suggested an even later influx of birds from these areas. Highest percentages of adults were recovered in the 8-14 day period of the Wisconsin season and also in the 29-35 day period (Table 19). Wisconsin recoveries and recoveries from more southern breeding grounds peaked in the 1-14 day period. For juvenile mallards, days 1-14 were the highest recovery periods for birds banded in all areas, but the peak percentage for juveniles from northern Canada was still in the 8-14 day period. Less than 30 percent of the recoveries from Wisconsin-banded mallards and also from those banded in southern Canada, etc., came after the first 21 days of the state's season, compared to about 40 percent of those banded in northern Canada. This would suggest that a slightly later opening might result in a harvest that included a greater proportion of mallards from the areas assumed to furnish a majority of the migrants into Wisconsin.

Recoveries of foreign-banded mallards in Wisconsin during 1950-60 showed two peak periods which might have indicated influxes of migrants into the state. One occurred between October 21-25 and the second, between November 5-9 (Fig. 9). There were no indications of similar peaks in the 1961-72 recovery data. The percent of foreign recoveries peaked between October 6-10 and declined steadily thereafter.

Effect of Bag Limits on Recovery Chronology. During 1961-72 there was only one opportunity to assess the impact of additional opening weekend protection (i.e. reduced bag limit) on recovery chronology. In 1972, the daily bag limit in Wisconsin was 4 mallards, but for the first two days of the season, the daily bag was limited to not more than 1 female mallard. Although restricting the take of females successfully reduced the proportion shot on the first 2 days, there was little evidence that it reduced the total season's hunting losses.

Fourteen percent of adult female mallard recoveries occurred within the first 2 days of the 1972 season. This was 68 percent less than the 1961-71 average of 43 percent, and was 63 percent less than the percentage obtained in the first 2 days of 1971. The adult male recoveries in the first 2 days of 1972 was 26 percent higher than in 1971. Percentage of female recoveries occurring in the first 2 days of 1972 was the lowest recorded during 1961-72. The 1 hen restriction also reduced the percentage of immature females recovered within the first 2 days, but less drastically than found for adult females. Immature female recoveries in 1972 within the first 2 days was 46 percent below the 1961-71 average and 44 percent less than the same percentage in 1971. The immature male recoveries within the first 2 days of 1972 also decreased 6 percent from 1971. Hunters may have been more reluctant to fire at the less colorfully plumaged immature males under the 1 hen restriction. The 1972 percentage of immature females recovered on the first 2 days was the third lowest recorded during 1961-72.

Female mallards banded on the Horicon NWR which already were being recovered in lesser proportions early in the season when compared to the statewide value (March 1976:146-147) showed no major difference in the percentage of recoveries occurring within the first 2 days of the 1972 season. Apparently the restrictive bag limit on hens had little effect on populations that already were somewhat protected from heavy shooting during early parts of the season.

While shooting pressure on females during the first 2 days did decline, and shooting pressure on males either increased or declined to a lesser rate, overall recovery rates for males during the entire season actually declined more than rates for adult females. Recovery rates in Wisconsin for adult and immature female mallards declined 17 percent and 58 percent respectively, between 1971 and 1972, but Wisconsin recovery rates for adult and juvenile males for which the bag limit was 4 birds, each also declined 58 percent in 1972.

Summary

Thirty-five percent of the direct recoveries from mallards banded and recovered in Wisconsin occurred on the first 2 days of the state's duck season; 52 percent occurred during the first 7 days. Female mallards were recovered in slightly greater proportions than males during the first 7 days of hunting. Longer seasons did not reduce the proportion recovered in the first 2 days or during the first 7 days. Also, the calendar date of the opening was not related to the percent recovered during the first 2 days. Based on indirect recoveries, which are less biased by excessive shooting in the vicinity of banding, local female mallards were shot in Wisconsin throughout the duck season, i.e. not all locals had migrated out of Wisconsin before the season ended.

Mallards banded outside Wisconsin tended to be recovered in smaller proportions during the first 7 days of hunting in the state when compared to Wisconsin-banded birds. After 7 days of hunting in the state, 43-56 percent of the recoveries from Wisconsin-banded mallards had occurred compared to only 29-36 percent of the recoveries from mallards banded on other breeding grounds south of 50° latitude and 20-24 percent of the recoveries from breeding grounds north of 50° latitude. This suggests that the mallard harvest in Wisconsin after the first week or two of hunting contained a greater proportion of migrants than the first week's harvest. As the percent of mallards banded elsewhere but recovered in Wisconsin during the first 2 days of hunting increased, the proportion of recoveries from Wisconsin-banded birds during those 2 days decreased. After the first 2 days this relationship was not found. Considerable evidence suggests that a season opening in Wisconsin after October 5 would harvest a greater proportion of migrant mallards.

Reducing the daily bag limit on female mallards for the first 2 days of the 1972 Wisconsin duck season reduced the proportion of females recovered during those 2 days but did not reduce overall hunting season losses. A restriction of the daily bag limit for the first 14 days of hunting should be effective in reducing overall hunting losses.

HUNTING LOSSES AND SURVIVAL RATES

"Hunting is responsible for a significant fraction of the total deaths of mallards," but "precise estimates of kill rates are difficult to make because of the uncertainties regarding band reporting rates and crippling loss in each area" (Anderson 1975:23). An average of 3.5 million mallards have been harvested in the United States since 1955 (Anderson and Henny 1972). Since mallards account for a greater proportion of the duck harvest in Wisconsin than any other species, hunting deaths incurred by local mallard populations should also represent an important source of mortality on these birds. To adequately manage mallard populations associated with Wisconsin, their rate of hunting kill, its distribution and total mortality must be measured. Assuming that hunting losses can represent "additive" mortality if they become excessive, i.e. above the as yet to be quantified "threshold" point of Anderson and Burnham (1976), effective means of controlling the harvest must also be applied. The role of hunting regulations on mallard harvest in Wisconsin, plus the interactions of related factors such as numbers of hunters or days of activity must also be considered. Of major importance to management alternatives would be the identification of the proportion of the Wisconsin harvest which is derived from locally breeding mallards. Estimating the percent contributed by local birds is the ultimate objective of this section and the investigation in general.

RATES OF HARVEST AND TOTAL HUNTING KILL

Methods

Harvest Rate. The standard method (from Geis 1972) of deriving harvest rates from band recoveries employs an average estimate of band reporting rate to adjust direct recovery rates for non-reported bands. Band report rates for mallards in the United States have declined from about 50 percent in the early 1950's to approximately 30 percent in the 1960's (Anderson and Henny 1972). In the Mississippi Flyway, the report rate was about 50 percent in 1954-56, 40-50 percent in 1958-60 and about 28-30 percent in the 1960's (from Anderson and Henny 1972). Wisconsin band report rates have been variously estimated at 21 percent in 1948 (Hopkins 1949), 36 percent in the early 1950's (calculated from Hunt et al., 1958), 46 percent in the 1954-57 seasons (Geis and Atwood 1961), 42.1 percent for 1947-57 (by Jahn and Hunt 1964, using the estimate of Geis and Atwood 1961, for the Mississippi Flyway overall), 43 percent in 1958-60 (estimated report rate for Mississippi Flyway from Martinson 1966) and 38.8 percent in 1965-69 (Anderson and Henny 1972). These estimates, while they do suggest a general decline in the number of bands reported from Wisconsin, also point out a considerable amount of variability inherent to such adjustments. Wisconsin hunters, however, do apparently report bands at a rate equal to or greater than the Mississippi Flyway as a whole.

Harvest rates calculated by March (1976:161) incorporate these regional differences in band report rate by using separate reporting rates for Wisconsin, each flyway and Canada. In practice, the method produced harvest rates 30-33 percent (females) to 44-54 percent (males) higher than rates estimated by Anderson (1975) who used band report rates from Henny and Burnham (1976).

Direct recoveries from each hunting period were sorted into those reported from: (1) Wisconsin; (2) other Mississippi Flyway states; (3) Central Flyway states; (4) Atlantic Flyway states; (5) Pacific Flyway states; (6) Canada; and (7) "unknown" locations. Each of the groups was then corrected for non-reported bands, using mallard band reporting rate estimates from the literature and associated with each region. The "adjusted" number of first-year recoveries was then summed for all regions and the total used to calculate a "weighted" annual harvest rate. For 1950-60, weighted harvest rates were based on reporting rates of 0.421, 0.506, 0.549 and 0.608 for the Mississippi, Central, Atlantic and Pacific Flyway, respectively (from Geis and Atwood, 1961). Because Wisconsin and Canadian hunters tend to report bands with generally greater frequency than hunters in the Mississippi Flyway overall (from Anderson and Henny 1972), 0.500 was selected as a reasonable estimate of reporting rates for that species in Wisconsin and Canada during 1950-60, and was used to derive harvest rates for those two regions. Weighted harvest rates for 1961-72 (from March 1976:161) were obtained using the 1965-68 mallard reporting rates in Table 9 of Anderson and Henny (1972:59). Rates used were: Wisconsin, 0.388; remainder of Mississippi Flyway states, 0.281; Central Flyway, 0.347; Atlantic Flyway, 0.287; and Pacific Flyway, 0.315. Canadian reporting rates for mallards have averaged between 40-50 percent (Anderson and Henny 1972)—0.450 was used for calculating adjusted recoveries from Canada. Recoveries from unknown locations were adjusted by a 0.300 reporting rate which Anderson and Henny (1972) considered about average for mallards in the United States during the 1960's.

Based on Henny and Burnham (1976:11), band report rates used here (and by March 1976) underestimate the "actual" 1961-72 report rates in all flyways and overestimate the Canadian report rate. However, since rates in Henny and Burnham (1976) also varied in relation to the distances between recovery and banding locations, a direct comparison of differences between their results and this study was not possible. Henny and Burnham's (1976) overall band report rate from Wisconsin was 0.467, or about 20 percent greater than the 0.388 used here.

Weighted harvest rates in Table 20 estimate the proportion of the mallard population shot and retrieved by hunters each fall, indicate the portion of that harvest occurring in Wisconsin and were used to derive the total rates of hunting kill discussed in the remainder of this section.

Hunting Kill Rate. To estimate the proportion of the mallard population dying as a direct result of shooting (hunting kill rate), the harvest rate must be increased to include a measure of crippling loss or the unretrieved hunting kill. Crippling losses, based on hunter reports, in Wisconsin averaged 21 percent of the total ducks shot during 1949-52 (Jahn and Hunt 1964). Losses recorded on individual hunting areas ranged from 12 to 28 percent. These values, since they are based on information volunteered by hunters were considered as minimal. The unretrieved duck kill in Wisconsin during the 1959 and 1960 seasons was 19 percent and 21 percent, respectively, of the total kill estimated by hunter mail surveys (Atwood and Wells 1961). Crippling losses in the 1952-60 seasons on the Upper Mississippi NWR, including data gathered on hunters in Wisconsin, Minnesota, Iowa and Illinois, averaged about 21 percent of the total kill (Green 1963). Geis et al. (1969) used 25 percent as the estimated loss to crippling each year for North American mallard populations. The most recent estimate for Wisconsin, based on U.S. Fish and Wildlife Service mail questionnaires and hunter performance surveys, was a crippling loss of 21 percent (from Martin and Carney 1977:133).

Based on the several estimates available, a 25 percent crippling loss was selected by March (1976) as a reasonable figure for Wisconsin and was also used here to obtain hunting kill rates.

Results and Discussion

Hunting Kill Rates. Twenty-eight percent of the adult males and 38 percent of the adult females banded in 1950-60 were estimated killed by hunters in the first season after banding (Table 21). For young-of-the-year mallards in that period, about 46-57 percent of the male cohort and 36-46 percent of the females were shot by hunters. Overall kill rates for 1961-72 were 23 percent, 33 percent, 55-57 percent and 42-44 percent respectively, for adult females, adult males, juvenile males and juvenile females. All cohorts except local females had their highest recorded rate of kill in the 1970 hunting season.

All 1961-72 mean rates of total kill for adults and immatures were significantly different from one another at $P < 0.05$. Means for total kill rates on locals were not different from rates of any other cohort at $P < 0.05$.

Mean kill rates in Wisconsin (Table 21) for adults were significantly less than mean kill rates in Wisconsin for immatures or for local females ($P < 0.05$).

Mean kill rates in Wisconsin represented 40 percent (local males), 41 percent (adult males), 50 percent (adult females), 65 percent (immature males), 66 percent (local females) and 70 percent (immature females) of the mean total kill rates in Table 21.

Kill Rates in Wisconsin Compared to Rates Elsewhere. During the 1950's, 56-64 percent of Minnesota's local mallard population was estimated shot each fall—as much as 70 percent of this mortality occurred in Minnesota (Jessen 1970). Minnesota habitat was thought to be under-utilized by mallards because of the overharvest of locals. Jessen (1970) used a 40 percent estimate of band report rate and a crippling loss of 33 percent when deriving the Minnesota kill rates. If the same adjustments are applied to the direct recovery rates from Wisconsin, kill rates estimated in 1950-60 would be raised to 52-60 percent for juveniles and 43 percent for adults. Without using Jessen's (1970) adjustments, kill rates associated with Wisconsin-banded juveniles (36-57 percent) were already approaching the lower limit of the range of losses estimated for Minnesota. Since Minnesota's supporting population indexes and production data suggested an overharvest of local mallards (Jessen 1970), similar reductions in breeding populations may also have occurred in Wisconsin. March et al. (1973) suggested that Wisconsin may have had fewer mallards in the early 1950's since the species only represented 30 percent of the spring breeding population of all ducks (Jahn and Hunt 1964), compared to 47 percent in 1965-70. Total breeding ducks apparently averaged about 270,000-280,000 birds in both periods (March et al. 1973).

The 1963-67 hunting kill rates for North American mallard populations included in annual surveys were between 29-41 percent, averaging 36 percent (Geis et al. 1969). Anderson (1975), using different band report rates and rate of crippling loss, estimated the mean 1961-70 North American hunting kill rates at 18 percent (females) to 20 percent (males) for adult mallards and 23 percent (females) to 26 percent (males) for juveniles. Estimated mallard kill rates in Wisconsin during 1963-67 were 24-32 percent for adults, 46-52 percent for flying immatures and 50-60 percent for locals (Table 21). The average 1961-70 kill rates in Table 21 were higher than Anderson's (1975) estimates for the Wisconsin-N. Illinois reference area and the North America overall rate. The higher band report rates and lower crippling losses used by Anderson (1975) are primarily responsible for differences between Table 21 and his Wisconsin-N. Illinois estimates. However, Anderson's (1975:23-24) average adult male

Table 20. *Weighted harvest rates[a] by sex and age cohorts for mallards banded during 1950-72.*

Year Banded	Age and Sex at Banding: Adult Male	Adult Female	Immature Male	Immature Female	Local Male	Local Female
1961	.171	.115	.374	.295	.2[b]	.1[b]
	(.038)	(.048)	(.222)	(.209)	(.1)	(.1)
1962	.256	.153	.31	.282	.5	-
	(.133)	(.104)	(.24)	(.215)	(.0)	-
1963	.24	.205	.410	.397	.6[b]	-
	(.12)	(.123)	(.297)	(.295)	(.4)	-
1964	.22	.173	.419	.355	-	.6[b]
	(.10)	(.089)	(.272)	(.214)		(.5)
1965	.20	.136	.330	.272	.4[b]	.2[b]
	(.07)	(.041)	(.098)	(.125)	(.0)	(.2)
1966	.263	.216	.360	.396	.51	.16
	(.071)	(.097)	(.212)	(.246)	(.42)	(.09)
1967	.26	.165	.422	.296	.32	.54
	(.12)	(.077)	(.279)	(.216)	(.12)	(.30)
1968	.163	.112	.343	.300	.32	.33
	(.062)	(.053)	(.218)	(.193)	(.14)	(.14)
1969	.274	.210	.492	.356	.41	.26
	(.136)	(.094)	(.378)	(.291)	(.17)	(.11)
1970	.36	.221	.621	.440	.56	.29
	(.11)	(.121)	(.400)	(.346)	(.20)	(.18)
1971	.36	.177	.477	.348	.37	.43
	(.19)		(.387)	(.280)	(.25)	(.31)
1972		.113				
	(.08)	(.066)	(.161)	(.123)	(.0)	(.3)
1961-72 Mean	.254	.166	.407	.328	.39	.34
	(.103)	(.084)	(.264)	(.229)	(.16)	(.22)
95% C.L.	±.042	±.026	±.059	±.044	±.15	±.12
	(±.027)	(±.017)	(±.061)	(±.044)	(±.09)	(±.08)
1961-72 Overall	.2482	.1725	.4128	.3334	.429	.315
1950-60 Overall	.21	.28	.427	.347	.35	.27

[a]Direct band recovery rate adjusted for differences in band report rates between Wisconsin and elsewhere. Harvest rate in Wisconsin is in parentheses.
[b]Less than 50 mallards banded.

(21 percent) and juvenile male (33 percent) and female (29 percent) kill rates for the Wisconsin-N. Illinois reference area were also above the continental average; the average Wisconsin-N. Illinois adult female rate (16 percent) was lower than the continental average.

Considering all seasons during 1961-72, kill rate sustained by adult females banded in Wisconsin was significantly less (chi-square value of 13.8, 1 df, $P < 0.01$) than their respective 1950-60 overall rate (Table 21). Overall rates for the other cohorts did not differ between the two periods ($P > 0.10$). However, kill rates for immatures in certain seasons were greater in 1961-72 than during 1950-60 overall. Immature male kill rate for the 1969-71 seasons was higher ($P < 0.005$) than the overall 1950-60 rate for that cohort; immature female kill rate for the 1963-64, 1966 and 1969-70 seasons was also greater than the 1950-60 rate ($P < 0.025$). For the cohort banded as locals, the 1970-72 kill rate was greater (at $P < 0.10$) than the overall rate for 1950-60.

Assuming that overharvest of local mallards could have occurred under the rates of kill incurred in 1950-60, then excessive shooting of several cohorts could also have taken place in recent seasons, particularly during 1969-72. However, the lower rate of kill on adult females appeared to be a key factor in maintaining Wisconsin's local population at the 100,000+ mallard level in the 1960's and early 1970's.

Kill Rate in Wisconsin in Relation to Total Kill Rate. Since over half the recoveries of mallards banded in Wisconsin occurred in the state (Table 12), the total rate of kill associated with these birds should be directly affected by the rate of kill encountered in Wisconsin. Regression coefficients in Table 22 suggest a significant direct relationship (at $P < 0.05$) between kill rate in Wisconsin and total kill rate for all cohorts except local males. Hunting

Table 21. *Hunting kill rates[a] by sex and age cohorts for mallards banded during 1950-72.*

Year Banded	Adult Male	Adult Female	Immature Male	Immature Female	Local Male	Local Female
1961	.228 (.051)	.154 (.064)	.499 (.296)	.393 (.279)	.2[b] (.2)	.2[b] (.2)
1962	.341 (.177)	.204 (.138)	.414 (.317)	.376 (.286)	.6[b] (.0)	- -
1963	.317 (.159)	.273 (.164)	.546 (.397)	.530 (.393)	.8[b] (.5)	- -
1964	.290 (.139)	.231 (.118)	.559 (.363)	.474 (.285)	- -	.8[b] (.7)
1965	.261 (.098)	.181 (.055)	.440 (.131)	.363 (.167)	.5[b] (.0)	.3[b] (.3)
1966	.351 (.095)	.289 (.130)	.480 (.283)	.528 (.328)	.69 (.56)	.21 (.12)
1967	.340 (.157)	.220 (.102)	.562 (.373)	.394 (.288)	.42 (.17)	.72 (.40)
1968	.217 (.083)	.149 (.070)	.458 (.290)	.400 (.257)	.43 (.18)	.44 (.19)
1969	.366 (.181)	.280 (.125)	.656 (.503)	.475 (.388)	.54 (.23)	.35 (.15)
1970	.483 (.144)	.294 (.161)	.828 (.534)	.587 (.462)	.75 (.27)	.39 (.24)
1971	.482 (.257)	.236 (.136)	.636 (.516)	.464 (.374)	.50 (.33)	.57 (.41)
1972	.378 (.108)	.171 (.088)	.441 (.214)	.264 (.164)	.6[b] (.0)	.7[b] (.4)
1961-72 Mean	.338 (.137)	.223 (.112)	.543 (.351)	.437 (.306)	.55 (.22)	.47 (.31)
95% C.L.	±.054 (±.036)	±.033 (±.023)	±.075 (±.081)	±.057 (±.059)	±.20 (±.12)	±.16 (±.11)
1961-72 Overall	.3309	.2300	.5504	.4445	.572	.420
1950-60 Overall	.28	.38	.569	.463	.46	.36

[a]Weighted harvest rates from Table 20, divided by 0.75 to adjust for a 25 percent crippling loss. Kill rate in Wisconsin is shown in parentheses.

[b]Less than 50 mallards banded.

kill within Wisconsin apparently was the single most important influence on total annual hunting losses suffered by juvenile cohorts since kill rate occurring outside Wisconsin was related to total kill rate for adults only (at $P < 0.05$; Table 22). Also, as expected, there was no significant relationship between kill rates in Wisconsin and kill rates incurred outside the state.

Regression coefficients obtained using only direct recovery rates (Table 22) showed the same significant relationships as kill rates. Apparently weighting the recovery data for differences in band report rates did not seriously affect results.

Since the samples of locals banded prior to 1966 (and also in 1972) were less than 50 birds each and were poorly distributed geographically, the relationship between kill rate in Wisconsin and total kill rate was tested only for the 1966-71 seasons. In those six seasons (when banded samples represented 50 or more invididuals of each sex), the female kill rate in Wisconsin was significantly correlated with total female kill rate at $P < 0.05$. For males, the relationship was significant only at $P < 0.20$ ("t" value of 1.573, 4 df). It does appear that in years with similar distribution of banding (and also larger numbers banded), the kill rate in Wisconsin incurred by separate sexes in the local cohort was also directly influencing the total kill rate on those birds.

Relationships Between Kill Rates in Wisconsin and Outside the State. Waterfowl managers are faced with the question of whether reducing the mallard harvest in Wisconsin would result in an increased harvest outside the state. To determine the potential effects of such a management decision, the relationships between Wisconsin and non-Wisconsin kill rates were examined among the several banded cohorts.

The 1961-72 kill rates (Table 21) were separated into: (1) seasons for which the kill rate in Wisconsin increased over the previous year (+ seasons); and (2) those in which the kill rate in Wisconsin decreased from the previous year (- seasons). The overall kill rates for each group of seasons were then tested for significant differences using chi-square with 1 df. During "-" seasons, the *kill rates in Wisconsin* were less than in "+" seasons (Table 23). Except for adult males, all differences between overall rates were significant at $P < 0.005$. Using $P < 0.05$ as an acceptable value for establishing significance, *total kill rates* in "-" seasons were also reduced for adult females, immatures and locals (Table 23). The *kill rate* incurred by adult females *outside Wisconsin* was also less ($P < 0.005$) in "-" seasons, suggesting a general reduction in shooting pressure on the cohort. For immatures the kill rate outside Wisconsin during "-" seasons was higher ($P < 0.05$) than in "+" seasons. However, reduced losses in Wisconsin were sufficiently large to offset the increased outside kill and a net decrease in total kill rate was realized.

Both the rate of kill outside Wisconsin and the total rate of kill for adult males were unchanged in "+" and "-" seasons. Compared to the other cohorts, a smaller proportion of adult male recoveries occurred in Wisconsin (44 percent compared to 51-75 percent; Table 12). Adult male kill rates in Wisconsin during "+" and "-" seasons also showed the smallest differences when compared to other cohorts (Table 23). As a result, total rate of kill on adult males was least affected by hunting losses in Wisconsin. Local male rate of kill in Wisconsin was lower ($P < 0.05$) in the one "-" season than the overall kill rate in Wisconsin for the three "+" seasons (Table 23). Total kill rate and kill rate outside Wisconsin on males was also reduced in the "-" season (at $P < 0.005$ and P 0.10, respectively). Local female kill rates showed much the same responses as male rates, except that outside kill rates were not different between "+" and "-" seasons at $P < 0.10$ (Table 23).

In general, lowered kill rates in Wisconsin were associated with lowered total kill rates for a particular cohort. Although kill rate outside Wisconsin did increase significantly for immatures in "-" seasons, these changes were not sufficiently large to prevent a reduction in the total rate of kill. Total kill rate for adult females was most directly affected since a reduced rate of kill in Wisconsin was associated with a concurrent decrease in outside kill rate during "-" seasons; net effect was a 25 percent reduction in total kill rate.

Since a reduced rate of kill in Wisconsin on mallards banded in the state resulted in a net reduction in total kill rate on these birds, steps taken to reduce harvest of these birds in the state should generally be successful, except perhaps when dealing with the adult male cohort.

Factors responsible for annual changes in proportions and rates of hunting kill that occurred in Wisconsin and elsewhere were difficult to identify between individual years. Changes in hunting regulations on mallards could have had a major effect on kill rates and this relationship is discussed later.

Migration chronology would be the other major influence on kill distribution. If a banded mallard is not present in Wisconsin during the hunting season, it obviously can not be shot there. With Wisconsin hunters accounting for more than half the recoveries of mallards banded in the state, major changes in the chronology or magnitude of migration from Wisconsin would have an important influence on distribution of kill on these birds. In years of earlier migration, kill rates in Wisconsin should be less since birds would not be exposed to shooting in the state for as long a period. Banded mallards which were not shot in Wisconsin would be available to hunters elsewhere. An early freeze-up in Wisconsin might be one example of a season having an unusually advance migration chronology and an associated lowered kill rate in the state.

Chronology of Female Mallard Hunting Losses. An overall view of hunting losses to the female cohorts of mallard populations in Wisconsin (combining results from Table 14, 18 and 21) shows that about 11 percent of the preseason-banded adults, assumed to represent mostly locally-nesting hens, and 22-31 percent of the banded juveniles are shot by the state's hunters in the first season after banding. From one-sixth to one-third of these deaths occur within the 10-minute block of banding. Twenty-five percent of the adult females eventually dying from hunting are killed within the first 2 days of the duck season, or, in other words, about 3 percent of the adult female population was shot within those 2 days. By the end of the second week of the season, 7 percent of the adult females have been killed, and about two-thirds of the deaths that take place in Wisconsin have already occurred.

For juvenile females, 8-12 percent of the population was removed by shooting within the first 2 days of the season, and 16-24 percent have died through the 14th day. After 14 days of shooting, about three-fourths of the juvenile shooting deaths in Wisconsin have already taken place. Within the first 28 days of hunting, 90+ percent of all banded female hunting deaths in

Table 22. *Correlation coefficients obtained in comparisons between annual kill rates in Wisconsin, kill rates outside Wisconsin and total kill rates for mallards banded in the state.*

Age and Sex	n-2 df	"r" Values[b]: Wisconsin Kill Rate vs. Total Kill Rate	Wisconsin Kill Rate vs. Total Kill Rate	Outside Kill Rate vs. Total Kill Rate
Ad. Male	10	0.707*(0.823**)	0.085(0.116)	0.765**(0.659*)
Ad. Female	10	0.844**(0.886**)	0.261(0.209)	0.738**(0.638*)
Im. Male	10	0.864**(0.928**)	-0.328(-0.321)	0.192 (0.055)
Im. Female	10	0.887**(0.934**)	-0.241(-0.247)	0.235 (0.116)
Loc. Male[a]	4	0.618 (0.795)	-0.490(-0.532)	0.382 (0.091)
Loc. Female[a]	4	0.914*(0.940**)	0.461 (0.477)	0.780 (0.749)

[a]Kill rates from the 1966-71 seasons only. Remainder are from 1961-72 seasons.

[b]Regression coefficients obtained when direct recovery rates were used in place of kill rates are shown in parentheses.

* $P<0.05$

** $P<0.01$

Table 23. *Kill rates from seasons when the rate of kill in Wisconsin was less than in the previous year, compared to rates in seasons when the kill rate in Wisconsin increased over the previous year.*[a]

Age and Sex	n	Kill Rate in Wisconsin	Kill Rate Elsewhere	Total Kill Rate
Ad. Male				
+ Seasons	5	0.156 ($P<0.05$)	0.205 ($P>0.5$)	0.361 ($P>0.1$)
- Seasons	6	0.134	0.209	0.344
Ad. Female				
+ Seasons	5	0.142 ($P<0.005$)	0.113 ($P<0.005$)	0.260 ($P<0.005$)
- Seasons	6	0.095	0.098	0.195
Im. Male				
+ Seasons	6	0.412 ($P<0.005$)	0.185 ($P<0.005$)	0.597 ($P<0.005$)
- Seasons	5	0.294	0.230	0.501
Im. Female				
+ Seasons	5	0.368 ($P<0.005$)	0.127 ($P<0.01$)	0.495 ($P<0.005$)
- Seasons	6	0.248	0.144	0.392
Loc. Male[b]				
+ Seasons	3	0.27 ($P<0.05$)	0.35 ($P<0.10$)	0.62 ($P<0.005$)
- Seasons	1	0.17	0.26	0.43
Loc. Female[c]				
+ Seasons	3	0.31 ($P<0.005$)	0.18 ($P<0.25$)	0.49 ($P<0.025$)
- Seasons	2	0.17	0.23	0.40

[a]Probability of a greater chi-square value, with 1 df, is shown in parentheses.

[b]Only data from four pairs of seasons were compared as the Wisconsin kill rate did not change between 1967 and 1968. Kill rates used were from seasons with 50 or more birds banded (1966-71).

[c]Kill rates from 1966-71 seasons only.

Wisconsin have occurred. At that point, about 16-28 percent of the band recoveries from migrant mallards (birds banded outside the state) still have not occurred (Table 19). Seven days previously, 80-85 percent of the Wisconsin-banded females shot in the state have already been recovered, but only about 40-60 percent of the migrants ultimately recovered in Wisconsin have been shot.

Summary

Hunting kill-rate estimates for mallards banded in Wiconsin (weighted for differences in band report rates and assuming a 25 percent crippling loss) averaged 22 percent for adult females, 34 percent for adult males, 44-47 percent for juvenile females and 54-55 percent for juvenile males during 1961-72. The 1970 hunting season produced the highest estimated kill rates.

Hunting losses in Wisconsin accounted for 40-65 percent (males) to 50-70 percent (females) of the total rate of kill estimated for Wisconsin-banded mallards. Annual changes in total kill rate on these birds were directly related to changes in their estimated rate of kill in Wisconsin. As a result, efforts to reduce the kill rate in Wisconsin should have produced a lower total rate of hunting loss on mallards associated with the state.

Both the average hunting kill rates for adult males and juvenile males and females shown in Table 21 and rates from Anderson (1975:23-24) for the Wisconsin-northern Illinois reference area were higher than the average North American estimated hunting kill rates for comparable sex-age cohorts.

SURVIVAL RATES

Methods

Annual and mean survival rates, their standard deviations, coefficients of variation and 90 percent confidence intervals for adult mallards were estimated by a modified version (Anderson et al. 1974; Anderson and Sterling, 1974) of Seber's (1970) probability model. This model, termed the "Seber-Robson-Young" method by Anderson (1975), and designed to estimate time-specific survival and reporting rates for adult birds from band returns (Seber 1970), also computed annual "reporting rates" (an index to annual hunting pressure similar to a direct recovery rate), the standard direct or first-season band recovery rates and the 90 percent confidence intervals for each estimator. A chi-square goodness of fit test was also performed on the survival estimates. A package computer routine, designed by Anderson et al. (1974) was used in the actual computations. Data preparation and analyses were accomplished by personnel and computer facilities of Department of Natural Resources' Bureau of Data Systems.

Adult mortality estimates were obtained by subtraction, using survival rates estimated by the Seber model.

Anderson (1975) discussed the models recently developed by Robson and Brownie (1973) and Brownie and Robson (1974) that are suitable for estimating survival from banding and recovery data for young birds. These models, which allow "recovery and survival rates of young to be age-specific" for the first year after banding (Anderson 1975), were not available to March (1976). Life table methods used as one estimate of juvenile survival (March 1976:193) were among those considered by Anderson (1975) to be "biased and inefficient." March (1976:193) also estimated juvenile survival using the relative recovery rate method (Geis 1972) and the model developed by Johnson (1974). Anderson (1975) considered the relative recovery rate method (as used by Miller et al. 1968) to be a special case of the more general theory behind the Seber-Robson-Young method. The Johnson model allows survival and recovery rates to vary with the calendar year and permits young-of-the-year birds to have different rates than adults. Recovery and survival rates of young are assumed to be proportional to those of adults (Anderson 1975). The Johnson Model is also similar to the Seber (1970) model for birds banded as adults (Johnson 1974). Tests by Anderson (1975) tended to support the assumptions associated with the Johnson model.

For purposes of this analysis, the 1961-70 juvenile survival rate estimates developed by Anderson (1975:85) for the "Wisconsin-northern Illinois" reference area will be used. Currently they represent the "best" available estimates of survival rates of juvenile mallards associated with Wisconsin. Survival estimates derived from the Johnson model and by the relative recovery rate method are presented for comparison purposes. The computer routine of Johnson's (1974) model which calculated overall adult-immature survival and recovery rates, differences in vulnerability between immatures and adults and the minimum standard errors of these estimators was provided by the northern Prairie Wildlife Research Center. Actual data preparation and analyses were performed by the Department of Natural Resources Bureau of Data Systems.

Results and Discussion

Adult Survival Rates. Adult female survival during 1961-71 averaged between 58-59 percent (Table 24). Interval survival rates presented in Table 28 were similar at $P < 0.10$. Truncated recovery data prevented estimation of the mean 1961-71 or 1961-72 survival rates. Survival rate for adult males averaged between 60-63 percent during 1961-71, with no differences (at $P < 0.10$) between interval survival rates (Table 24). Mean adult female survival for 1961-70 was less than mean 1961-69 adult male survival at $P \cong 0.10$; survival rates were not different between sexes for other time intervals compared.

Combined survival rate for both sexes was 59 percent during 1961-71. Using the Dynamic Life Table (Geis 1972), combined survival of small samples of adult males and females banded in 1950-60 was also 59 percent (March 1976:349).

Chi-square tests of the fit of the data to Seber's (1970) model suggested that recovery distributions did not meet the model's assumptions well for several of the longer survival intervals in Table 24, or for males and females combined. Validity of the estimates, particularly their variances, is therefore open to question.

Although survival rates were generally similar between sexes, Seber's (1970) recovery rate, which is useful as an index to annual harvest rate and has a smaller variance than the direct recovery rate (Anderson and Sterling 1974), was significantly lower for females for all intervals (at $P < 0.10$). Although females had lower shooting rates, their survival rate was poorer than or only equal to that for males, suggesting higher non-hunting mortality among females. Anderson (1975) drew a similar conclusion for North American mallard populations.

Annual estimates of Seber's (1970) recovery rate and survival rates for both males and females are compared in March (1976:352-353).

Regional Adult Survival Rates. Using the Seber Model, individual survival estimates were obtained for adults banded in eastern Wisconsin (east of 90° longitude) and western Wisconsin, and also for all major preseason banding sites. The absence of banded samples in some years

Table 24. *Mean[a] recovery and survival rates for adult mallards banded in Wisconsin during 1961-71, using the model developed by Seber (1970).*

Survival Interval	Mean Recovery Rate (%)[b]	S.E.	90% Confidence Interval	Mean Survival Rate (%)	S.E.	90% Confidence Interval	Chi-Square
Adult Males:							
1961-62	6.44	0.55	5.53-7.35	60.70	4.18	53.84-67.55	21.2 (15)
1961-69	7.04	0.30	6.54-7.54	63.05	1.48	60.63-65.48	52.9* (36)
1963-70	7.66	0.40	7.00-8.31	61.82	2.01	58.53-65.11	38.0 (28)
1964-71	7.96	0.43	7.25-8.67	60.33	2.09	56.90-63.76	49.4* (28)
Adult Females:							
1961-62	4.56	0.28	4.10-5.01	59.26	2.90	54.51-64.01	16.1 (15)
1961-70	5.64	0.17	5.37-5.92	57.94	1.27	55.87-60.02	62.3* (45)
1963-71	5.77	0.20	5.44-6.10	58.88	1.65	56.18-61.58	69.2** (36)
All Adults:							
1961-71	6.11	0.15	5.87-6.35	59.31	0.91	57.81-60.81	99.6** (55)

[a]Arithmetic means

[b]Seber's (1970) index to harvest or shooting rate. Annual values listed in Appendices XI and XII.

*= significant at P 0.05; ** = significant at P< 0.01.

and truncated recovery distributions made it impossible to compare survival for exactly the same intervals.

Mean survival estimates for males and females banded in both eastern and western Wisconsin were not different at $P < 0.10$. Between regions, survival also was not different between cohorts of the same sex.

Survival estimates obtained for individual banding sites were generally disappointing. Only the Horicon NWR and Crex Meadows had sufficient continuous annual recovery data to estimate survival rates in more than 1 or 2 years. Sites with only a few years of continuous data generally yielded mean estimates with confidence intervals and standard errors much too large for any constructive interpretation.

There were no significant differences at $P < 0.10$ between sexes for cohorts banded at either Crex Meadows or Horicon NWR.

Hunting and Nonhunting Mortality of Adults. The 1961-72 overall rates of hunting kill were 33 percent for adult males and 23 percent for adult females (Table 21); by calculating total mortality rates from survival rates in Table 24, 55 to 82 percent of the adult deaths for this period were estimated to be the direct result of hunting. In 1950-60, adult kill rates were 28 percent and 38 percent respectively, for males and females (Table 21). Assuming a 41 percent mortality rate, hunting would have accounted for 68 to 93 percent of the total adult deaths in those seasons. The latter value is unrealistic as it would only allow a 3 percent nonhunting mortality rate for adult females.

Various estimates of nonhunting losses incurred by continental adult mallard populations are available. Crissey (1969), with an estimated 37 percent adult kill rate, predicted nonhunting mortality at 16 percent during 1955-65. Nonhunting losses in 1962-67 were an estimated 9-21 percent, with annual hunting losses of 29-41 percent (Geis et al. 1969). Recent estimates of nonhunting mortality by Anderson (1975) were higher than previously reported. Unweighted average nonhunting mortality for all geographic areas and years was 15 percent for adult males, 25 percent for adult females, 24 percent for immature males and 27 percent for adult females (from Anderson 1975:23-24).

Nonhunting mortality associated with Wisconsin-banded mallards was estimated from hunting kill rates in Table 21 and adult survival rates in March (1976:352-353). After subtracting annual kill rates from the 1961-71 annual mortality estimates, nonhunting mortality in Wisconsin averaged 8 percent for adult males (mean kill rate of 33 percent and mean mortality of 41 percent) and 20 percent for adult females (kill rate of 22 percent, total mortality of 42 percent). Male estimates were less consistent than those for females—in 1963 and 1966, the estimated rate of hunting kill exceeded total mortality for males. By omitting the 2 years with negative survival, male nonhunting losses were increased to 10 percent. The average of annual nonhunting losses for males (excluding 1963 and 1966) was also 10 percent; the female average nonhunting loss was 20 percent. These losses are considerably less than the 18 percent (males) and the 26 percent (females) nonhunting mortality estimated by Anderson (1975:23-24) for adults banded in Wisconsin-northern Illinois. As discussed previously for immatures, disagreement between the two estimates are largely the result of using different methods to derive kill rates.

The general principle that adult males suffer higher rates of hunting kill, but, because of lower nonhunting

Table 25. *Survival rates for juvenile mallards banded in Wisconsin during 1961-72.*

Year Banded	Males: Estimated Survival Rate (%)	S.E.	Females: Estimated Survival Rate (%)	S.E.
1961	33.1	5.0	47.0	5.9
1962	38.5	7.2	59.0	6.8
1963	46.9	7.7	43.1	6.1
1964	49.5	7.0	61.7	8.5
1965	44.3	5.4	50.3	5.7
1966	38.5	5.8	40.6	5.9
1967	35.8	5.8	46.3	7.6
1968	35.0	5.2	51.0	6.9
1969	34.6	6.0	47.7	6.9
1970	24.9	5.8	52.6	11.0
Mean	38.1	1.9	49.9	2.3

[a]Data in Table 25 are taken from Anderson (1975:85) and represent probabilities of survival derived by the Robson-Brownie methods.

losses, survive at a higher rate than females, still appears valid for mallards banded in Wisconsin. Adult females, despite a lower shooting rate than males, have poorer overall survival, presumably because of greater nonhunting losses associated with the nesting and brood rearing activities.

Juvenile Survival Rates. Survival estimates for juvenile mallards were generally lower than estimates for adults. Table 25 lists Anderson's (1975:85) 1961-70 survival estimates for young (both locals and flying immatures) mallards banded in Wisconsin and northern Illinois. A majority of the banding was done in Wisconsin. Mean survival of males (38 percent) was less than female survival (50 percent). Chi-square tests for goodness-of-fit indicated a poor fit of the data to the Robson-Brownie model, however.

Average 1961-72 juvenile survival estimates obtained by March (1976:193) using relative recovery rates were 35 and 38 percent for local and immature males and 55 percent for local and immature females. These rates were not a great deal different than average Wisconsin-N. Illinois survival estimates from Anderson (1975:85).

The Johnson (1974) model, which combined adult and juvenile banding data, estimated survival during 1961-71 at 62-65 percent for males and 58-59 percent for females (March 1976:193). These estimates were quite similar to adult survival rates obtained with the Seber (1970) model. According to Johnson's (1974) differential vulnerability factors, "H" and "D," which were also estimated by his model, local males were 1.7 times more vulnerable to hunting in their first year than adult males, and survived their initial year at only 49 percent of the adult rate (H = 1.71 and D = 0.490). For immature males, H = 1.898 and D = 0.606. Local females were 2.1 times more vulnerable to shooting than adult females (H = 2.076) and survived at only 81 percent (D = 0.810) of the adult rate in the first year. Immature females had an H value of 2.134 and a D value of 0.878.

By combining the vulnerability factors (D values) from the Johnson (1974) model with survival estimates from the Seber (1970) model, an additional estimate of first-year juvenile survival was obtained. First-year survival of local males was estimated at only 29 percent by multiplying the 60 percent adult male survival rate from Table 24 by the D value of 0.49 for local males. For immature males, survival was estimated at 36 percent (60 percent times 0.606). These indirect estimates were slightly lower than the average survival rates obtained by Anderson (1975) or by the relative recovery rate method (March 1976:193). Local females had a first-year survival rate of 47 percent (adult female survival of 58 percent times a D value of 0.810), and immature females, a 51 percent survival (58 percent times 0.878). Both female estimates are similar to those from Anderson (1975:85).

For the remainder of this report, juvenile male survival is assumed to equal 38 percent and juvenile female survival, 50 percent.

Using these values for survival rate, hunting mortality accounted for 86 percent and 78 percent respectively, of the total first-year deaths incurred by juvenile males and females during 1961-72. These values are quite different from the 53-58 percent of total mortality attributed to hunting by Anderson (1975). The differences in our results are again primarily related to the method (s) used to derive kill rates.

Relationship Between Hunting Losses and Total Mortality. The relationship between the rate of hunting kill and total mortality incurred by migratory game birds and the mallard in particular, has been discussed by Hickey (1952), Geis (1963) and Geis et al. (1969). Results of their analyses suggested that as shooting rate increased, so did total mortality. Hunting mortality apparently was not compensated for by a reduction in nonhunting mortality (Geis 1963) but instead added to, or replaced only a small part of, losses from other causes. In general, the additive hunting mortality hypothesis was based on a significant correlation between estimated average annual mortality and average first-year recovery rates (Anderson and Burnham 1976). However, using different analytical methods, Anderson and Burnham (1976) concluded that the inference that hunting is an additive form of mortality has been based on incorrect analyses of banding data. More specifically, use of a simple correlation-regression analysis of estimated average recovery rates versus estimated average mortality rates produced totally "spurious" results since the two rates already had very high sampling correlations (Anderson and Burnham 1976:42-43).

March (1976:181-191) also utilized the "Hickey Triangle" (after Geis 1972) as the accepted method of examining relationships between hunting and nonhunting mortality associated with Wisconsin mallard populations. In view of Anderson and Burnham's (1976) conclusions regarding this approach, a detailed discussion of March's (1976:184-191) results is of questionable value. In general, recognizing that the methodology used may have yielded incorrect results, adult male mallard survival appeared strongly affected by recovery rates, i.e., hunting was additive. For adult females, the relationship was not as strong, suggesting that nonhunting mortality also had an important influence on annual survival. In the absence of hunting, annual mortality was estimated to be 22 percent for adult females and 24 percent for adult males.

Anderson and Burnham (1975) reject the hypothesis that hunting is a completely additive form of mortality and conclude that "for kill rates below some threshold point, hunting mortality is largely compensated for by other forms of mortality." The population data available from Wisconsin are not sufficient to combine with banding data to either support or challenge their conclusion. Final resolution of whether mallard hunting mortality is additive or compensatory must await additional research at both the continental and local level.

Anderson and Burnham (1975:42-43) did make several points that are of immediate importance to Wisconsin mallards, however. First, although they were "unable to demonstrate that survival was increased in years when restrictive hunting regulations were enacted and/or kill rates were low" (Anderson and Burnham 1976:43), previous work does support "the concept that *waterfowl hunting regulations strongly affect both the size of the kill and the rate of the kill of mallards*" (emphasis on the latter phrase is ours). Evidence from Wisconsin, presented later, also tends to support that conclusion.

Secondly, and most important, Anderson and Burnham (1976:43) emphasize that *"hunting mortalities can be compensated for only to a point" (still undefined quantitatively) and that "kill rates may have exceeded the threshold point on a local basis"*, particularly on the breeding grounds or in areas where birds are especially vulnerable. Wisconsin's locally nesting mallards should qualify as prime candidates for both categories.

Survival of Populations Outside Wisconsin. Bellrose and Chase (1950) are generally credited with the first annual estimate of survival rates for North American mallard populations. Annual adult survival was an estimated 56-60 percent for males and 52 percent for females (Bellrose and Chase 1950). Most recently, Anderson (1975) estimated adult male survival at 62 percent for all years and geographic areas examined; adult female survival was 54 percent overall. The 1961-71 survival rates for adult male mallards banded in Wisconsin was 60-63 percent (Table 24) or similar to the continental average. Adult females banded in Wisconsin had a survival rate of 58-59 percent, or slightly better than the overall value for North American populations.

Young male mallards from all geographic regions had an average survival rate of 48 percent, while young females survived at a lower overall rate, 46 percent (Anderson 1975). Using Anderson's (1975:85) estimates, juvenile males banded in Wisconsin and northern Illinois were surviving at a poorer rate than those banded in other regions (Table 25). Wisconsin-N. Illinois juvenile females were surviving at a slightly higher rate than the continental average.

Adult and local female mallards banded in Minnesota during 1967-70 had an average survival of about 50 percent (Johnson 1974). Survival of those cohorts in Wisconsin during 1961-71 was greater, 59 percent (March 1976:199), using the Johnson (1974) model. However, according to Anderson (1975:63-64 and 84-85), the average 1961-70 survival rates for all cohorts banded in Minnesota equalled or exceeded survival rates of the corresponding cohorts banded in Wisconsin. Although survival rates in Wisconsin did not depart greatly from the average survival for all geographic areas, mallards banded in the state incurred similar or higher mortality during the 1960's than birds from Minnesota.

Mallards banded in the Michigan-N. Ohio-N. Indiana reference area also survived at higher rates during 1961-70 than corresponding cohorts banded in Wisconsin-N. Illinois (Anderson 1975:64-65, 85-86). Overall, mallards associated with Wisconsin seemed to survive at generally poorer rates than populations from neighboring states.

Survival Rate and Population Change. Numbers of breeding mallards in Wisconsin (Table 9), after declining between the springs of 1965 and 1966, apparently remained relatively stable between 1966 and 1968, then increased annually in 1969 and 1970. Female survival rates (March 1976:353), production ratios (Tables 3 and 7) and rates of hunting kill (Table 21) were compared to determine if changes in survival and/or productivity might have accounted for observed population trends.

Adult and immature female survival rates in 1965 were not significantly different at $P < 0.10$ from the 1964 rates (March 1976:353; Table 30). Also, the adjusted wing survey age ratio in 1965 (Table 7) was the second highest during 1961-72. None of these vaiables could therefore have been strongly associated with the "observed decline" in breeding populations between 1965 and 1966. An above-average age ratio of 1.7 immatures:adult in the 1965 preseason banded sample (Table 3) also was not consistent with the population decline in 1966. Rates of hunting kill from Table 21, starting in 1964, also did not suggest any direct relationship between population trend and shooting losses. Kill rates for adult and immature females during the 1965 season were lower ($P < 0.005$) than in 1964, and the 1965 rates for those cohorts were also less than the overall kill rates for 1961-72 ($P < 0.005$).

Both Jessen (1970) and Anderson (1975) also reported a decline between 1964 and 1965 in the kill rate associated with mallards in Minnesota. Breeding populations in western Minnesota (Reference Area #133, Pospahala et al. 1974) declined about 33 percent in 1966, however. Since the overall North American spring mallard population increased about 22 percent between 1965 and 1966 (Pospahala et al. 1974), declines in Wisconsin and Minnesota were not a part of the predominant continental trend.

Breeding population estimates were not available for Wisconsin in 1967. The breeding population in 1968 was about the same as in 1966, suggesting little change in 1967. The spring population increase observed between 1968 and 1969 was accompanied by a decreased adult female survival between 1967 and 1968 ($P < 0.10$), and no change in immature female survival between those years (Table 30). Adjusted wing survey age ratio for 1968 was the lowest recorded during 1961-72; age ratio in the preseason banded sample was about average for 1961-72 and represented no change from 1967. Adult female kill rate in 1968 was less than in 1967 ($P < 0.005$) but immature female kill rate was unchanged. Both were less than the 1961-72 average. Kill rate for local females was also less than in 1967 and below the 1961-72 average. Continental mallard populations increased slightly between 1968 and 1969, but Minnesota's spring population showed no change from 1968 (Martinson et al. 1969). None of the variables examined appeared to support the observed trend in the spring population in Wisconsin except possibly the decreased adult female kill rate. Females not shot in the fall have a better than 50:50 chance of surviving to nest the following spring.

In 1969, increased survival and productivity were consistent with the increased mallard breeding population in 1970 (highest recorded in 1965-66 and 1968-70). The 1969 adult female survival rate was significantly higher ($P < 0.10$), 69 percent versus 44 percent, than the 1968 survival rate. Immature female survival was numerically higher in 1969 than in 1968 (Table 25), but the associated standard errors did not suggest significant differences between years. Production ratio from the adjusted wing survey data was 1.0 immature:adult, or slightly better than the 1961-72 average of 0.9 immature:adult, and was much improved from the 1968 age ratio. Age ratio of the preseason banded sample was the highest recorded during 1961-72, 2.1 immatures:adult (Table 3). However, both adult and immature females incurred higher ($P < 0.005$) rates of hunting kill in 1969 than they did in 1968 (Table 21). Apparently reduced nonhunting mortality and increased productivity in

1969—not reduced hunting losses—were responsible for the 42,000 bird increase in breeding mallards recorded in 1970. For North America overall, and also in Minnesota, mallard populations also increased 20 or more percent in the spring of 1970 (Chamberlain et al. 1971).

Efforts to associate changes in estimated survival and productivity with observed changes in breeding populations of mallards in Wisconsin during 1964-70 were inconclusive and conflicting in two of the three examples. The change between 1969 and 1970 was in the direction predicted by associated changes in survival rates and age ratios. However, the increase between 1968 and 1969 could also have resulted from decreased shooting losses. The proportion of the spring population comprised of pioneering pairs from other areas is a major unidentified factor in both examples. Perhaps conflicting results should be expected when the extremely large variances inherent to the variables, including breeding population estimates, being compared are considered. Additional years of breeding population estimates, plus the supporting survival and production information, are needed to more adequately test these relationships. Major unknowns also are the effect of spring weather and habitat conditions in Wisconsin as they may increase or decrease the number of pioneering mallards attracted to the state.

Survival in Years With Above-Average Kill Rates. Adult female kill rates in 1963, 1966, 1969 and 1970 exceeded an estimated 25 percent of the banded cohort; immature females had estimated kill rates in excess of 50 percent in 1963, 1966 and 1970 (Table 25). Overall kill rate in those years was higher than kill rates for all other years combined ($P < 0.005$, chi-square values = 204 and 198, 1 df) and for 1961-72 overall ($P < 0.005$, chi-square values = 91.0 and 198, 1 df). However, average survival rates for both adult (March 1976:353) and immatures females (Table 25), in years with high kill rates, were not different from average survival in all other years at $P < 0.10$. We can only conclude from these data that although hunting removed more than one-fourth of the adults and over one-half of the juveniles, these losses did not significantly alter estimated female survival rates. Again, the large variances associated with survival estimates may have masked any "real" increased mortality.

Summary

In 1961-71, adult males had a mean survival rate of 60-63 percent. Mean hunting mortality was 33 percent and nonhunting mortality, 7-10 percent. Mean 1961-71 survival rate for adult females was 58-59 percent. Female mortality included a 22 percent loss to hunting and 20 percent to other causes. Annual survival estimates for males ranged from 44 percent in 1970 to 74 percent in 1963 (March 1976:352). For females, survival ranged from 44 percent in 1968 to 73 percent in 1964 (March 1976:353).

In 1961-71, juvenile survival in Wisconsin was an estimated 35 percent for males. Survival of juvenile females was an estimated 50 percent. With a first-year mortality of 65 percent, hunting losses averaged 56 percent and nonhunting losses, 9 percent. For females, hunting losses took 43 percent and nonhunting losses, 7 percent.

Juvenile male mallards banded in Wisconsin had poorer estimated survival rates than continental populations. Adult male mallard survival was similar to the North American average while all female cohorts banded in Wisconsin survived at a slightly higher rate than continental populations. When compared to male mallard survival (1961-70) in Minnesota, Michigan, Ohio and Indiana, all Wisconsin-banded cohorts survived at poorer average rates. Female cohorts from Wisconsin (1961-70) survived at an average rate equal to or poorer than females banded in those four states.

Available evidence from Wisconsin does not reject Anderson and Burnham's (1976) hypothesis that hunting mortality is compensatory to a threshold point. However, "goodness of fit" tests suggest that the Wisconsin data do not agree well with the assumption associated with models used by Anderson (1975) and March (1976) to calculate survival. One must therefore be cautious when considering changes (or lack of change) in annual survival estimates obtained by these models for Wisconsin-banded cohorts. The generally higher rates of hunting loss (and poorer survival rate estimates) associated with Wisconsin-banded mallards, when compared to neighboring states and North America overall, suggest that our local birds may be excessively vulnerable to shooting. Based on that assumption, shooting losses to local populations in Wisconsin may have exceeded Anderson and Burnham's (1976) threshold point in some seasons.

HARVEST AND HUNTING SEASON STATISTICS

Methods

Waterfowl Harvest Estimates. Annual estimates of Wisconsin's retrieved duck harvest were available for 1932-72. The 1932-51 total duck harvest estimates were obtained from voluntary returns of hunter kill report cards to the Wisconsin Conservation Department and represent unpublished data from Department files. Thompson (1951; 1953) discussed these results in comparison with post-hunt mail surveys of hunter kill, and indicated an average return of about 20 percent for the voluntary report cards. Wisconsin mallard harvests were also estimated from the voluntary reports during 1932-48, with species composition based on hunter identification. Jahn and Hunt (1964), and Hunt (1971) found that Wisconsin hunters identify 96-99 percent of the mallards correctly to species. The voluntary hunter reports were not adjusted for response biases (discussed by Atwood 1956) that would have tended to exaggerate estimated hunting kill.

The 1952-72 mallard harvest estimates for Wisconsin were taken from Martin and Carney (1977). Total Wisconsin duck harvest estimates for 1952-70 used in this report were also obtained from Martin and Carney (1977) by dividing their annual Wisconsin mallard harvest estimates by the percentage of mallards in total estimated Wisconsin duck kill.

The adjusted U.S. Fish and Wildlife Service harvest estimates from Martin and Carney (1977) were considered to represent figures relatively free of response bias. Duck harvest estimates from Department of Natural Resources (the former Wisconsin Conservation Department) mail surveys were available for six of the same years as the U.S. Fish and Wildlife Service estimates. The Department of Natural Resources estimates were found to be approximately 25 percent greater than the U.S. Fish and Wildlife Service harvest figures (March 1976:208). This was assumed to be due to response bias on the part of respondents to the Department of Natural Resources survey. Therefore all the previous Wisconsin Conservation Department estimates were multiplied by 0.75 to adjust for this potential bias. In 1949-51, when mallards were not recorded as separate entries on Wisconsin hunter report cards, the average percent mallards in the 1932-48 harvest was used to estimate the proportion of the total duck harvest represented by mallards.

Duck Stamp Sales, Number of Active Hunters and Hunter-Days. Annual duck stamp sales in Wisconsin were taken from Jahn and Hunt (1964), Schroeder et al (1974a;) and Carney et al. (1978).

Beginning with the 1959-60 season, the U.S. Fish and Wildlife Service annually estimated the number of active adult waterfowl hunters in each state and also, since the 1960-61 season, the number of days of waterfowl hunting activity. This information was taken from the appropriate Waterfowl Status Reports and from Schroeder et al. (1974b).

The 1960-72 mallard harvest estimates were divided by the 1000's of active waterfowl hunters and 1000's of hunter-days to obtain an estimate of mallards bagged per 1000 active hunters per 1000 hunter-days. This value is an index to the annual individual return per amount of hunting effort.

Mallard Bag-Days. The mallard daily bag limit was multiplied by the length of the duck hunting season in days (March 1976:366) to obtain the annual number of mallard "bag-days." Bag-days represent an index to the restriction or liberalization of the annual duck hunting season in regard to mallards. For example, a 2-mallard daily bag limit and a 45-day duck season would equal 90 mallard bag-days of hunting opportunity, not considering possession limits.

Factors Affecting Annual Hunter Numbers and Harvest. To gain insight into which factors caused changes in the numbers of duck hunters in the field as well as which factors caused changes in their annual harvest, we ran simple regression analyses between the Wisconsin mallard harvest estimates, duck stamp sales, number of active adult hunters, number of hunter-days, days per hunter, opening dates, duck season lengths, daily bag limits on mallards and mallard bag-days. Two factors that cannot be adequately measured but may influence the harvest and hunter participation are waterfowl populations in Wisconsin each fall and weather as it determines migration patterns and daily bird activity. Hopefully, additional investigation, using some form of multi-variate analysis, would more clearly define the roles of various factors. Krause et al. (1970) have already made considerable progress in predicting waterfowl harvests from annual regulations.

Results and Discussion

Mallard Bag-Days of Hunting Opportunity. Table 26 lists mallard "bag-days" of hunting opportunity for the 1932-72 waterfowl seasons in Wisconsin. The most liberal hunting season on mallards during the 41 years was 1,200 bag-days in 1944, and the most restrictive was 25 bag-days in 1962. In general, the 1932-46 hunting seasons, with a mean of 566 bag-days and a standard error of $\pm$ 65, and the 1952-58 seasons, with a mean of 254 $\pm$ 12 bag-days, were the more liberal periods in terms of mallard regulations. The 1961-69 seasons, with a mean of 57 $\pm$ 8 bag-days, were the most restrictive, having 90 bag-days or less each year (Table 26). Mallard regulations in the 1970's were more liberal than in the 1960's, but were more restrictive than in earlier periods.

Duck Stamp Sales. Wisconsin duck stamp sales have averaged slightly more than 100,000 annually since the Migratory Bird Hunting Stamp Act was enacted in 1934. However, sales did not regularly exceed 100,000 stamps until 1948 (Table 26). Since 1947, sales have dropped below 100,000 in only 3 years, 1961 through 1963. The early 1970's have been the peak sales years thus far, reaching an all-time high of 160,400 in 1971.

There was a direct relationship between the number of duck stamps sold and the number of mallard bag-days of opportunity. Stamp sales and mallard bag-days showed positive correlations during the pre-World War II years, 1934-41 ($r = 0.859$, $P < 0.01$), and during 1960-72, a period of generally restrictive regulations (Table 27). Bag-days and stamp sales were also correlated for the entire 1946-72, or post-war, period ($r = 0.447$, $P < 0.05$). Of the two components, season length and daily bag limit (incorporated into bag-days), the number of days of hunting opportunity had the higher "r" values for all periods. Presumably more duck stamps would have been sold during

Table 26. *Mallard "bag-days" and duck stamp sales in Wisconsin.*

Year	Bag-Days[a]	Thousands of Duck Stamps Sold[b]	Year	Bag-Days[a]	Thousands of Duck Stamps Sold[b]	Year	Bag-Days[a]	Thousands of Duck Stamps Sold[b]
1932	780	-	1946	315	103.0	1960	150	109.9
1933	636	-	1947	120	91.3	1961	60	89.8
1934	360	40.3	1948	120	101.8	1962	25	73.1
1935	300	35.2	1949	160	103.8	1963	70	94.2
1936	300	49.0	1950	136	104.0	1964	80	104.5
1937	300	61.8	1951	176	103.4	1965	40	105.8
1938	450	79.7	1952	220	134.4	1966	90	108.8
1939	450	84.1	1953	220	131.0	1967	80	110.5
1940	600	89.3	1954	220	127.4	1968	30	105.1
1941	600	89.2	1955	280	131.1	1969	40	122.3
1942	700	83.5	1956	280	130.3	1970	110	151.5
1943	700	66.3	1957	280	115.2	1971	200	160.4
1944	1,200	75.2	1958	280	109.3	1972	200-males 194-females	138.0
1945	800	83.7	1959	150	100.6			

[a]Mallard daily bag limit x duck season length in days.

[b]"Year" refers to a particular Wisconsin duck season. Sales data from Jahn and Hunt 1964, Crissey 1962 and Schroeder et al. 1974b.

Table 27. *Correlation coefficients obtained in comparisons between Wisconsin mallard harvest estimates in 1960-72 and several factors thought to affect the harvest and associated hunter participation.*

	"r" Values							
	Opening Date	Duck Season Length	Mallard Daily Bag Limit	Mallard Bag-Days	Wis. Duck Stamp Sales	# of Active Adult Hunters	# of Hunter-Days	Days Per Hunter
Harvest	-0.599*	0.777**	0.589*	0.746**	0.811**	0.819**	0.754**	0.166
Stamp Sales	-0.789**	0.845**	0.616*	0.728**	-	0.991**	-	-
Active Hunters	-0.773**	0.845**	0.478	0.696**	-	-	0.988**	-
Hunter-Days	-	0.836**	0.552	0.691**	-	-	-	0.390

* $P < 0.05$

**$P < 0.01$

Table 28. *Thousands of active adult waterfowl hunters, thousands of hunter-days of activity and average days afield per hunter during the 1959-72 Wisconsin waterfowl seasons.*[a]

Duck Season	% Duck Stamps Sold to Potential Adult Hunters	# of Active Adult Hunters	# of Hunter-Days	Average Days Afield
1959	-	92.9	-	-
1960	-	96.0	753.6	7.8
1961	-	79.8	537.1	6.8
1962	-	63.5	452.9	7.2
1963	99.5	75.9	516.6	5.2
1964	99.5	86.3	646.2	5.8
1965	98.3	92.7	748.3	6.7
1966	98.9	94.7	665.0	5.8
1967	98.9	95.1	722.3	6.2
1968	99.1	88.6	663.7	6.0
1969	99.5	110.7	897.3	6.9
1970	99.7	131.4	1,171.7	7.2
1971	98.9	135.5	1,139.9	6.7
1972	99.3	119.0	1,025.0	7.0
Mean	99.2	97.3	764.6	6.6

[a]Data taken from the following sources: Atwood and Wells 1961, Crissey 1962 and 1963, Hansen 1964, Hansen and Hudgins 1965 and 1966, Hansen 1967, Martinson et al. 1968 and 1969, Chamberlain et al. 1971 and 1972, and Benning et al. 1975.

1942-44, as predicted by the higher numbers of bag-days (Fig. 10), if the war had not been in progress.

The overall relationship between bag-days and stamp sales for 1934-72 was negative ($r = -0.376$, $P < 0.05$). Assuming that mallard populations during the period were either stable or declining and that numbers of hunters were increasing, then regulations had to become more restrictive over time, creating a negative relationship between stamp sales and days of opportunity. Continental mallard populations in the 1950's were generally higher than in the 1960's when spring populations declined below 10 million breeding birds (Pospahala et al. 1974). This decline resulted in generally more restrictive regulations in the 1960's compared to the previous 30 years, and since duck stamp sales had increased steadily after 1945, a negative relationship was established over the 41 years.

Active Adult Hunters and Total Waterfowl Hunter-Days. Although 99+ percent of the duck stamps sold in Wisconsin went to potential hunters (Table 28), not all purchasers went afield in a given year. Comparison of the estimated numbers of active adult hunters with Wisconsin duck stamp sales showed that 86 ± 8 percent (S.E. of mean) of the stamps were sold to active adult hunters (Table 28). Juvenile hunters under the age of 16 years are not required to purchase duck stamps and are not represented in the estimated number of active hunters.

Annual duck stamp sales and the number of active adult hunters were strongly correlated during 1960-72 (Table 27). This substantiates the validity of using duck stamp sales as annual indexes to trends in the numbers of adult waterfowl hunters actually

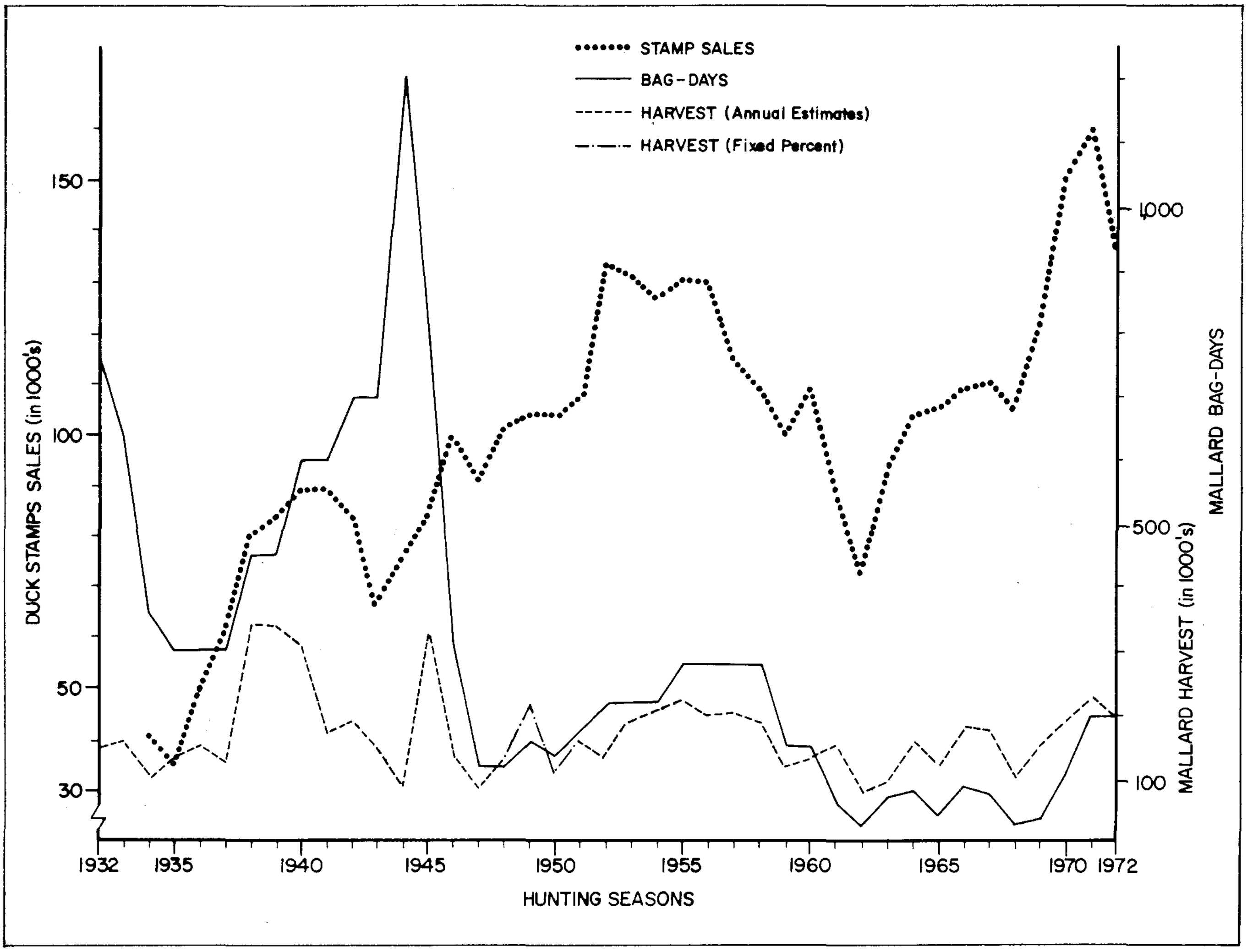


FIGURE 10. *Duck stamp sales, mallard bag-days of hunting opportunity and estimated mallard harvests in Wisconsin during 1932-72.*

afield in Wisconsin. Hunter-days remained less than 800,000 until 1969 (Table 28). When seasons became more liberal in 1970-72, hunter-days exceeded one million annually.

Percent Mallards in the Harvest. During 1932-48, Wiconsin hunters responding on voluntary Wisconsin Conservation Department report cards identified an average of 36.5 percent of their retrieved duck kill as "mallards." During the 1959-72 seasons, mallards averaged 33.8 percent of the Wisconsin duck harvest (Geis and Carney 1961; Martin and Carney 1977). From 1959 through 1965, mallards represented 23-45 percent of the Wisconsin harvest. Since 1966, mallards have represented between 28-34 percent of the harvest. Both the hunter reports from the 1930's and 1940's and the more refined system of judging species composition from actual wings submitted, indicated that about one-third of the ducks shot and retrieved in Wisconsin were mallards.

Retrieved Mallard Harvest Estimates. Trends in annual retrieved mallard harvest in Wisconsin are presented in Figure 10; annual harvest estimates for mallards and all ducks are included in Appendix B. There is no way to determine the accuracy of the harvest estimates or measure the variability associated with estimates for individual seasons; valid trends in the magnitude of the harvest should be indicated, however.

Highest mallard harvests, about 340,000 ducks, were estimated in 1938 and 1939 (Fig. 10). Since 1950, the highest mallard harvest was 225,400 birds in 1971. The lowest post-1950 harvest, 77,600 mallards, was recorded in 1962.

Table 29 presents the mean duck stamp sales, mean mallard harvest for 1932-39, 1940-49, 1950-59, 1960-69 and 1970-72, and mean mallards bagged per duck stamp sold during the same periods. The 41-year mean harvest was 169,800 $\pm$ 17,300 mallards. Mean mallard harvest per duck stamp sold in 1934-72 was 1.8 $\pm$ 0.2 birds. Confidence intervals for means were calculated at $P = 0.10$ rather than $P = 0.05$ because of the many biases inherent to the annual harvest estimates.

Means for mallard harvest and harvest per stamp sold were highest in 1970-72 and 1934-39, respectively (Table 29). The 10-year mean harvest estimates declined progressively after 1939. Mean number harvested per stamp sold also declined for each 10-year period. The 1950-59 and 1970-72 mean mallard harvest estimates (174,300 and 202,300 birds) were significantly greater at $P < 0.10$ and $P < 0.05$ respectively, than the 1960-69 mean harvest (134,800 birds). All other comparisons between periods were not significant at $P < 0.10$.

In terms of mallards harvested per duck stamp sold, mean values for 1940-72 (1.3 to 2.0) were all significantly less than the 1934-39 mean (3.2) at P 0.05. The 1940-49 mean (2.0) was also greater than the 1960-69 mean (1.3) at $P < 0.05$. After 1949, there was no difference at $P < 0.10$ in mean numbers of mallards harvested per stamp sold in Wisconsin.

Mallards Harvested Per 1,000 Active Hunters Per 1,000 Hunter-Days. The mean of mallards harvested per 1,000 active hunters per 1,000

Table 29. *Mean values for annual mallard harvest estimates, mallards harvested per duck stamp sold, plus 90% confidence intervals, and duck stamp sales in Wisconsin during 1932-72.*[a]

Hunting Seasons	In Thousands: Mean Mallard Harvest[b]	In Thousands: 90% Confidence Interval	In Thousands: Mean Duck Stamp Sales	Mean Mallards Harvested Per Duck Stamp Sold	90% Confidence Interval
1932-39[c]	184.5	118.9-250.1	58.4	3.2	2.4-4.0
1940-49	178.8	130.4-227.2	88.7	2.0	1.5-2.5
1950-59	174.3	151.9-196.7	119.2	1.4	1.3-1.6
1960-69	134.8	113.2-156.4	110.8	1.3	1.1-1.5
1970-72	202.3	175.2-229.4	150.0	1.3	1.1-1.5
1932-72 Mean	169.8	152.5-187.1	100.1	1.8	1.6-2.0

[a]Annual harvest data are taken from Wisconsin Department of Natural Resources files (1932-51) and Martin and Carney (1977); annual duck stamp sales are listed in Table 26.

[b]Harvest data are adjusted for response bias.

[c]Duck stamps were not required until 1934.

Table 30. *Number of mallards harvested in Wisconsin per 1000 active hunters per 1000 hunter-days during 1960-72.*

Year	Number of Mallards Harvested Per 1000 Active Hunters Per 1000 Hunter-Days	Year	Number of Mallards Harvested Per 1000 Active Hunters Per 1000 Hunter-Days
1960	2.0	1967	2.6
1961	3.5	1968	1.6
1962	2.7	1969	1.6
1963	2.5	1970	1.2
1964	2.7	1971	1.4
1965	1.6	1972	1.6
1966	3.0		
1960-64 Mean (90% Confidence Interval)			2.7 (2.2-3.2)
1965-69 Mean (90% Confidence Interval)			2.1 (1.5-2.7)
1970-72 Mean (90% Confidence Interval)			1.4 (1.1-1.7)

hunter-days was significantly higher ($P < 0.10$) in 1960-64 than the mean for 1970-72 (Table 30). The 1965-69 mean was not significantly different ($P < 0.10$) from the 1960-64 or 1970-72 means. Average numbers of active hunters increased from 80,300 in 1960-64 to 96,400 in 1965-69, then rose to 128,600 in 1970-72. The number of hunter-days averaged 581,300 in 1960-64, 739,300 in 1960-65 and 1,112,200 in 1970-72.

Factors Affecting Hunter Participation and Mallard Harvest. All factors in Table 27 except days per hunter were significantly correlated at $P < 0.05$ with the 1960-72 mallard harvests in Wisconsin. Other than the effect of opening date (Fig. 11), all factors had a positive relationship with harvest.

A number of the factors in Table 27 are also highly correlated with each other, and as a result, "r" values obtained with harvest would have little meaning. Placing the several components relating to harvest in a chronological sequence and introducing a new factor, the 1960-72 fall flight estimates for North America (calculated from data in Geis et al. 1969, Pospahala and Anderson 1972 and Sorenson et al. 1973) into the analysis, gave a more useful interpretation of these relationships. Since 1948, hunting season frameworks have been based on trends in populations and vulnerability of the birds within individual flyways (Anderson and Henny 1972). Regulations are selected which will produce a harvest consistent with the predicted fall mallard flight (Geis et al. 1969). During 1959-72, mallard hunting regulations in Wisconsin (Table 26 and March 1976:366) changed annually, presumably in response to differences in the regulations enacted by the U.S. Fish and Wildlife Service. The frameworks should have reflected trends in continental mallard populations. Fall mallard flight estimates used here do not represent the actual forecasted values, since they are based on corrected age ratios and harvest estimates obtained after the hunting season (Anderson and Henny 1972). The adjusted fall flight estimates should, however, show the same trends in continental mallard numbers as the original fall forecasts.

Mallard bag-days of hunting opportunity were significantly correlated with the continental fall flight estimates during 1960-72 (Table 31). Season length apparently was the major adjustment made in annual regulations since it also was significantly related to fall flights (Table 31). Although daily bag limits on mallards were generally lower in years with poorer fall flights, the two variables were not correlated at $P < 0.05$. Apparently, at least during 1960-72, hunting regulations in Wisconsin varied directly with the anticipated supply of mallards available in the fall. Although bag-days for mallards were changed only once between 1955 and 1959 (from 280 in 1955-58 to 150 in 1959), the reduction in opportunity was also in direct response to a decline in the estimated fall flight, from 25-30 million mallards in 1955-58 to 18 million in 1958. Bag-days and fall flight were significantly correlated for that same period ($r = 0.902$, 3 df, $p < 0.05$).

Assuming that preseason announcements of fall flight prospects and hunting season frameworks directly influence the number of persons choosing to hunt each fall, then fall flight estimates and mallard bag-days should also be related to the number of active hunters afield. Significant correlations between those three variables during 1960-72 (Tables 27 and 31) suggested that they were directly related. Duck stamp sales in 1955-59 (used as an index to hunter numbers in those seasons) were not correlated at $P < 0.05$ with the estimated fall flight or bag-days of opportunity for mallards. For some unknown reason, even though the fall flight estimates and number of bag-days did not decline until the 1959 season, duck stamp sales dropped annually between 1956 and 1959.

The number of active adult hunters and season length should be the two main components influencing numbers of hunter-days of activity. Numbers of hunter-days shown in Table 28 also include estimated days of hunting activity by hunters under 16 years old (Hansen and Hudgins 1966). Since hunter-days are estimated directly from the number of active hunters (times their average days afield) except for the additional activity by hunters under 16, comparison of the two variables is essentially meaningless. However, the correlations between season length and hunter-days and between season length and number of active adult hunters (Table 27) would indicate that longer hunting seasons attract more participants and/or result in more days of hunting activity.

The annual mallard harvest in Wisconsin results from a complex series of interrelated factors. There was a significant relationship between the continental fall flight estimate and the harvest in Wisconsin (Table 31). Whether the changes in harvest represented a direct response to fluctuations in numbers of mallards, or an indirect response to regulation changes, hunter numbers and days of hunting activity, is not known. Season length, mallard daily bag limit, number of active adult hunters and the number of hunter-days were all significantly correlated with the 1960-72 harvest. Number of

Table 31. *Correlation coefficients obtained between continental fall mallard flight estimates in 1960-72, and harvest, numbers of active adult hunters and mallard hunting regulations in Wisconsin.*

Variables Compared	"r" Values	Level of Significance
Fall Flight Estimate[a]:		
Mallard Bag-Days in Wisconsin	0.606	$P < 0.05$
Mallard Daily Bag Limit in Wisconsin	0.506	$P > 0.05$
Wisconsin Duck Season Length	0.767	$P < 0.01$
Number of Active Adult Hunters:		
Fall Flight Estimate	0.714	$P < 0.01$
Wisconsin Mallard Harvest:		
Fall Flight Estimate	0.646	$P < 0.05$
Total Duck Harvest in Wisconsin	0.882	$P < 0.01$

[a]Calculated from Geis et al. 1969, Pospahala and Anderson 1972, and Sorenson et al. 1973.

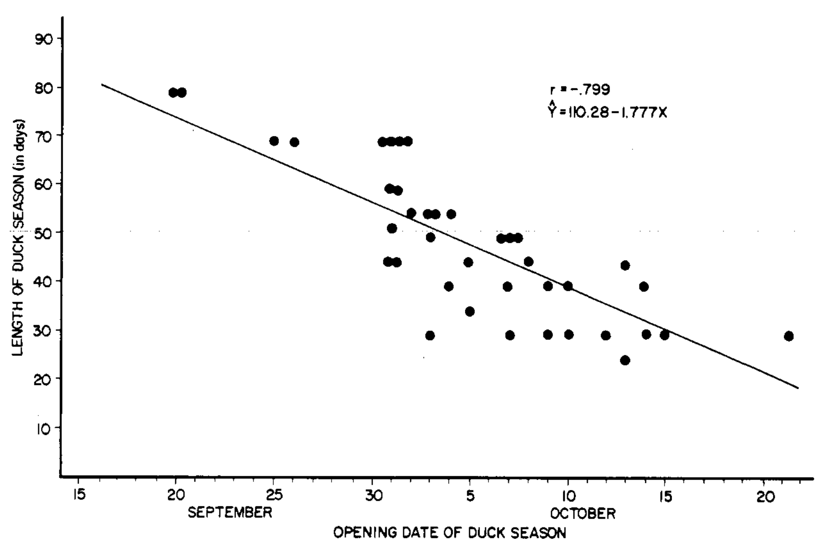


FIGURE 11. *Relationship between the opening date of the Wisconsin duck season and the season length in days during 1932-72.*

hunter-days produced the highest "r" value when compared with harvest (Table 27). Since the estimated harvest is derived indirectly from the ducks bagged per successful active hunter, mallards harvested and active hunters would have an expected high correlation; hunter-days, which are highly correlated with number of active hunters, would also be directly related before any biological considerations were involved. Since mallards have represented a relatively constant proportion of the total duck harvest (Martin and Carney 1977), mallard harvest and total duck harvest would also have a strong direct relationship.

A general conclusion that *supply* (the fall flight of mallards) influences legislated *opportunity* (season regulation framework) which in turn affects *demand* (number of hunters) and *effort* (number of hunter-days) might be drawn. All these factors, plus the unknown effects of weather and migration chronology, were interrelated with the annual take of mallards. Which of these factors, if any, has the primary influence cannot be determined at this stage of analysis.

A negative relationship between the 1932-72 mallard harvests and choices of opening dates apparently was the result of later openings being associated with shorter hunting seasons (Fig. 11). Since shorter seasons were usually selected in years with fewer mallards forecasted, daily bag limits were also lower in years with later openings. Duck stamp sales and numbers of active hunters were also negatively correlated ($P < 0.05$) with the opening date. Again, this was related to more restrictive regulations and/or pessimistic fall flight forecasts attracting fewer hunters.

Except for estimates of 300,000+ mallards bagged in 1938-40 and 1945, the 1932-72 harvest in Wisconsin had a range of 77,600-225,400 birds (Fig. 10). Despite more restrictive hunting regulations on mallards during 1961-69, the range of annual harvest estimates in those seasons (77,600-186,600 birds) were not a great deal different than ranges during 1932-48 (83,400-187,600 birds if the four 300,000+ years are excluded) when hunters provided species composition of their bag, or during 1949-60 (109,400-220,500 birds) using a fixed 36.5 percent of the total duck harvest or U.S. Fish and Wildlife Service estimates of species composition.

Looking at mean values and their confidence intervals (Table 34), the apparent differences in average mallard harvest in Wisconsin since 1949 would seem to be directly associated with fluctuations in the number of waterfowl hunters, as reflected in duck stamp sales. While the mean number of mallards harvested per duck stamp sold has remained relatively stable through the 1950's, the 1960's and at least through 1972, the mean numbers of mallards harvested was lower in 1960-69 than in 1950-59 or 1970-72. Prior to 1950, the numbers of mallards available to hunters may have exerted a greater influence on the total birds shot than did the number of hunters afield. With the number of mallards available in the past 25 years, it was the number of hunters rather than the number of ducks that seems to have determined the size of the harvest. Regulations (and initially the fall flight forecast) were indirectly involved in the management of harvest since season frameworks had a direct influence on the number of active hunters and days of hunting activity.

As far back as the 1930's and 1940's, the presence of fewer hunters, rather than greater abundance or availability of mallards, could have produced a larger average harvest per duck stamp sold in Wisconsin. Fewer hunters meant less crowding and disturbance, and provided better shooting conditions for those afield. Such a hypothesis may have had some validity in the early 1930's, when numbers of ducks reached their lowest point in modern history (Anderson and Henny 1972). The major drought period began about 1929, peaked in 1934 and continued on through about 1938 (Salyer and Gillett 1964).

Although mallard daily bag limits in 1932-38 remained at 10-12 birds, season lengths in 1934-37 were reduced to 30 days (March 1976:366). Average estimated harvest of mallards in 1932-37 (132,600 birds) was generally less than mean harvests in the 1940's and 1950's, and was similar to mean harvest in the 1960's (Table 29). Despite the low continental duck populations and short seasons, 2.0-3.6 mallards were harvested per duck stamp sold in Wisconsin during 1932-37. In 1938, when continental populations were still recovering from from the drought, the Wisconsin mallard harvest estimate was the highest recorded during 1932-72 and the harvest per duck stamp sold reached the 41-year high of 4.3 mallards. About 80,000 duck stamps were sold in Wisconsin during 1938, indicating that only 75,000+ adult hunters were afield. Despite the relatively low continental duck numbers, these hunters, with the addition of 15 days more of hunting opportunity, were able to bag more than double the number of mallards estimated harvested in any of the 6 previous years. The average success at bagging mallards was considerably better (for whatever the reason) in the 1930's and early 1940's, than it was during the late 1940's and on through the 1950's and 1960's.

In the 27 years since duck stamp sales first surpassed the 100,000 mark in Wisconsin (purchases first exceeded 100,000 in 1946), mallards harvested per duck stamp sold has exceeded 2.0 birds only in 1949, and was more than 1.5 birds in only eight of the other 26 seasons. For 5 consecutive years (1954-58) when spring continental mallard populations were at high levels (Pospahala et al. 1974) and fall flights exceeded 20 million mallards annually (from Geis et al. 1969), mallards harvested per duck stamp sold in Wisconsin did average 1.6, with a range of 1.5-1.7.

Between 1934-45, the average mallard harvest per duck stamp sold was 2.8 birds, with annual values less than 2.0 mallards in only 2 years and less than 1.5 in only one. Even though duck populations recovered substantially from the low levels of the drought years, the average harvest per duck stamp sold was never again higher than the mean recorded during 1934-45. These figures indirectly suggest that the harvest was more strongly related to the number of hunters and their annual success than to the number of mallards available. Also, after 1948, hunting regulations apparently were successful, either directly or indirectly through influencing hunter numbers and participation, in controlling harvest.

An alternative explanation, at least for the higher Wisconsin harvests between 1937 and 1946, would be that the state's local ducks were contributing a larger segment of the kill. Since habitat in Wisconsin would have been less affected by the drought, locally breeding mallards may have maintained their usual productivity. Also, the size of the breeding populations within Wisconsin might have been larger in that period. There is no information to substantiate or refute this explanation, however.

An estimate of the number of mallards bagged per active adult hunter per day of effort was not available until 1960 (Table 30). Mean numbers of mallards harvested per 1,000 active adult hunters per 1,000 hunter-days were 1.9, 2.9 and 1.4 birds respectively, for 25-40, 60-80 and 90-200 bag-day seasons. The 95 percent confidence intervals for all 3 means overlapped considerably, however. Although mallard bag-days of opportunity increased substantially in the 1970-72 hunting seasons, mallards bagged per 1,000 active hunters per 1000 hunter-days did not show a corresponding increase until 1972. Instead, mallards bagged per 1,000 active adult hunters per 1,000 hunter-days were generally less than during the four most restrictive seasons, 1962, 1965, 1968 and 1969 (Tables 26 and 30). Continental fall flight estimates during those four years averaged only 15 million mallards (from Geis et al. 1969), compared to an average of 18 million during 1970-72 (from Pospahala and Anderson 1972 and Sorenson et al. 1973).

Also, on the average, hunters bagged almost twice as many mallards per day afield in the 1960-61, 1963-64 and 1966-67 seasons than they did during 1970-72, although mallard bag-days exceeded 80 in only two seasons of the first three groups of years (Table 26). Fall flights averaged 16 million mallards continentally in 1960-61, 1963-64 and 1966-67 (from Geis et al. 1969; Pospahala and Anderson 1972; Sorenson et al. 1973). Increased numbers of active hunters in 1970-72, plus more total activity afield are suggested as the reasons for the lowered average individual return.

During 1970-72, there were approximately 33,700 to 48,300 more active adult Wisconsin waterfowl hunters (mean of 44,100 more) than during 1960-64 and 1966-67. There were also some 418,600 to 530,900 more hunter-days (mean of 498,800 more) of activity in 1970-72 than during 1960-64 or 1966-67. These additional hunters and greater total activity apparently kept the 1970-72 individual return per day of effort at levels associated with the more restrictive 1965, 1968 and 1969 hunting seasons.

That excessive numbers of hunters afield could affect success is further evidenced by the 1960 and 1962 data. In 1960, the number of mallard bag-days (150) was the third most liberal during 1960-72, but mallards bagged per 1,000 active hunter per 1,000 hunter-days was only 2.0. The number of active hunters was 96,000, the highest level reached during 1959-68, and the number of hunter-days was 753,600, or again the highest level recorded during 1960-68. The continental fall mallard flight of 20 million in 1960 (from Geis et al. 1969) was below the 1955-59 average but was higher than any other estimated fall flight during 1959-72. More active hunters and hunter-days in 1960 apparently resulted in a return per hunter per day that averaged lower than in six of the next eight seasons (Table 30).

In 1962, the most restrictive season on mallards over a 41-year period (25 bag-days), 2.6 mallards were harvested per 1,000 active adult hunters per 1,000 hunter-days. There were only 63,500 active hunters and only 452,900 hunter-days of activity—both were lowest values recorded for 1960-72. Less crowding and activity apparently enabled active hunters to maintain a reasonably high return per day of effort, even with a reduced fall flight of only 13 million mallards (from Geis et al. 1969), a 1-mallard daily bag limit and only 25 days of hunting opportunity.

Effect of Regulations on Kill Rate in Wisconsin. Increasing the bag-days of mallard hunting opportunity in Wisconsin from 25-40 to 60-80 had no effect on adult female kill rate in the state (Table 32). However, for seasons when bag-days of opportunity equalled 90-200, the overall adult female kill rate in Wisconsin was significantly greater ($P < 0.01$) than overall Wisconsin kill rates for that cohort in 25-40 or 60-80 day seasons.

Juvenile mallards had higher overall Wisconsin kill rates in 60-80 and 90-200 bag-day seasons than in 25-40 bag-day seasons (Table 32). Increasing bag-days from 60-80 to 90-200 did not significantly change juvenile kill rates in Wisconsin.

Adult male kill rate in Wisconsin was significantly higher in 90-200 bag-day seasons than in 60-80 bag-day seasons. However, kill rate in Wisconsin for that cohort was higher in 25-40 bag-day seasons than in seasons with 60-80 bag-days and was not different from the kill rate from 90-200 bag-day seasons (Table 32).

Annual Wisconsin kill rates were not correlated at $P < 0.05$ with bag-days of opportunity for any sex or age cohort during 1961-72. If hunting regulations were, in fact, set to maintain a relatively constant rate of hunting kill, then this lack of correlation would be expected.

Similarly, no significant correlations were obtained at $P < 0.05$ between the 1961-72 Wisconsin kill rate for any cohort and hunter-days, season length, daily bag limit, opening date or the number of active adult hunters.

During 1961-72, changes in mallard hunting regulations and the estimated rate of hunting kill in Wisconsin were not directly related. Apparently regulations enacted (which were changed in response to anticipated fall populations) during those seasons were at least partially successful at minimizing fluctuations in rates of hunting kill. However, these adjustments were not perfect and kill rates for most sex-age cohorts reached significantly higher levels in the more liberal seasons (Table 32). Alternatively, kill rates must have fluctuated independently of mallard hunting regulations in Wisconsin.

"Hunting regulations influence the proportion of migratory game bird populations that are harvested which in turn influences annual mortality rates" (Geis 1963). This would be true only if hunting mortality was additive and regulations were not adjusted to mallard population levels, which apparently was done during the 1960's. Also, Jessen (1970) concluded that hunting losses and total mortality incurred by local mallards in Minnesota did not decline until regulations became extremely restricted in the 1962 and 1965 seasons. Despite "major" annual differences in numbers of hunters and total duck harvest during 1962-67, hunting losses for local mallards in Minnesota were not greatly different from those of the 1950's (Jessen 1970). Anderson and Burnham (1976) were unable to demonstrate increased mallard survival rates even in years of restrictive hunting regulations and lower harvests and rates of harvest. They did, however, find evidence that survival in 1964, a liberal season in terms of "high" harvest rate and only "average" fall flight, was lower than in the restrictive seasons of 1962 and 1965.

Krause et al. (1970) have shown that hunting regulations are also effective influences on harvest. Their model, based on past daily bag limits, season lengths and harvest data, was able to closely predict the size of the mallard harvest that would occur under a given set of hunting regulations in Wisconsin and other Mississippi Flyway states.

Kill rates within Wisconsin on local mallard populations during 1961-72 seem to further support Jessen's (1970) conclusion that only major changes in regulations can significantly alter hunting losses on local birds. Seasons with 40 or less mallard bag-days produced lower overall kill rates in Wisconsin than rates recorded in seasons with 60-80 or 90-200 bag-days (Table 32).

Total kill rates for local mallards were similar in 25-40 and 60-80 bag-day seasons, but during 90-200 bag-day seasons, the total kill rate on locals was significantly higher than during either the 25-40 or 60-80 bag-day seasons (Table 32). Kill rates outside Wisconsin were not different between seasons, suggesting a more constant rate of hunting losses once locals left Wisconsin. Rate of kill on juvenile mallards in Wisconsin under 60-80 bag-days may be the maximum that can be reached regularly within the state, since after bag-days exceeded 80, the rate of kill in Wisconsin did not change (Table 32). It would seem that on the average, the 60-80 bag-days season would have been the best choice for maximum return of local mallards to Wisconsin hunters in 1961-72 and still have had the least effect on future populations. When bag-days exceeded 80, additional hunting losses did not greatly benefit Wisconsin hunters and only increased the number of active hunters and days of hunting activity. This increased hunting pressure apparently did raise the rate of hunting kill on adult females.

Although the kill rate outside Wisconsin did increase significantly for adult females in 60-80 bag-day seasons

Table 32. *Chi-square values obtained in comparisons of rates of hunting kill from Wisconsin hunting seasons with different mallard bag-days of hunting opportunity.*[a]

Age-Sex Cohort and # of Bag-Days	Chi-Square Values Obtained in Kill Rate Comparison[b]: Kill Rates in Wisconsin	Kill Rates Outside Wisconsin	Total Kill Rates
Adult Males:			
25-40 vs. 60-80	13.72** (0.14 - 0.10)	(0.16 - 0.17)	2.92 (0.30 - 0.27)
25-40 vs. 90-200	0.32 (0.14 - 0.13)	(0.16 - 0.27)	41.01** (0.30 - 0.40)
60-80 vs. 90-200	6.56* (0.10 - 0.13)	(0.17 - 0.27)	66.99** (0.27 - 0.40)
Adult Females:			
25-40 vs. 60-80	0.00 (0.11 - 0.11)	3.93* (0.09 - 0.10)	2.03 (0.20 - 0.21)
25-40 vs. 90-200	16.13** (0.11 - 0.13)	33.64** (0.09 - 0.13)	55.26** (0.20 - 0.26)
60-80 vs. 90-200	17.33** (0.11 - 0.13)	23.62** (0.10 - 0.13)	38.35** (0.21 - 0.26)
Immature Males:			
25-40 vs. 60-80	4.75* (0.33 - 0.36)	(0.19 - 0.18)	3.78 (0.52 - 0.54)
25-40 vs. 90-200	13.90** (0.33 - 0.38)	(0.19 - 0.21)	34.64** (0.52 - 0.59)
60-80 vs. 90-200	2.35 (0.36 - 0.38)	(0.18 - 0.21)	15.06** (0.54 - 0.59)
Immature Females:			
25-40 vs. 60-80	9.45** (0.28 - 0.31)	2.46 (0.13 - 0.14)	15.42** (0.41 - 0.45)
25-40 vs. 90-200	22.77** (0.28 - 0.33)	1.20 (0.13 - 0.13)	27.08** (0.41 - 0.46)
60-80 vs. 90-200	2.78 (0.31 - 0.33)	0.13 (0.14 - 0.13)	1.66 (0.45 - 0.46)
Locals (Both Sexes):			
25-40 vs. 60-80	5.06* (0.18 - 0.25)	0.01 (0.25 - 0.21)	0.58 (0.43 - 0.46)
25-40 vs. 90-200	25.30** (0.18 - 0.29)	2.54 (0.25 - 0.25)	18.51** (0.43 - 0.54)
60-80 vs. 90-200	1.53 (0.25 - 0.29)	1.34 (0.21 - 0.25)	4.76* (0.46 - 0.54)

[a]Each of the different bag-day groupings represented overall kill rates from 4 hunting seasons combined. Kill rates compared are in parentheses.

[b]2 x 2 contingency table with 1 df; reference values for chi-square were 3.84 for P = 0.05 (*) and 6.63 for P = 0.01 (**).

(from rates in 25-40 bag-day seasons), total rate of kill did not change (Table 32). In 90-200 bag-day seasons, however, the total kill rate incurred by adult females, their kill rate in Wisconsin and also their kill rate outside the state were all significantly higher ($P < 0.01$) than in 25-40 or 60-80 bag-day seasons. The most liberal hunting regulations apparently increased shooting losses on these birds in all regions.

For immature females, total kill rates were higher in 60-80 and 90-200 bag-day seasons than during 25-40 bag-day seasons (Table 32). The higher total kill rates were directly associated with significant increases in the Wisconsin kill rate. The rates of kill on immature females outside Wisconsin were similar in all comparisons. Also, 90-200 bag-day seasons did not result in kill rates higher than those attained in 60-80 bag-day seasons (Table 32).

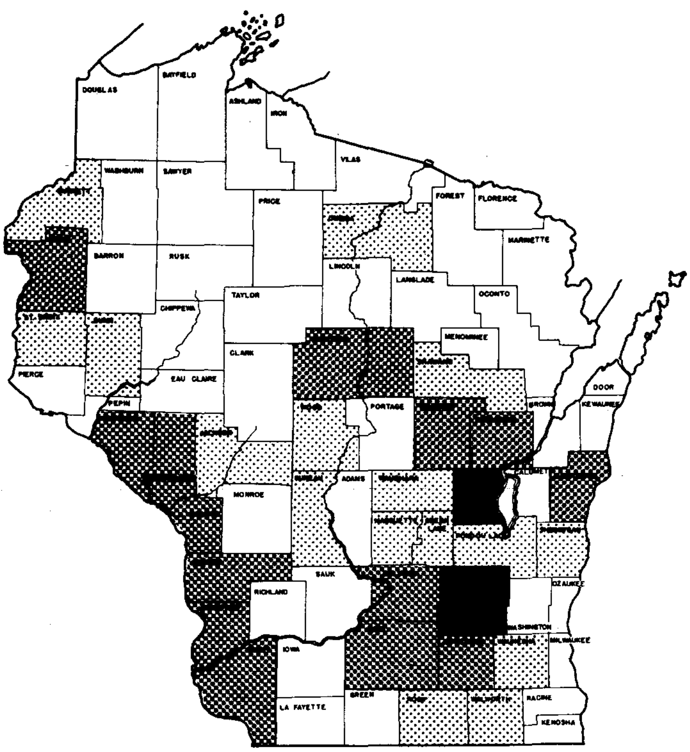
In general, seasons which increased mallard bag-days of opportunity from 25-40 to 60-80 increased the *rate of kill in Wisconsin* on immature female cohorts and locals but not on adult females. *Total rate of kill* increased only for immature females. When the number of bag-days was increased from 60-80 to 90-200, the adult female *kill rate in Wisconsin* also increased. In addition, *total rates of kill* on adult and immature females and locals all were higher in 90-200, bag-day seasons.

When 25-40 bag-day seasons were compared with 90-200 bag-day seasons, both the *total rate of kill* and the *rate of kill in Wisconsin* for adult females, immature females and locals increased under the more liberal regulations (Table 32).

Although changes in bag-days (between various seasons) were larger than observed changes in rates of hunting kill, there is considerable evidence that regulations effective during 1961-72 did not always tend to stabilize kill rates on mallards associated with Wisconsin. Differences in rates of kill were most pronounced, however, when the most restrictive seasons were compared with the most liberal. Liberalizing mallard regulations in Wisconsin to 90 bag-days or more, on the average, increased the exploitation rate of adult females.

Geographic Distribution of the Mallard Harvest in Wisconsin. Figure 12 presents mean percentages of the 1961-70 Wisconsin mallard harvest estimated in each county. Values for individual counties are based on the U.S. Fish and Wildlife Service's hunters mail surveys and mallard wings submitted to the parts collections from that county by Wisconsin hunters during the 10 years. Data were taken from Carney and Sorenson (1975:48 and 50). Major harvest areas were two blocks of counties in the southeast and central regions, Waupaca-Outagamie-Winnebago and Columbia-Dodge-Dane-Jefferson, and along the Mississippi River in Buffalo-Trempealeau-La Crosse-Vernon-Crawford-Grant counties. Those 13 counties combined to account for 53 percent of the average Wisconsin mallard harvest. The 5 counties representing the largest proportions of the total harvest (in decreasing order) were: Dodge, Winnebago, La Crosse, Columbia and Vernon. Three counties were in the southeast/central region and 2 were along the Mississippi River. Only 2 counties in the north central and far

1961-70



Adams	0.8	Marathon	2.8
Ashland	0.1	Marinette	0.5
Barron	0.8	Marquette	1.6
Bayfield	0.5	Menominee	Tr
Brown	0.6	Milwaukee	Tr
Buffalo	3.1	Monroe	0.6
Burnett	1.7	Oconto	0.8
Calumet	0.6	Oneida	1.4
Chippewa	0.4	Outagamie	2.8
Clark	0.1	Ozaukee	0.5
Columbia	3.8	Pepin	0.3
Crawford	3.0	Pierce	0.7
Dane	2.9	Polk	2.3
Dodge	11.4	Portage	0.2
Door	0.1	Price	0.5
Douglas	1.0	Racine	0.5
Dunn	1.4	Richland	0.2
Eau Claire	0.3	Rock	1.5
Florence	0.1	Rusk	0.1
Fond du Lac	1.8	St. Croix	1.8
Forest	0.3	Sauk	0.3
Grant	2.6	Sawyer	0.9
Green	0.3	Shawano	1.0
Green Lake	1.6	Sheboygan	1.0
Iowa	0.1	Taylor	0.5
Iron	0.1	Trempealeau	2.0
Jackson	1.1	Vernon	3.1
Jefferson	3.2	Vilas	0.8
Juneau	1.9	Walworth	1.4
Kenosha	0.3	Washburn	0.6
Kewaunee	0.3	Washington	0.2
La Crosse	4.7	Waukesha	1.6
Lafayette	0.2	Waupaca	2.1
Langlade	0.1	Waushara	1.2
Lincoln	0.4	Winnebago	8.6
Manitowoc	2.6	Wood	1.1

LEGEND

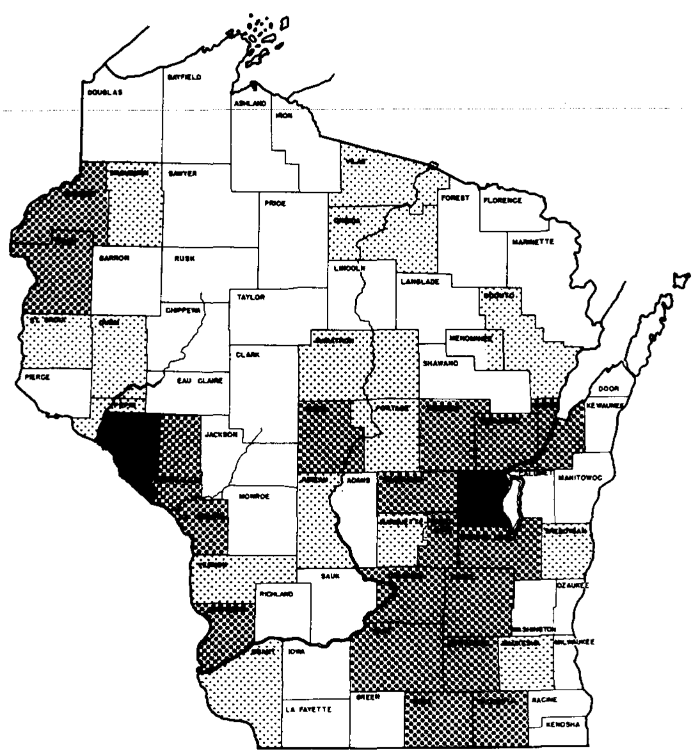
0.0-0.9 % of WISCONSIN TOTAL

1.0-1.9 % of WISCONSIN TOTAL

2.0-4.9 % of WISCONSIN TOTAL

5.0 % or more of WISCONSIN TOTAL

1938-43



Adams	0.5	Marathon	1.2
Ashland	0.3	Marinette	0.9
Barron	0.9	Marquette	1.8
Bayfield	0.5	Milwaukee	Tr
Brown	2.1	Monroe	0.5
Buffalo	6.2	Oconto	1.1
Burnett	2.9	Oneida	1.2
Calumet	0.6	Outagamie	2.3
Chippewa	0.6	Ozaukee	0.3
Clark	0.1	Pepin	1.2
Columbia	3.2	Pierce	0.6
Crawford	2.1	Polk	3.2
Dane	2.4	Portage	1.0
Dodge	4.5	Price	0.2
Door	0.2	Racine	0.8
Douglas	0.6	Richland	0.3
Dunn	1.0	Rock	2.6
Eau Claire	0.5	Rusk	0.3
Florence	0.2	St. Croix	1.3
Fond du Lac	3.2	Sauk	0.6
Forest	0.6	Sawyer	0.7
Grant	1.6	Shawano	0.7
Green	0.4	Sheboygan	1.2
Green Lake	2.4	Taylor	0.1
Iowa	0.3	Trempealeau	2.0
Iron	0.2	Vernon	1.6
Jackson	0.6	Vilas	1.0
Jefferson	2.9	Walworth	2.5
Juneau	1.2	Washburn	1.0
Kenosha	0.6	Washington	0.5
Kewaunee	0.1	Waukesha	1.8
La Crosse	4.3	Waupaca	4.1
Lafayette	0.2	Waushara	2.1
Langlade	0.3	Winnebago	8.3
Lincoln	0.2	Wood	2.0
Manitowoc	0.7		

FIGURE 12. *Comparison of the distribution of the 1961-70 mallard harvest in Wisconsin by county with harvest distribution during the 1938-43 period. County percentages represent average values for each period.*

north, Marathon and Polk, accounted for at least 2 percent of the state's total mallard harvest. Thirty-nine of Wisconsin's 72 counties each had less than 1 percent of the total harvest; 17 had between 1.0-1.9 percent; 14 had 2.0-5.0 percent; and only 2 had more than 5 percent. Although about half the harvest was concentrated in only a few counties, the remainder was relatively well-distributed over the other counties.

By comparing Figure 1 and Figure 12, there appears to be a relationship between counties with the higher proportions of the kill and also the greater breeding densities of mallards. Numbers of waterfowl hunters, as evidenced by county duck stamp sales shown in Schroeder et al. (1974a), were also higher in those counties or in the surrounding ones. The quality and amount of wetland habitat in these regions influences both breeding populations, numbers of hunters and harvest, and one factor cannot be isolated from the other.

Counties in Figure 12 were assigned to 1 of 4 regions after approximately quartering the state along the 45° latitude and 90° longitude lines. Counties having area in more than one region were assigned to the region containing the greater portion of the county. Fifty-eight percent of the 1961-70 average Wisconsin mallard harvest occurred in the southeast, 27 percent in the southwest, 10 percent in the northwest and only 5 percent in the northeast.

The annual mallard harvest during the 1930's and most of the 1940's was also estimated for individual counties in Wisconsin by voluntary hunter-report cards submitted to the Wisconsin Conservation Department. The average percentage of the total 1938-43 Wisconsin mallard harvest reported in each county is shown in Figure 12. Again, only 2 counties accounted for at least 5 percent of the total harvest. Comparison with the 1961-70 map showed that Winnebago County was one of the 2 highest kill counties in both periods, accounting for over 8 percent of the kill. Buffalo County, the second highest kill county, in 1938-43, was replaced by Dodge County in recent years. In 1938-43, more counties in southeast Wisconsin individually accounted for 3 percent or more of the kill than in 1961-70. Fewer counties along the Mississippi River had at least 2 percent of the kill in 1938-43, and an additional county in the north had over 1 percent of the kill in those years (Fig. 12).

When the percentages of the 1938-43 harvest for individual counties were assigned to the 4 regions, based on 45° latitude and 90° longitude, 55 percent of the mallard harvest occurred in the southeast, 26 percent in the southwest, 13 percent in the northwest and 6 percent in the northeast. Except for the slight decreases in the percent of harvest in northern regions and corresponding increases in the south, the overall regional distribution of mallard harvest in Wisconsin was about the same during 1961-70 as in 1938-43.

Counties with at least a $\pm$ 0.5% or more change in the proportion of the kill between 1938-43 and 1961-70 are indicated in Figure 13. Buffalo County, which had over 6 percent of the state mallard kill in 1938-43, showed the largest decline of any county. Habitat deterioration in Pool 5 of the Mississippi River may be at least partially responsible for Buffalo County's decline in importance. Other counties with large declines in their proportion of the harvest were Brown, Rock and Walworth. The decline in harvest in Brown County was probably indicative of the habitat deterioration along Green Bay, since percentages in Marinette, Oconto and Door counties also declined, but less than 0.5 percent. Loss of habitat on Lake Koshkonong (Jahn and Hunt 1964) and other wetlands in Rock and Walworth counties may have contributed to their decline. Surprisingly, the proportion of the kill in Winnebago County increased slightly even though marshy habitats on Lakes Poygan, Winneconne, Buttes des Morts, Rush and Winnebago have severely deteriorated in the 1950's and 1960's. Major diving duck flights through these lakes during the 1950's (Jahn and Hunt 1964) became drastically reduced in recent years.

Increased proportions of the harvest occurring in some counties (Fig. 13) could be indirectly attributed to the development of major waterfowl management projects in those counties. Marathon County, which gained 1.6 percent of the state harvest, includes a major portion of the Mead Wildlife Area which was activated in the early 1960's. In Manitowoc County, which gained 1.9 percent of the harvest, the Collins Marsh Wildlife Area was established during the 1960's. The best example is found probably in Dodge County, where both the Horicon Marsh Wildlife Area and the Horicon National Wildlife Refuge were activated in the 1940's to reflood the Horicon Marsh, which had been in a semi-drained condition since the early 1900's (Personius 1975). Dodge County gained almost 7 percent of the state mallard kill between 1938-43 and 1961-70. Recent development of the Crex Meadows area in Burnett County, the Grand River Marsh in Green Lake and Marquette counties and Eldorado Marsh in Fond du Lac county did not seem to have similar effects since mallard harvests declined in each county.

Distribution of fall flights of mallards, and the associated shooting pressure on these birds, apparently has not changed drastically at the regional level in the past 30-35 years. There was no strong evidence that the percent harvest which occurs along the Mississippi River had significantly increased in recent years. Instead the percent taken in the 3 counties south of La Crosse county (Vernon, Crawford and Grant) increased from 5.3 percent of the state's total in 1938-43 to 9.3 percent in 1961-70, while the percent taken in Pepin and Buffalo counties decreased, or increased only slightly in Trempealeau and La Crosse counties (Fig. 13).

Summary

The 1961-69 Wisconsin duck seasons were generally restrictive in terms of mallard bag-days (daily bag limit x season length) of hunting opportunity. The 1970-72 seasons were more liberal in terms of mallard regulations. Between 1934-72, an average of about 170,000 mallards were estimated shot and retrieved annually in Wisconsin.

Although the average mallard harvest estimates in 1950-59 and 1970-72 were higher than in 1960-69, the average number of mallards harvested per duck stamp sold did not change during the 23 years. The number of active adult hunters and hunter-days of activity increased during the 1970-72 seasons but the average return in mallards harvested per 1,000 active hunters per 1,000 hunter-days decreased or was no better than during the 1960-69 seasons. Excessive numbers of hunters spending more days afield are suggested as being responsible for the poorer average return.

Although mallard hunting regulations during 1961-72 were enacted with the general intent of minimizing fluctuations in the rate of hunting kill, kill rates were higher in 90-200 mallard bag-day seasons than during 25-40 season. Going from 60-80 to 90-200 bag-days also increased exploitation rates associated with the adult female mallard cohort banded in Wisconsin.

Hunting regulations seemed to have their greatest impact on harvest, etc. by influencing the number of hunters afield. Preseason fall flight predictions and the potential bag-days of opportunity for mallards were directly associated with the eventual number of active hunters.

Annual regulations effective for mallards (numbers of bag-days) were directly related to the preseason fall flight forecast; i.e. regulations were apparently being adjusted to match the expected supply of mallards. More mallard bag-days and a more optimistic fall flight prediction were characteristic of seasons with higher numbers of active adult hunters and more hunter-days of activity.

Seasons with 60-80 bag-days of mallard hunting opportunity appeared to be an optimum framework for Wisconsin, since individual return per unit of hunting effort was higher than in 90-200 bag-dag seasons. Also, in 60-80 bag-day seasons exploitation rates on adult female mallards did not increase over the rate in 25-40 bag-day seasons and were less than in 90-200 bag-day years.

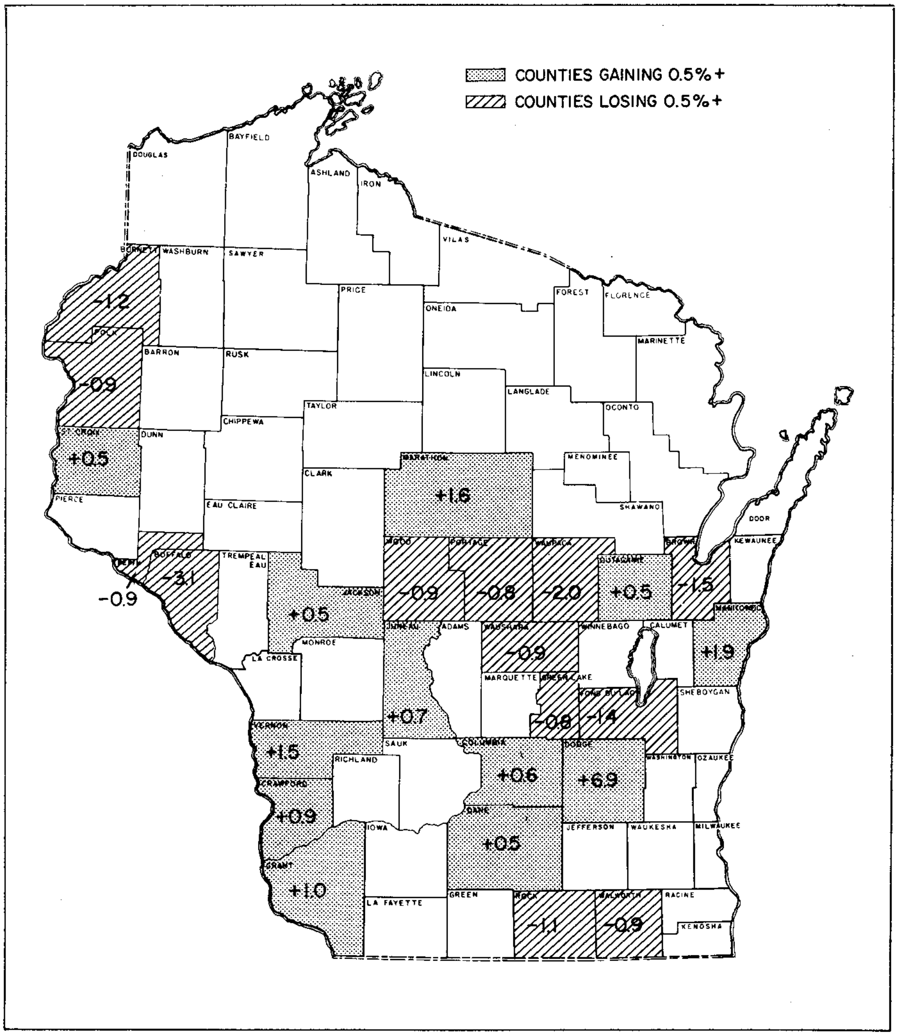


FIGURE 13. *Wisconsin counties in which the proportion of the total state mallard harvest changed at least 0.5 percent between 1938-43 and 1961-70. Appendix B lists percentages of the state harvest by counties during the two periods.*

CONTRIBUTION OF LOCAL MALLARDS TO THE WISCONSIN HARVEST

Methods

Prehunting Season Population Estimates. Geis (1972:10-11) described how band recovery rates, band report rates, sex and age composition of the kill and harvest estimates can be combined to estimate prehunting season populations of ducks. He also noted, however, that "an estimate such as this relating to a specified area must be interpreted with caution because . . . the movement of banded ducks away from (the area) . . . or unbanded ducks into it both tend to cause an inflated estimate". Recognizing these problems, preseason population estimates of mallards furnishing the Wisconsin harvest were derived for the 1961-72 hunting seasons. The preseason estimates utilized annual mallard harvest estimates and sex and age ratios from duck wing collections in Wisconsin (Martin and Carney 1977) as well as estimates and harvest rates in Wisconsin for mallards banded in the preseason (Table 20). Annual population estimates obtained were not necessarily intended to represent actual numbers of ducks present in Wisconsin at any given date during the fall. Instead, they reflect the approximate size of the fall mallard flight through the state that was needed to attain the "known" harvest by sex and age cohort, given March's (1976:161) estimates of annual Wisconsin harvest rates for each cohort.

Derivation of Local Contribution. Production estimates for Wisconsin during 1965-66 and 1968-70 (Table 9) were used to derive the contribution of locally reared juveniles to the state's harvest. Adult mallard contribution to the harvest was derived from the spring breeding populations in Wisconsin (Table 9), less 5 percent mortality between May 15 and October 1. The latter value, taken from Geis et al. (1969), may be too low. Anderson (1975) considered 8-9 percent (males) and 16-18 percent (females) to be "reasonable values" for mid-May to mid-August adult mortality. No adjustments were made for ingress or egress of mallards, either adults or juveniles, between May and October. This almost certainly occurred, particularly among male cohorts. Any attempt to compensate for such movements of birds would have to be done without supporting data. Within the state's preseason population, losses to emigration are assumed to equal the replacement by early migration from outside Wisconsin.

Harvest rates used to calculate local contribution are the means of the 1965-66 and 1968-70 Wisconsin harvest rates for adult and juvenile mallards (Table 20) banded during the summer and preseason period in the state. The harvest rate for juveniles is the average of separate rates for individual cohorts banded as flying immatures and as flightless young.

Results and Discussion

Preseason Populations. The average 1961-72 adult mallard harvest in Wisconsin was 43,500 birds (Table 33). Mean harvest of juvenile mallards was 107,300 birds (Table 33). Harvest was slightly higher to males in both age cohorts. Average 1961-72 Wisconsin harvest rates were 10 percent, 8 percent, 26 percent and 23 percent respectively, for adult males, adult females, juvenile males and juvenile females. (Table 20).

The mean 1961-72 preseason population estimate was 1,003,800 mallards (Table 33); included were 529,000 adults and 474,800 juveniles. Annual preseason estimates were "reasonable" in most years, considering the potential biases and adjustments inherent to the data. The six annual estimates that each exceeded one million mallards were probably inflated, especially those for 1965-66. North American and Wisconsin mallard populations were at lower levels in those 2 years (Pospahala et al. 1974; March et al. 1973). The 1972 preseason estimate, although it may not have been as high as 1.7 million mallards, undoubtedly exceeded the one million bird level. In 1970-72, continental populations of mallards were higher than during the previous 10 years (Pospahala et al. 1974) and the 1970 Wisconsin breeding population was also high (March et al. 1973). The 1961 estimate of 1.7 million mallards would also seem to be unreasonably high based on continental populations (Pospahala, et al. 1974) and the fall flight estimate (Geis et al. 1969).

In broadest terms, Table 33 suggests that Wisconsin was the recipient of a fall flight of between 500,000 to 1,000,000+ mallards during 1961-72. The preseason estimate fell below 500,000 birds in 2 of the 12 seasons. Between 1955 and 1972, continental mallard populations were lowest in 1962 and 1965 (Pospahala et al. 1974). Lowest of the two Wisconsin preseason estimates was also recorded in 1962—the second lowest was estimated one year later in 1963.

Contribution of Locals Under Fixed Reproductive Rates. Table 34 presents the average estimated 1965-66 and 1968-70 harvests of local mallards under 30 percent and 46 percent reproductive success. Local populations contributed an average of about 27 percent of the adult harvest in Wisconsin and either 24 percent or 37 percent of the young-of-the-year harvest, depending on rate of success (Table 34). Using Anderson's (1975) values for summer adult mortality, local breeders contributed 25 percent of the average adult harvest.

Annual contributions by locally breeding adult mallards ranged from an estimated 16 to 43 percent of the adult mallard harvest in Wisconsin. For juveniles, assuming that 30 percent of the pairs were successful, annual contributions ranged between 18 and 32 percent of the harvest. If 46 percent of the pairs were assumed successsful, 28 to 49 percent of the juvenile harvest was furnished by local production.

Total representation of local mallards within the preseason population was also considered. Since the preseason estimate was dependent on the size of the total mallard harvest and the harvest rate in Wisconsin, proportions of locals were similar to those found in relation to the harvest. Local production, however, did make up a slightly larger mean proportion of the preseason juvenile population estimate than it did of the estimated harvest (Table 35). Overall, the mean 1965-66 and 1968-70 fall flight of mallards (May breeders plus offspring) originating from Wisconsin was 242,200 birds, assuming 30% success, or 307,800 birds with 46% success. High and low annual estimates were 416,400 mallards at 46% in 1970 and 199,000 mallards at 30% success in 1966. The percentages of the annual preseason population estimates represented by local mallards ranged from 16 percent for 30% success in 1965 to 65 percent for 46% success in 1970. The greatest contribution attained under the lower estimate of pair success was 42 percent of 1970 preseason population. Smallest contribution under 46% pair success was 25 percent in 1965.

Contribution of Locals Using Annual Reproductive Rates. When the reproductive rate was allowed to vary annually, using adjusted wing collection age ratios (from Table 7), the mean contribution to the harvest, 23 percent, was similar to the percent contribution derived using 30 percent female success (Table 34).

Using age ratios from the Wisconsin preseason-banded samples (from Table 3) as annual reproductive rates, the contribution of locals more closely resembled that derived from the 46 percent female success (Table 34).

Both estimates of contribution based on annual reproductive rates would be slightly lower if Anderson's (1975) values for summer adult mortality were used.

Factors Potentially Affecting the Annual Contribution by Locals. The estimated proportions of local mallards in the 1965-66 and 1968-70 Wisconsin harvests were compared by March (1976:266-268), using simple linear regression, with various harvest and population parameters to examine the effects of these factors on the input of locals. No significant relationships were found at $P<0.05$ between the percent local contribution and Wisconsin's total mallard harvest or the harvest of adults and juveniles when tested separately. Harvest rate in Wisconsin for each age was also not significantly correlated with the associated level of local contribution ($P<0.05$). Other parameters tested were: Class III brood size, unadjusted age ratio from the harvest, percent mallards in Wisconsin's duck harvest, number of mallard bag-days, opening date of the Wisconsin season, duck season length and mallard daily bag limit. None of these were correlated with the percent of local contribution at $P<0.05$.

Since the major portion of the Wisconsin recoveries of mallards banded in the state occurred early in the hunting season (Table 18), the 1965-66 and 1968-70 percentages of Wisconsin recoveries reported for the opening day, within the first 2 days and within the first 7 days were compared with the several annual estimates of percent contribution by locals given in Table 34. No significant relationships were found for either adults or juveniles at $P<0.05$. Also because levels of local contribution are almost certainly related to the volume of migrant mallards entering Wisconsin each fall, the 1965-66 and 1968-70 percentages of foreign band recoveries (Table 19) in Wisconsin on opening day, within the first 2 days, the first 7 days, days 8-14, days 15-21, days 22-28 and the percent after 28 days were each compared with the several annual estimates of local contribution from Table 34. Again, none of these comparisons were significantly correlated at $P<0.05$. However, annual percentages of contribution by juvenile mallards obtained using adjusted wing collection age ratios were negatively correlated with the proportion of foreign band recoveries occurring within the first 7 days of the 1965-66 and 1968-70 Wisconsin duck seasons at $P<0.10$ ($r=-0.829$).

A significant negative correlation has been indicated ($P<0.05$) between the percentage of Wisconsin-banded mallards recovered in the state during the first 2 days of hunting and the percentage of foreign-banded mallards recovered in Wisconsin within those same days. Such a relationship, together with the indication that annual contribution of local production was negatively associated with the proportion of foreign mallard band recoveries within the first 7 days of hunting, suggests that a later opening date in Wisconsin would result in a greater proportion of migrant mallards being harvested.

Two management alternatives are possible. The first, with a goal of additional shooting of migrants, would be to delay the opening date until at least the October 5-7 period. The second alternative, with a goal of maximizing local contribution to the harvest, would be to open the duck season as early as possible. An October 1 opening date would be desirable in that case.

During 1968-70, the May breeding population increased annually in Wisconsin (Table 9); the adult harvest rate in Wisconsin (Table 21), the number of local breeders harvested in the state, the total Wisconsin harvest of adult mallards (Table 33) and the percent contribution by local breeders also increased annually in those seasons. A direct relationship between those five variables was suggested. The 1965 adult data also fit into a similar pattern, but in 1966, when the May population reached its lowest point, all other parameters except the contribu-

Table 33. *Retrieved mallard harvests and preseason population estimates in Wisconsin during 1961-72.*

Parameter	Hunting Season												
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	Mean
Retrieved Harvest in Wisconsin[a]													
Adult Males	26,800	9,000	11,300	22,500	16,700	26,800	25,100	10,300	21,200	21,100	43,400	31,300	22,100
Adult Females	27,500	11,600	17,600	19,000	10,400	29,900	27,300	12,500	18,500	23,000	33,600	25,600	21,400
All Adults	54,300	20,600	28,900	41,500	27,100	56,700	52,400	22,800	39,700	44,100	77,000	56,900	43,500
Immature Males	51,100	30,300	34,100	58,400	38,400	66,300	69,300	36,600	63,300	81,100	80,900	71,900	56,800
Immature Females	46,300	26,700	35,300	51,300	42,400	63,600	54,300	35,300	55,800	65,200	67,500	62,300	50,500
All Immatures	97,400	57,000	69,400	109,700	80,800	129,900	123,600	71,900	119,100	146,300	148,400	134,200	107,300
Preseason Population Estimate in Wisconsin[b]													
Adult Males	705,300	67,700	94,200	225,000	238,600	377,500	209,200	166,100	155,900	191,800	228,400	391,200	254,200
Adult Females	572,900	111,500	143,100	213,500	253,600	308,200	354,500	235,800	196,800	190,100	329,400	387,900	274,800
All Adults	1,278,200	179,200	237,300	438,500	492,200	685,700	563,700	401,900	352,700	381,900	557,800	779,100	529,000
Immature Males	230,200	126,200	114,800	214,700	391,800	312,700	248,400	167,900	167,500	202,800	209,000	446,600	236,100
Immature Females	221,500	124,200	119,700	239,700	339,200	258,500	251,400	182,900	191,800	188,400	241,100	506,500	238,700
All Immatures	451,700	250,400	234,500	454,400	731,000	571,200	499,800	350,800	359,300	391,200	450,100	953,100	474,800
Total Population	1,729,900	429,600	471,800	892,900	1,223,200	1,256,900	1,063,500	752,700	712,000	773,100	1,007,900	1,732,200	1,003,800

[a]Mallard harvest estimates and sex and age composition of harvest are from Appendices B and March (1976:318).

[b]Retrieved harvest - mallard harvest rate in Wisconsin for each cohort, from Table 20.

Tabble 34. *Average contributions by local mallards to the Wisconsin harvest, 1965-66 and 1968-70.*[a]

Age Cohort	Mean Mallard Harvest[a] in Wisconsin: Locals	Total	Percent Locals
Adults:	10,300	38,100	27.0
	(4,100-19,100)	(22,800-56,700)	(15.8-43.3)
Juveniles:			
30% Success	26,400	109,600	24.1
	(14,600-46,400)	(71,900-146,300)	(18.1-31.7)
46% Success	40,600	-	37.0
	(22,400-71,500)		(27.7-48.8)
Adjusted Wing Survey Age Ratio	25,200	-	23.0
	(10,200-45,500)		(14.2-31.1)
Preseason Banding Age Ratio	38,400	-	35.0
	(16,400-68,200)		(12.6-51.1)

[a]Adult populations and associated production estimates are from Table 9; minimum and maximum estimates are in parentheses. Mean adult harvest rate was 8.2 percent (range of 4.2-11.8 percent) and mean juvenile harvest rate was 21.0 percent (range of 12.1-28.1 percent).

Table 35. *Contribution of locally-reared mallards to Wisconsin's fall population using two fixed rates of reproductive success. Estimates are the mean data from 1965-66 and 1968-70.*[a]

Parameter	Proportion of Females Successfully Rearing Broods: 30%	40%	Source
1. Fall flight of adult mallards through Wisconsin[b]	462,900	462,900	Table 38
2. Number of adult breeders present on October 1	119,600	119,600	Table 9 (less 5%)
3. % of fall flight that represents locally breeding adult mallards	25.8	25.8	
4. Fall flight of juvenile mallards through Wisconsin[b]	480,700	480,700	Table 38
5. Number of flying young produced in Wisconsin and available on October 1	122,500	188,200	Table 9
6. % of fall flight that represents locally-reared juvenile mallards	25.5	39.2	

[a]Years for which Wisconsin breeding population estimates were available.

[b]Preseason population estimates obtained from harvest estimates, age ratio data and harvest rates in Wisconsin.

tion of locals to the harvest increased.

The percent contributions of juveniles to the Wisconsin harvest, under fixed rates of reproductive success, were not correlated with the size of the spring adult population ($P < 0.05$). Rate of harvest and total harvest of juveniles in Wisconsin also influenced the percent contribution. Highest contribution by local production occurred in 1970, the year of the largest breeding population; this was also the year with the highest juvenile harvest rate in Wisconsin. Harvest of juvenile mallards in Wisconsin during 1965-66 and 1968-70, was also highest in 1970 (Table 33). Smallest percentages of contribution by local production, under fixed rates of reproductive success, were in 1965, a year with average numbers of spring breeders but with the lowest harvest rate on juveniles and also a lower total harvest of young birds in Wisconsin. In general, under fixed reproductive rates, because of the changes in harvest rate and total juvenile mallard harvest, the percentage contributed by locals was different than predicted solely by the size of the May breeding population.

Use of fixed rates of reproductive success precluded any effect on the contribution of local production associated with annual changes in productivity.

Annual production rates affected the contribution by local mallards in a more predictable manner than noted for fixed rates of reproductive success. Although the relationship was still not linear, the highest contribution by local production did occur in years with "good" or "average" productivity and the lower contributions came in "average" or "poor" summers (based on Table 7). With age ratios from the preseason banding, the relationship was less clear, although the two highest contributions were made in years with "good" (1969, 51 percent) or "average" (1970, 47 percent) productivity.

Wisconsin's average Class III mallard brood sizes for 1965-66 and 1968-70 (Table 22) were inversely correlated with the size of the May breeding populations in the same years. The effect of this inversity on contributions by locals to the state's harvest was considered. Local contributions were determined using the same procedures as in Table 39 for 30 percent reproductive success but substituting annual Class III brood sizes for the fixed size of 6.5 young. Despite smaller average brood sizes, largest numbers of young mallards would still have been produced in 1965, 1969 and 1970, the springs with the three highest breeding populations. Contribution of locals to the harvest was also highest (28 percent) in 1970, the year of highest May population but lowest brood size (5.8 ducklings). Results from the other 4 years were inconclusive. Percentages of local contribution were similar in 1965 and 1966 (19 percent), 2 years with considerable difference in the number of May breeders (Table 9). In 1968 and 1969, locals contributed 26 percent and 25 percent, respectively. A larger brood size in 1968 offset a smaller number of breeding adults. Overall, there was no significant correlation between percent contribution by locals and Class III brood size at P 0.10 (r=-0.492). While there was some suggestion of an inverse relationship between May population size, annual brood size and contribution of locals to the harvest, their interactions could not be clearly defined. One relationship was evident however—*local birds contributed the most to the Wisconsin harvest in years with high breeding populations.* Managing local populations to sustain or increase the number of adults breeding in the state would seem to be the correct strategy even though inversity may limit potential productivity at higher population levels.

Other Estimates of Contribution by Local Mallards in Wisconsin. Jahn and Hunt's (1964:137) data for mallards, indicated that 15-19 percent of the Wisconsin harvest was derived locally. Geis (1971) used band recoveries weighted by a Wisconsin breeding population of 150,000 mallards to estimate that as much as 70 percent of the state's harvest was locally produced. Recalculation of those same data, using the 1966-68 breeding population estimates, credited about 64 percent of the Wisconsin harvest to local mallards (March et al. 1973). By means of a linear programming model, based on some of the same data from Geis (1971), Bontadelli (1972) estimated that 72.1 percent of Wisconsin's mallard kill was produced in the state. The average percentages of contribution by locals shown in Table 34 were intermediate between the values presented by Jahn and Hunt (1964) and those estimated by Geis (1971) and Bontadelli (1972). From a management standpoint, it would be very advantageous if local mallards did actually furnish 60-70 percent of the harvest each year. Wisconsin's harvest regulations and management objectives could then be established more independently of continental population trends. Unfortunately, although local populations did contribute an estimated one-half of the Wisconsin mallard harvest in some years, depending on the rate of reproductive success used, the average estimated contribution was usually less.

The higher values obtained by both Geis (1971) and Bontadelli (1972) probably resulted from the larger numbers of mallards banded and reported shot within Wisconsin in relation to the size of the state's breeding population. Compared to much of the Canadian breeding grounds, especially those areas which appear most closely associated with Wisconsin, mallards present in this state during the preseason period are "over-banded". This was not the case for the segment of the "true" local population however. Being a high harvest state, Wisconsin recovered a large segment of its banded mallards, especially when they were relatively vulnerable in the vicinity of banding. On the average, Wisconsin hunters were also more willing to report the banded ducks shot than were hunters in other regions. The higher band report rate from Wisconsin helped to inflate the proportion of "locally banded" mallards taken in Wisconsin in comparison to other areas which may actually have equally high harvest rates. The high proportion of recoveries from a large banded sample of mallards, compared to "migrant" populations which have a much lower percentage of banded birds (some populations are essentially unbanded) and which come from a broad geographic area representing many population segments, overestimates the importance of Wisconsin-banded birds to the state's kill, even when weighting factors are used. Also, the breeding population estimate provided Geis (1971) from Wisconsin was at the high end of the range of values for the state. Most recently, Pospahala et al. (1974), using Wisconsin survey data and other indirect information, assigned 135,000 mallards to the minor reference area which included both Wisconsin and northern Illinois.

Even though Wisconsin has the opportunity to control the destiny of only about one-third or less of the source of its mallard harvest, such a proportion still represents a substantial potential for management. Jessen (1970), in estimating that about 25 percent of Minnesota's mallard kill was locally-produced, concluded that reducing harvest by the proper regulations could probably increase local populations and their ultimate production. Habitat in Minnesota apparently was under-utilized by breeding mallards. Additional mallard pairs could probably also be accommodated in Wisconsin. In addition to stabilizing the mallard harvest at levels (i.e. below the threshold point of Anderson and Burnham 1976) which would not tend to reduce local birds, efforts to improve the survival of broods currently being produced in some regions of the state are probably also needed. Duckling survival in southern Wisconsin apparently is poor because of a shortage of permanent wetlands. Pairs are attracted to abundant temporary wetlands in May, but little habitat remains to support broods in June and July (Gates 1965; Wheeler 1975). Many duck broods which do survive in the southeast region, must rely for their rearing habitat on the ditches originally intended to drain natural wetlands.

A Population Model for Female Mallards in Wisconsin. Jahn and Hunt (1964:49) presented what they considered as a "stochastic" model of the female segment of Wisconsin's mallard population. The model was based on the "productivity characteristics, mortality rates and assumptions" available at that point in time (Jahn and Hunt 1964). Female cohorts showed annual increases of 18 percent and 16 percent in the two years generated. Table 36 attempts to duplicate and refine procedures in the earlier model by incorporating more recent data on productivity and mortality. Also, the model in Table 36, based on definitions in Anderson (1972), is probably better described as "deterministic" rather than "stochastic" as exact survival rates are used instead of estimated probabilities of survival. Since females were, and still are, the primary cohort of interest when considering local breeding populations, the model is again limited to that sex. The following assumptions were made in regard to the model used in Table 36:

1. Thirty percent of the females present on May 1 successfully rear a brood to flying. Average size of fledged broods was 6.5 young. The two values combined represent an annual productivity rate of 1.95 young:adult female present on May 1.
2. Juvenile sex ratio is 1.0 male:female on October 1.
3. Annual mortality rates (October 1 to October 1—Jahn and Hunt 1964, used September 1 to September 1) equal 42 percent for adults and 55 percent for juveniles (March 1976:197).
4. Mortality is not uniform throughout the year (Jahn and Hunt, 1964:46 assumed that it was). Based on an estimated rate of hunting kill of 23 percent (Table 12), 54.8 percent of the total adult female mortality occurred during the hunting season (October through January). On this basis, adult female mortality from October 1 to May 1 is assumed to equal 23 percent (October-January hunting losses) plus an additional 7 percent to account for non-hunting losses during February-April (the balance of adult annual mortality, 19 percent, is assumed to be uniform between February 1 to October 1), or a total loss of 30 percent. For juvenile females available on October 1, 78 percent of the subsequent total mortality was considered to result from hunting. Using the same procedure followed for adults, October 1 to

Table 36. *Indicated change in Wisconsin female mallard population over a 5-year period.*[a]

		Number of Females														
		Cohort 1		Cohort 2		Cohort 3		Cohort 4		Cohort 5		Cohort 6		Cohort 7		
Year	Date	No.	Age	No.	Age	No.	Age	No.	Age	No.	Age	No.	Age	No.	Age	Total
A	Oct. 1	100	2	100	1	195	1									395
	May 1	70		70		101										
B	Oct. 1	58	3	58	2	88	1	235	1							439
	May 1	41		41		62		122								(+11%)
C	Oct. 1	34	4	34	3	51	2	106	1	259	1					484
	May 1	24		24		36		72		135						(+10%)
D	Oct. 1	20	5	20	4	30	3	61	2	116	1	284	1			531
	May 1	14		14		21		43		81		148				(+10%)
E	Oct. 1	12	6	12	5	17	4	35	3	67	2	128	1	313	1	584
	May 1[b]	8		8		12		24		47		66		163		(+10%)

[a]Based on production rate, mortality and assumptions presented in text.

[b]Breeding population on May 1 went from 241 to 328 females over five springs or a 36 Percent increase.

May 1 juvenile female mortality is assumed to be 48 percent.

Table 36 suggests, based on assumptions made, that Wisconsin's mallard population was able to make small annual gains with a reproductive success of 30 percent. The 10-11 percent increases were attained under average conditions encountered during 1961-72. Hunting regulations in those years tended to restrict hunting losses on mallards and were aimed at increasing or stabilizing continental populations of the species.

An increase in harvest rate (assuming no compensating decline in October 1 to May 1 nonhunting mortality occurred) or decreases in survival rate or productivity would have stabilized the population in Table 36 or caused it to decline. For example, survival rates for adult and juvenile females were lower (when considered in combination) in 1963 than in any year during 1961-70 (March 1976:353 and Anderson 1975:85). Total mortality in 1963 was 52 percent for adult females and 57 percent for juvenile females; associated estimated rates of hunting kill in 1963 were 27 percent and 53 percent (Table 21). When these rates were substituted into Table 36 in Year A, the October 1 population in Year B was only 392 mallards compared to 395 in Year A.

Conversely, any improvement in reproductive success, better survival or lowered hunting losses (and/or reduced October 1 to May 1 nonhunting mortality), would have produced larger annual increases in the October 1 population and in the following spring population.

Increasing reproductive success to 40 percent in Year A, then dropping back to 30 percent success in the following May, would have resulted in an October 1 population in Year B that was 14 percent greater than the original value obtained in Table 36.

Over the 5-year period estimated in Table 36, the May 1 breeding population went from 241 females in the first spring to 328 in the fifth spring, an increase of about 36 percent. This is particularly important, since the May breeding population estimates for Wisconsin increased 63 percent between 1968 and 1970 (from March et al. 1973 and Table 9). The observed increases in breeding populations were 22 percent between 1968 and 1969, and 33 percent between 1969 and 1970. In order for increases of such magnitude to have occurred, survival and/or productivity must have increased. If neither of those adjustments occurred, then the "observed" increases in breeding population must have resulted from mallards "pioneering" into Wisconsin from other regions. As discussed previously, increased survival and productivity in 1969 could have accounted for the increase in 1970. However, similar data for 1968 did not suggest that an upward trend in the 1969 population should have occurred.

Summary

From a fall flight of mallards that apparently exceeded a million birds in at least 4 years during 1961-72, Wisconsin hunters managed to bag about 150,000 mallards annually. More than half of those ducks were adults at least one year old. In the average season, about one out of every three or four of the adults shot and retrieved was a mallard that bred in Wisconsin during the previous spring. From one-fourth to one-third of the young-of-the-year birds shot were also hatched and reared in Wisconsin. In some seasons, over 40 percent of the adults and half the young mallards bagged represented local breeders and their offspring. Under average harvest and survival rates and a reproductive success of 30 percent, Wisconsin mallards should have been able to maintain small, annual population increases. With only slightly better productivity, e.g. 40 percent, breeding populations should have made even greater gains. When survival rates decreased to less than 50 percent for adult cohorts and rates of shooting losses were above average for 1961-72, breeding populations should have stabilized or declined slightly; additional mortality would have caused population declines, assuming productivity did not improve.

MANAGEMENT CONSIDERATIONS

BANDING

Continuation of Wisconsin's participation in the continental preseason mallard banding efforts is essential to effective waterfowl management. Quotas should be based on needs established by the U.S. Fish and Wildlife Service and the Mississippi Flyway Council, with a minimum annual sample banded in Wisconsin of 1,000 mallards.

In general, annual survival rates calculated by March (1976:352-353), using the Seber model, were least variable when the annual banded samples for one sex exceeded 1,000 mallards. On the basis of standard errors shown in Anderson (1975), annual sample sizes of 1,000+ banded birds for each sex and age cohort also gave the better results with the Robson-Brownie methods. A minimum preseason banding objective to meet needs for calculating Wisconsin survival rates would therefore be approximately 4,000 mallards annually—1,000 of each sex and age cohort.

Preseason banding sites are needed to represent all major breeding and preseason population segments in Wisconsin. Additional sites are needed north of 45° latitude and south of 43° latitude. Banding efforts on the Crex Meadows WLA, the G. W. Mead WLA, the Collins WLA, the Horicon NWR and the Necedah NWR should be continued. Preseason mallard banding should also be re-activated along the Upper Mississippi River. Any major banding efforts on additional sites should be initiated only if specific management objectives require evaluation.

If budgetary constraints permit the banding of flightless young mallards, a reasonable objective would be to band at least 300 locals in each of the following degree blocks: 42°-088°, 42°-089°, 43°-089°, 44°-087°, 44°-088°, 44°-089°, 44°-092°, 45°-089° and 45°-091°. A minimum annual sample of 200 locals is needed statewide to adequately detect annual differences in recovery and kill rates of 50 percent (assuming $P < 0.05$ is an acceptable level of significance).

Comparisons of recovery rates and distributions suggested almost no differences between samples banded as flightless young and those banded as flying immatures in August and September. Higher costs associated with banding flightless birds may not be not justified since these bandings do not provide any substantial additional statewide information.

To insure adequate sample sizes for estimating survival rates of mallards banded on a specific site, a minimum of 100 birds of each age and sex cohort marked annually are needed for a minimum of 5 consecutive years. Annual sample sizes of 1000+ birds for each sex-age cohort, collected over longer time intervals, are needed if long-term survival is to be estimated statewide or for a particular region.

Banding and recovery files should be updated to include data accumulated since 1972. Computer programs to adjust mallard band recoveries for reporting rate differences (Henny and Burnham 1976) and to estimate survival rates of young birds (Anderson 1975) should be requested from the Migratory Bird and Habitat Research Laboratory. Adjusted adult mallard recovery rates for Wisconsin bandings should be re-calculated for 1961-72 and the data from subsequent years included in the analysis. Adult survival rates should also be re-estimated with the Seber-Robson-Youngs model, incorporating recoveries and banded samples available from 1973-77. Survival rates for young mallards banded in Wisconsin should also be estimated for all years, using the method of Robson and Brownie (1973) as presented by Anderson (1975).

Age ratios of preseason-banded mallards duing 1967-72 showed potential as indexes to annual productivity in Wisconsin. Additional use of these data should be investigated. Annual samples from individual banding sites could be compared with other indexes to productivity, e.g., adjusted wing collection age ratios or brood surveys, to determine if the banded samples are at least indicative of trends in reproductive success. Evidence that productivity in Wisconsin is at least partially independent of habitat conditions and reproductive success in the major prairie-parkland nesting areas indicates a need for better annual information from the state. A more intensive evaluation of the age ratios from August- and September-trapped samples of mallards could be the first step.

Implicit to the use of preseason banding age ratios as indexes to productivity is the assumption that *all* birds handled in the banding operation will be aged and sexed. Sorting of birds to fill banding quotas for a particular sex-age cohort would bias age ratios unless the age and sex of unbanded, released birds was also recorded.

REGULATIONS

Local mallards made their greatest contribution to the harvest in Wisconsin when spring breeding populations were highest. With a May population of more than 150,000 breeders, adults contributed 44 percent of the harvest and their offspring furnished 33-53 percent. A management objective of establishing a spring breeding population of at least 150,000 mallards would improve the contribution by local birds, assuming that maximizing return from the available habitat was an acceptable management goal.

Female cohorts of populations associated with Wisconsin should have increased annly under average survival and productivity encountered during 1961-72. Most importantly, those were years of generally restrictive hunting seasons on mallards (less than 90 bag-days of mallard hunting opportunity during 8 of the 12 seasons). Additional hunting losses (without a compensating reduction in nonhunting mortality) or decreased survival rates, and/or lowered productivity, should have stabilized populations or caused long-term declines.

Based on the 1961-72 data, maintaining female mallard hunting regulations at less than 100 bag-days should stabilize average hunting losses on the nesting cohort at less than 25 percent for adults and at about 45 percent or less for juveniles. Since total rates of kill incurred by banded adult female and juvenile mallards were directly associated with the rates of kill occurring in the state, efforts in Wisconsin to regulate hunting losses to local populations should be successful. Over half the hunting season losses on banded female cohorts were in Wisconsin.

Annual hunting regulations are strongly oriented toward the anticipated fall flight of mallards. Both the fall flight forecast and bag-days of hunting opportunity were directly related to the eventual numbers of active adult hunters and days of hunting activity. Since 1950, changes in the number of hunters appeared to be a major cause of variations in mallard harvest in Wisconsin. Average numbers of mallards bagged per duck stamp sold in the state did not change after 1949. When mallard bag-days of hunting opportunity increased in 1970-72, total harvest also increased but the return in mallards bagged per individual per day of activity was poorer than in seasons with more restrictive mallard regulations. More hunters afield for more days resulted in a greater total harvest despite reduced average individual success. Based on these relationships, a more stable mallard harvest and a better average return per hunter might be achieved through indirect control of hunter numbers. By maintaining 100,000 or fewer active adult hunters in Wisconsin, average individual return should increase and total harvest should stabilize at about 130,000 to 170,000 mallards. During 1950-72, seasons with about 100 mallard bag-days tended to attract an average of less than 100,000 active adult hunters.

Since mallard flight forecasts and announced hunting regulations were strongly related to duck stamp sales and numbers of active hunters, the eventual harvest could be influenced prior to the season. By maintaining a low profile when publicizing major changes in fall flights and regulations, hunter numbers and associated harvests should tend to stabilize over time. Again, based on the 1961-72 data, a relatively stable combination of season length and/or daily bag limit that allows about 80 bag-days of mallard hunting opportunity, might be a reasonable choice for Wisconsin. Probabilities of significant rises in hunter numbers and harvest could also be lessened by avoiding major increases in bag-days of hunting opportunity in years with the more optimistic flight forecasts.

Information gathered during 1961-72 suggested several other potential approaches to regulating shooting losses on local mallard populations. When the daily bag limit was reduced to 1 female mallard during the first 2 days of hunting in 1972, the proportion of banded females recovered within those 2 days was 40-70 percent below the 1961-71 average. A lowered rate of hunting kill in Wisconsin during the entire season could not be demonstrated, however. The restricted bag limit on females apparently was not effective for a sufficiently long period of the season. About 70 percent of the in-state recoveries from mallards banded in Wisconsin came within the first 14 days of hunting. By restricting the harvest of females in that period, a significant reduction in their overall shooting losses should be achieved. The additional shooting pressure that might be shifted to drakes by these differential sex regulations should also be considered. Sex ratios in the Wisconsin harvest, when adjusted for differential vulnerability, showed that Wisconsin hunters are already shooting drake mallards in greater proportions than their representation in the preseason population.

Choice of opening date of the Wisconsin duck season was associated with the proportion of banded migrant mallards shot in the state. Prior to October 6, mallards banded in other states and provinces were recovered only with half the frequency of Wisconsin-banded birds. Peak recovery period for migrants was October 6-15. Also a greater proportion of banded migrant mallards recovered in the first 2 days of hunting was associated with a reduced proportion of recoveries from Wisconsin-banded birds recorded during those 2 days. Migrants banded on the more northerly breeding grounds of Canada were recovered in greater proportions later in the Wisconsin duck season. Only 3-5 percent of the recoveries of Wisconsin-banded mallards occurred after 35 days of hunting, compared to 7-16 percent of the recoveries from banded migrants. Local birds, however, were subjected to shooting throughout the Wisconsin season since recoveries of locals were still being recorded in Wisconsin during the last week of the duck season. The percent contribution to the state harvest by local mallards was reduced in seasons when greater proportions of banded migrants were recovered in the first week of the Wisconsin season.

If the proportion of migrant mallards taken were to be increased in an effort to reduce shooting pressure on local birds, the Wisconsin duck season should open after October 5. Since a major source of migrants into Wisconsin appears to be the northern forested regions of Ontario, Manitoba and Saskatchewan, a later opening date should also initiate hunting when more of these Canadian mallards are present in the state. If the goal were to maximize the contribution made by local mallard populations, the season should be opened as close to October 1 as possible.

In 1965-70, the production of young mallards in Wisconsin was estimated at 120,000 to 190,000 birds, depending on the rate of reproductive success used. During 1965-69, an average of 105,100 immature mallards were bagged in Wisconsin. Another 26,300 were estimated lost as cripples. For the period, Wisconsin's contribution to the fall flight of mallards in North America should have about equalled the number of birds dying as the direct result of shooting in the state. If Wisconsin had an established management objective of producing one mallard for each bird shot in the fall, that goal should have been met during 1965-69.

Hunting losses in Wisconsin during 1970-72 (including cripples) averaged about 180,000 young-of-the-year mallards. Based on the range of production estimates obtained in 1965-70, Wisconsin was probably shooting more young mallards than it produced in 1970-72. Mallard harvests, plus crippling loss, that approach the 200,000-bird level for young birds in Wisconsin, exceed the expected production from the state.

FUTURE RESEARCH

Limited band recovery data and indirect productivity indexes suggest western Ontario, northern Manitoba and northern Saskatchewan as logical major sources of mallards migrating through Wisconsin in the fall. Populations from those regions are essentially unbanded. Anderson (1975:12) identifies the lack of banding programs in all of northern Canada, Alaska, British Columbia and western and northern Ontario as a major problem in "the scientific and rational management" of continental mallard populations. If survival of these essentially unbanded populations was substantially different from those elsewhere in North America, then Anderson (1975:38) suggests his average survival estimates would be affected. A concerted effort should be made to initiate a cooperative banding program in the northern forested breeding grounds of Canada. Although such a program would be costly, accomplishing its objective would help to fill an information void important to the understanding of mallard populations associated with Wisconsin as well as the continent.

Mallards raised in Minnesota, South Dakota, North Dakota, southwestern Manitoba and southeastern Saskatchewan also make important contributions to migrant flights of mallards entering Wisconsin, particularly along the Mississippi River. These states and provinces share a common interest with Wisconsin in regard to maintaining huntable populations of mallards within the region. Efforts to manage habitat and populations with these breeding grounds and in Wisconsin, as a single unit should be encouraged. Wisconsin should support and participate actively in programs such as those proposed under the Mid-continental Waterfowl Management Unit.

Simple linear regression analysis of factors influencing the mallard harvest in Wisconsin identified several potentially important relationships. How these factors interacted with each other from year-to-year or which factor(s) accounted for the greatest portion of the variation in annual harvests was beyond the scope of this analysis.

A multi-variate approach should be used to examine mallard harvest and its potential influencing factors in Wisconsin. Development of an improved model utilizing the methods of Krause et al. (1970) for predicting harvests in Wisconsin under various regulation choices could be one objective of this investigation. Data collected during 1973-77 should be integrated into the analysis. Additional efforts should also be made to test and improve a mallard population simulation model for Wisconsin. The initial efforts by Stiff and Ek (1975) might be expanded and new subroutines added as needed. Other simulation models such as the one used by Anderson (1975:106), designed to answer specific management questions or to assist in program planning, should also be considered.

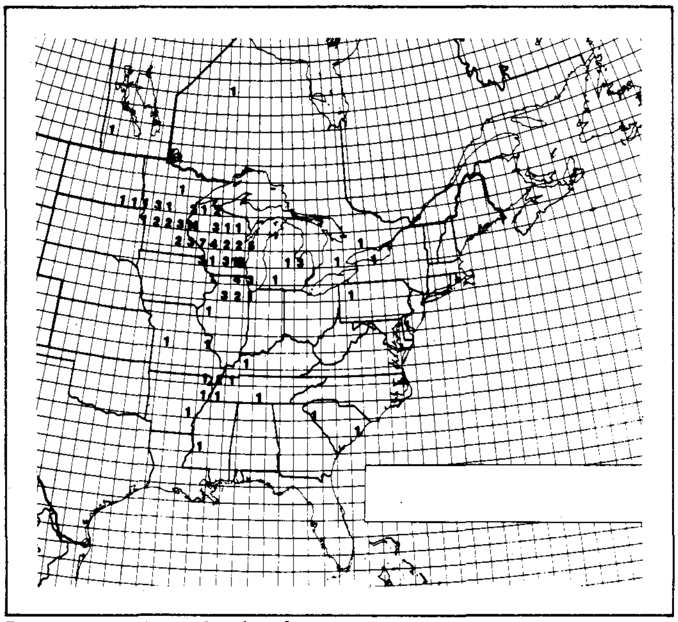
Adult female mallards apparently survive at a lower overall rate than males, despite the higher rate of hunting season loss associated with male cohorts. Nonhunting mortality, presumably during the reproductive period, apparently removes an important segment of the female population annually. The magnitude and causes of these losses, together with their chronology, should be investigated further. By assuming that hunting losses can be compensatory, nonhunting losses become particularly important since their identification and eventual reduction through appropriate management should directly benefit overall survival.

Additional studies of regional reproductive success in Wisconsin are needed. Wheeler (1975) found only about 30 percent of the pairs successfully reared broods in southeast central Wisconsin. A similar study is needed to measure productivity in the northern forested counties. Monitoring annual pair success for 5 to 10 years on several wetland complexes and/or specific study areas should show the effects of habitat and population changes on productivity.

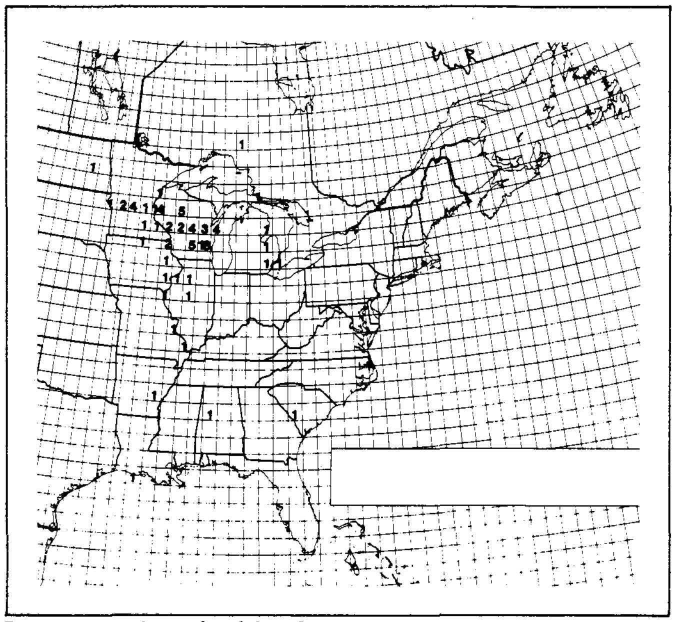
The effectiveness of specific habitat management techniques, such as plantings of dense nesting cover or flowage developments should be evaluated in relation to their success at improving nest success or duckling survival.

Annual survival and productivity in Wisconsin could only be associated with breeding population changes observed between 1969 and 1970. Large variances characteristic of the several estimates may have obscured any additional relationships. As additional annual breeding population estimates accumulate during the 1970's, observed population changes should be compared to associated survival and production information. Long-term information on year-to-year changes in breeding population, when combined with the appropriate data on habitat, harvest, rate of harvest and survival, is essential to understanding the relationship between hunting and nonhunting mortality. If, as Anderson and Burnham (1976) suggest, hunting is a compensatory form or mortality below some unknown level of exploitation, then it is particularly important to the future of Wisconsin's local mallard population that its threshold point be identified. Without long-term population and survival data, this could not be accomplished.

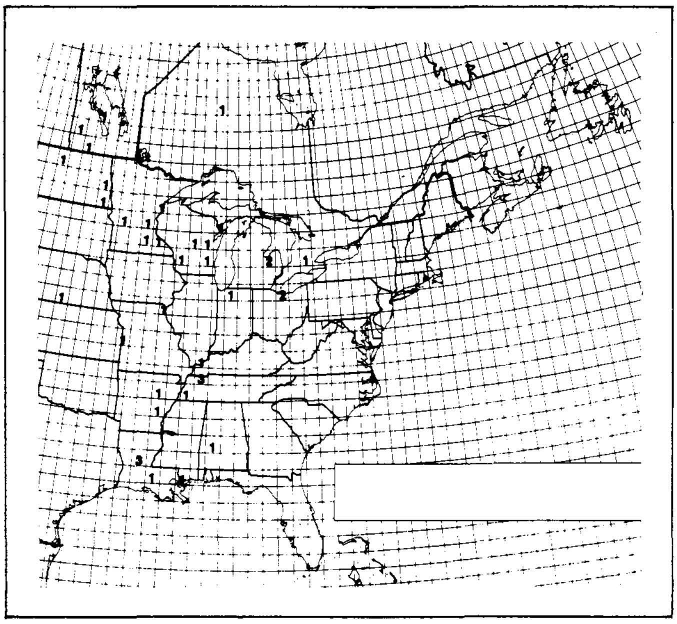
A: Maps of Recovery Distributions of Mallards Banded in Wisconsin 1961-72



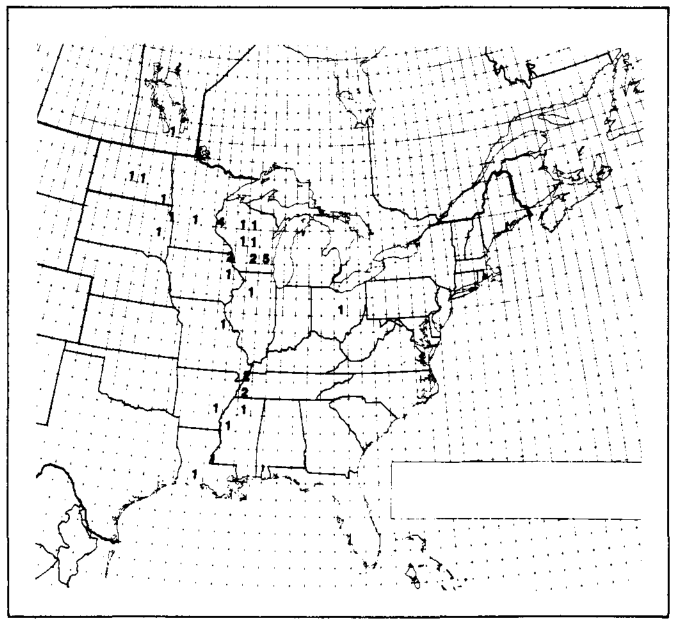
Direct recoveries — local males.



Direct recoveries — local females.



Indirect recoveries — local males.

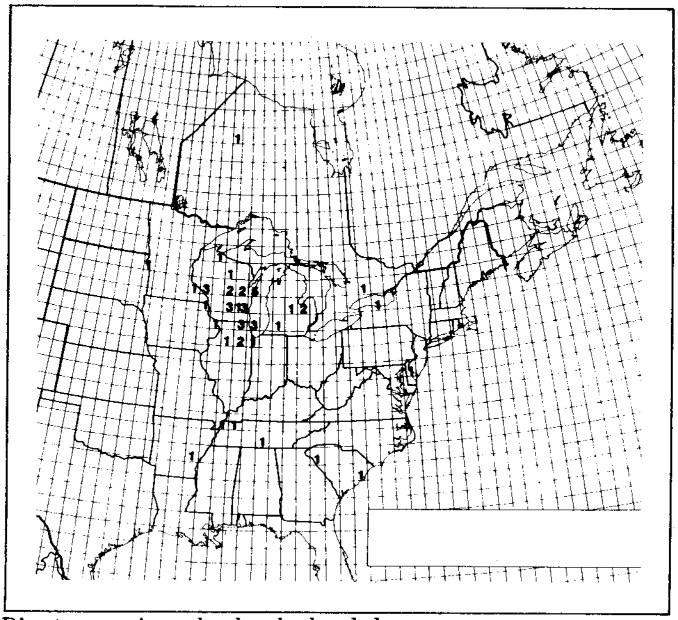


Indirect recoveries — local females.

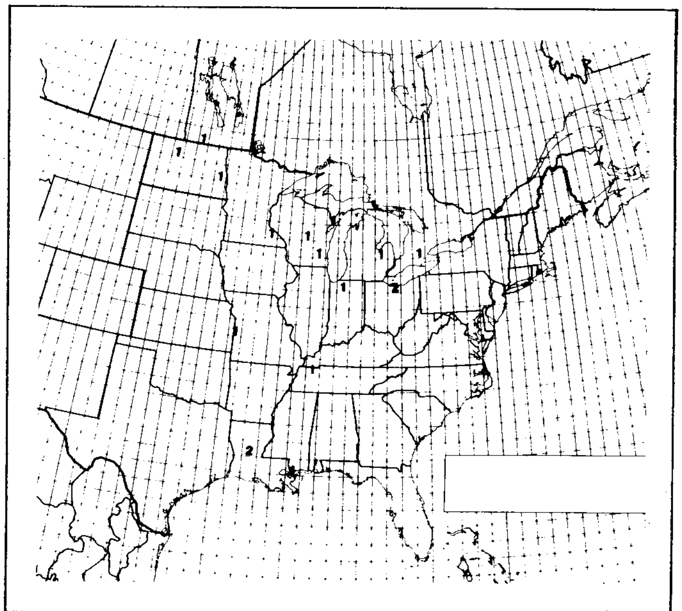
SCALE

0 200 400 600 800 1000

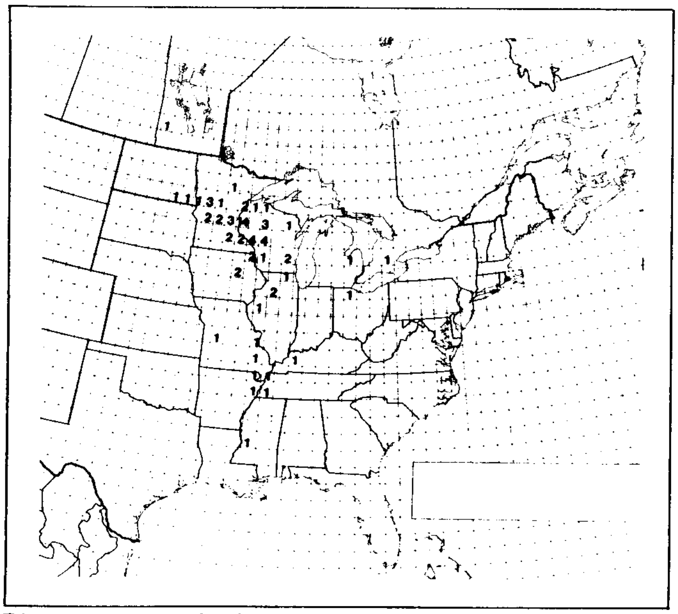
STATUTE MILES



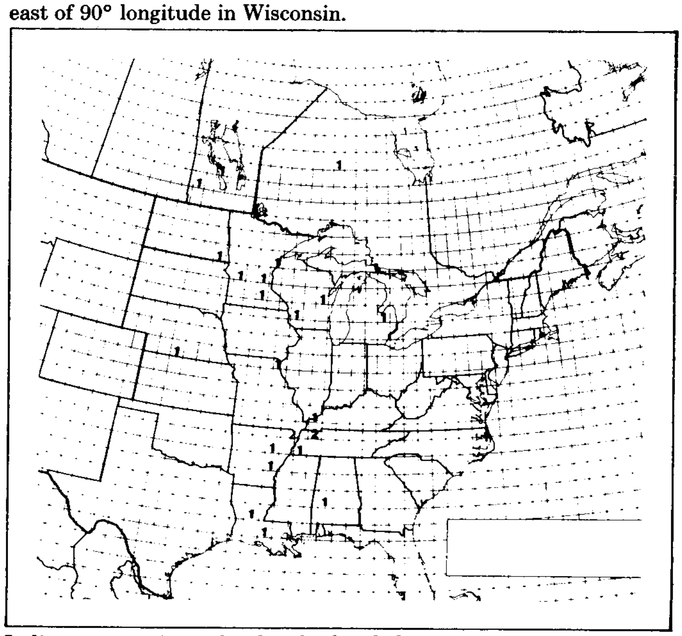
Direct recoveries — local males banded east of 90° longitude in Wisconsin.



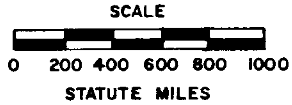
Indirect recoveries — local males banded east of 90° longitude in Wisconsin.

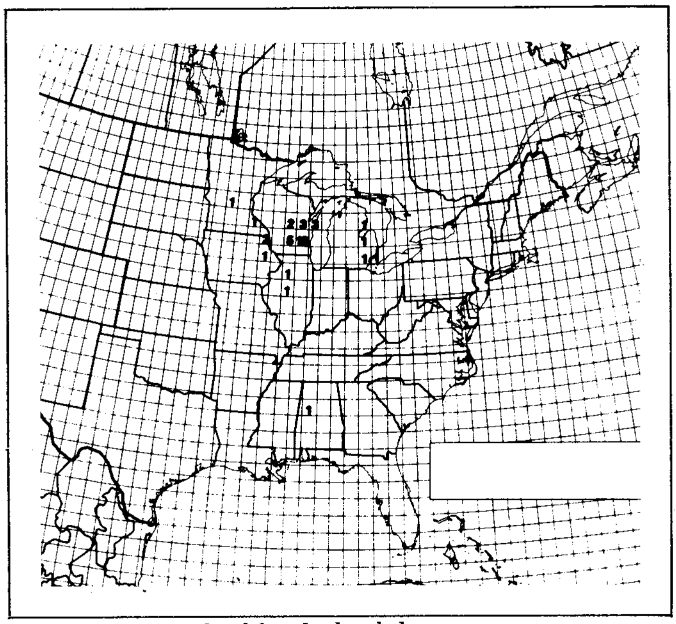


Direct recoveries — local males banded west of 90° longitude in Wisconsin.

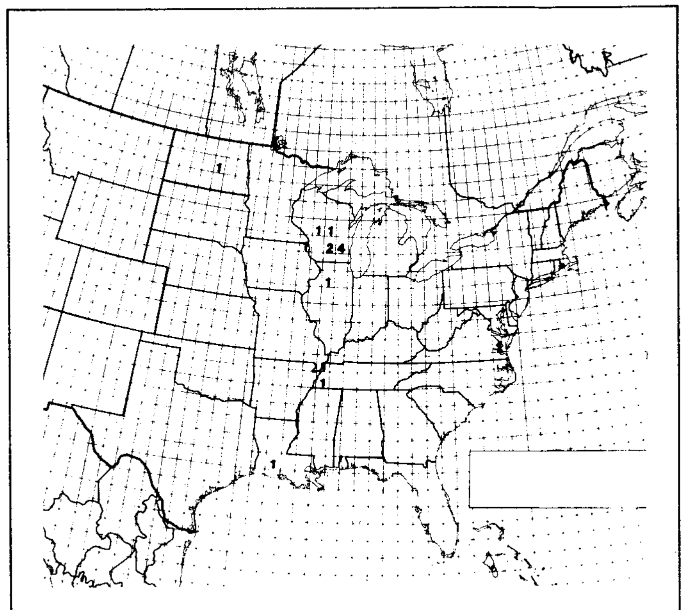


Indirect recoveries — local males banded west of 90° longitude in Wisconsin.

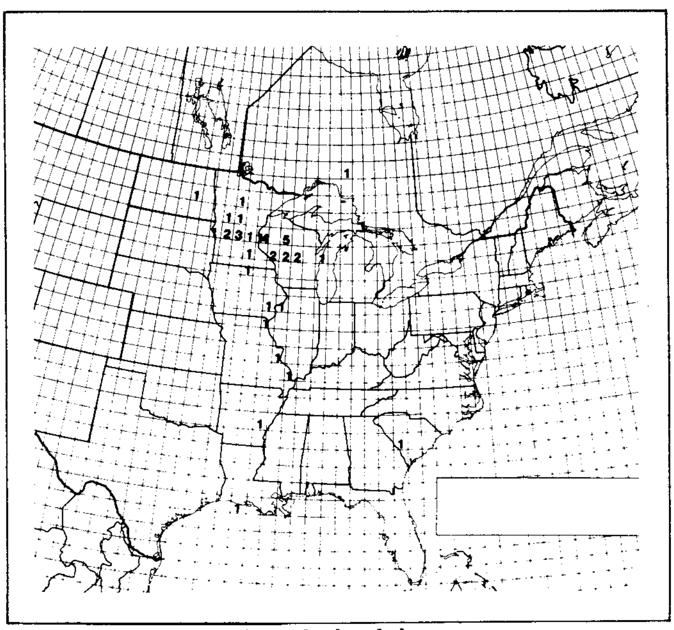




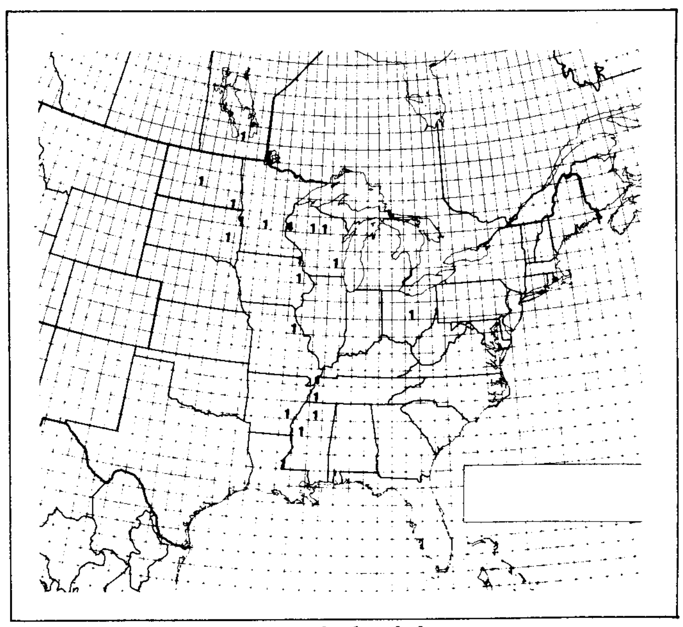
Direct recoveries — local females banded east of 90° longitude in Wisconsin.



Indirect recoveries — local females banded east of 90° longitude in Wisconsin.



Direct recoveries — local females banded west of 90° longitude in Wisconsin.

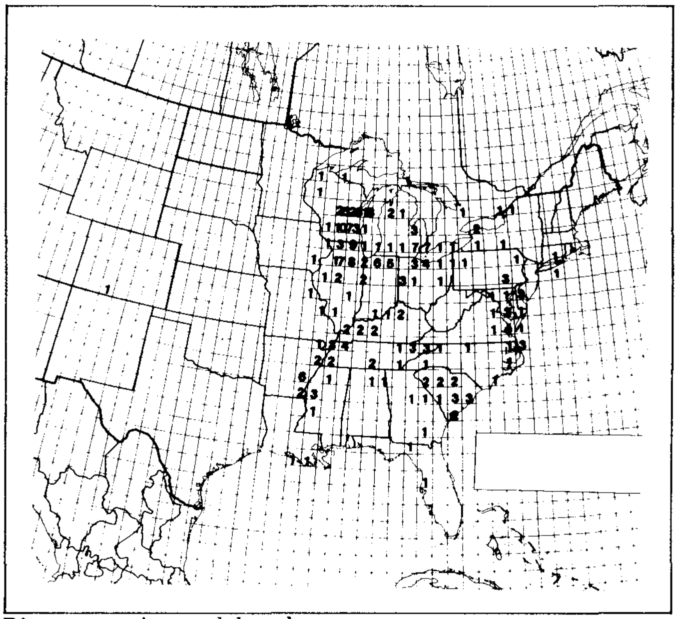


Indirect recoveries — local females banded west of 90° longitude in Wisconsin.

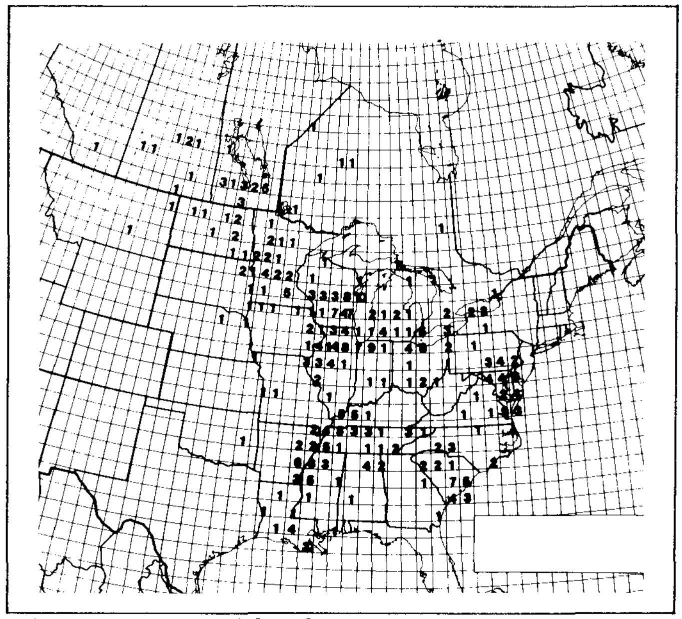
SCALE

0 200 400 600 800 1000

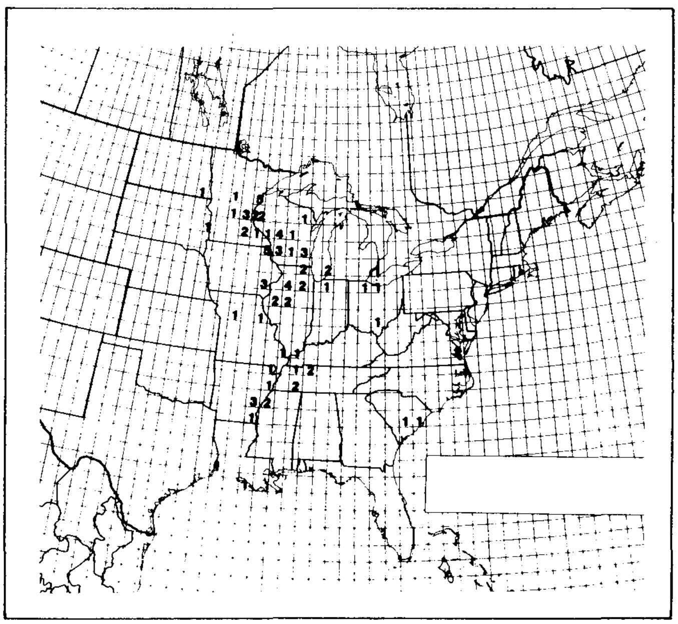
STATUTE MILES



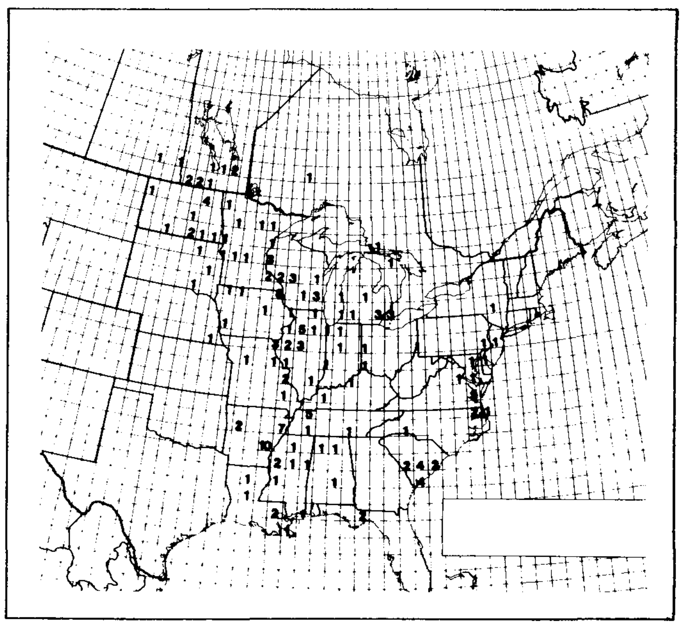
Direct recoveries — adult males
banded preseason east of 90° longitude.



Indirect recoveries — adult males
banded preseason east of 90° longitude.



Direct recoveries — adult males
banded preseason west of 90° longitude.



Indirect recoveries — adult males
banded preseason west of 90° longitude.

SCALE

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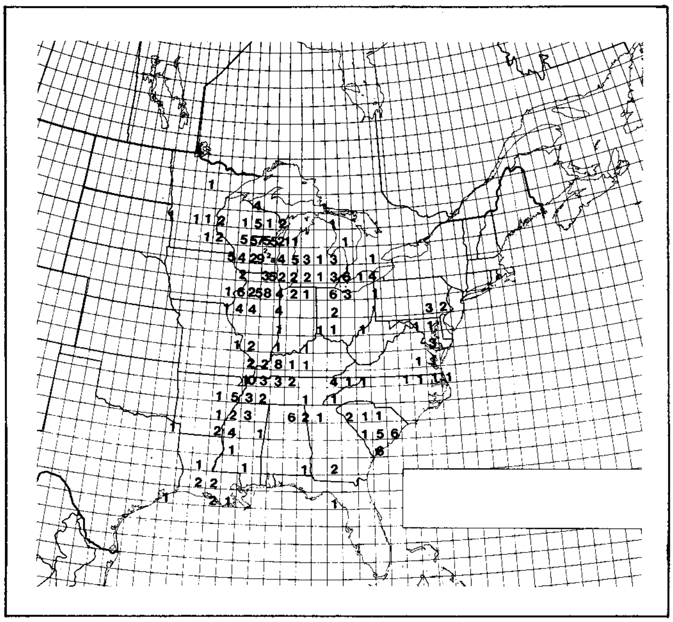
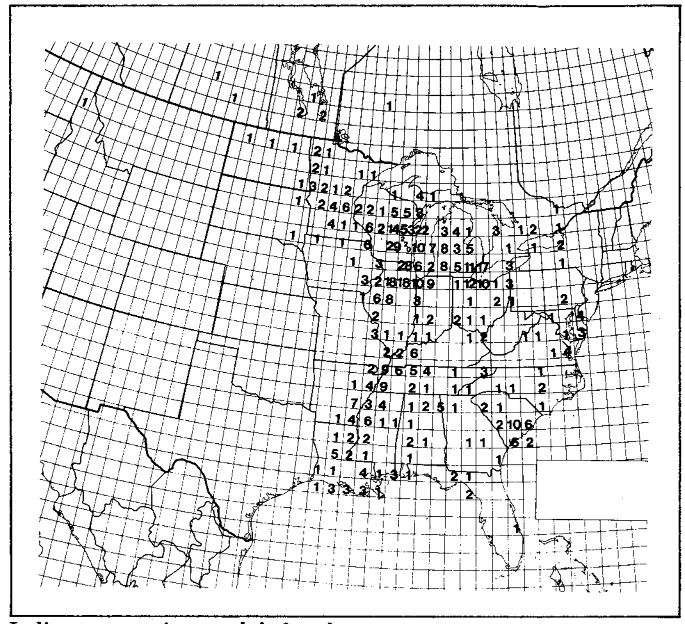
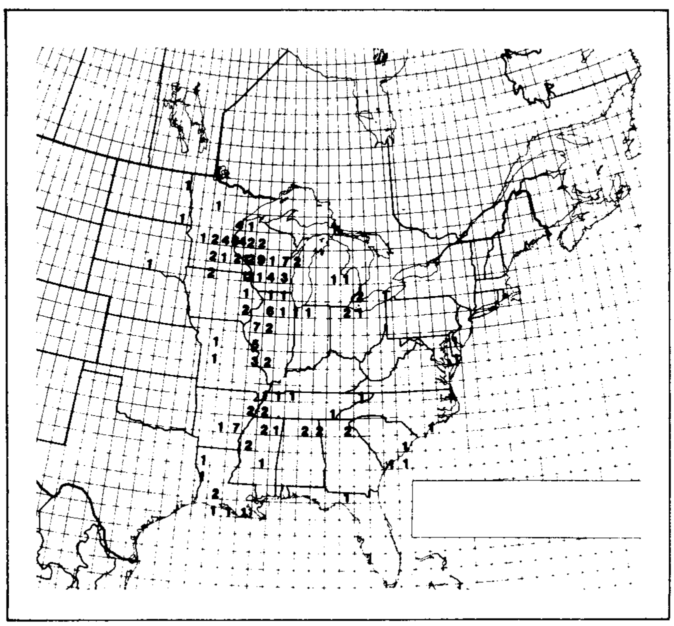
STATUTE MILES



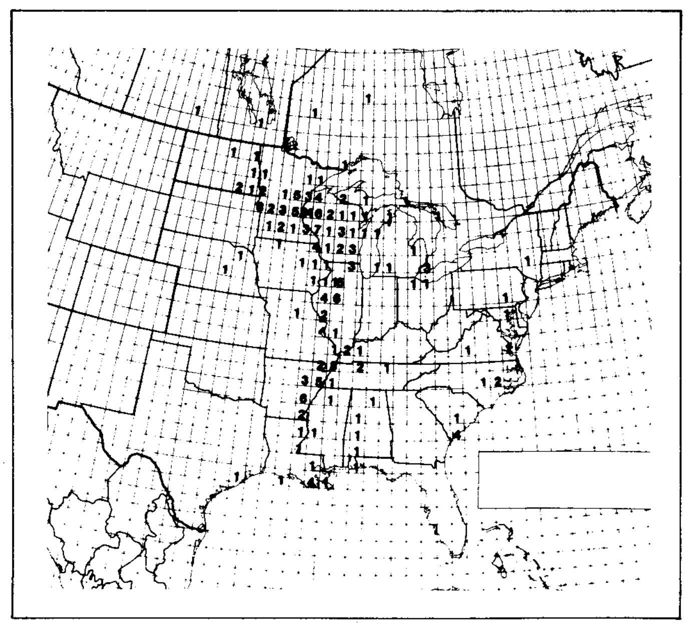
Direct recoveries — adult females
banded preseason east of 90° longitude.



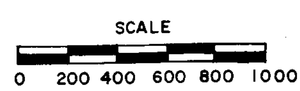
Indirect recoveries — adult females
banded preseason east of 90° longitude.

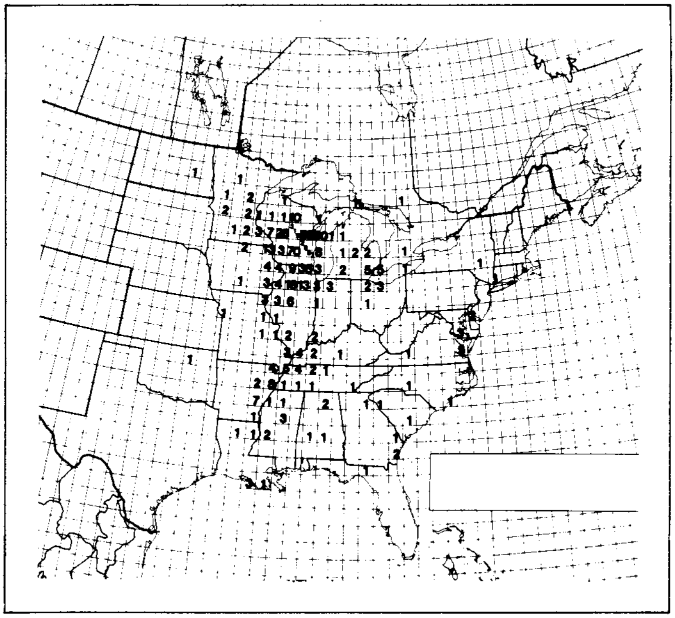


Direct recoveries — adult females
banded preseason west of 90° longitude.

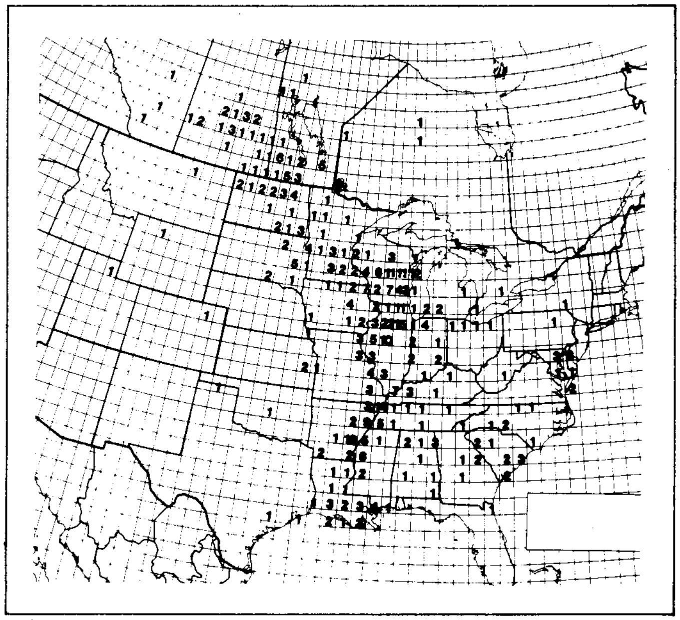


Indirect recoveries — adult females
banded preseason west of 90° longitude.

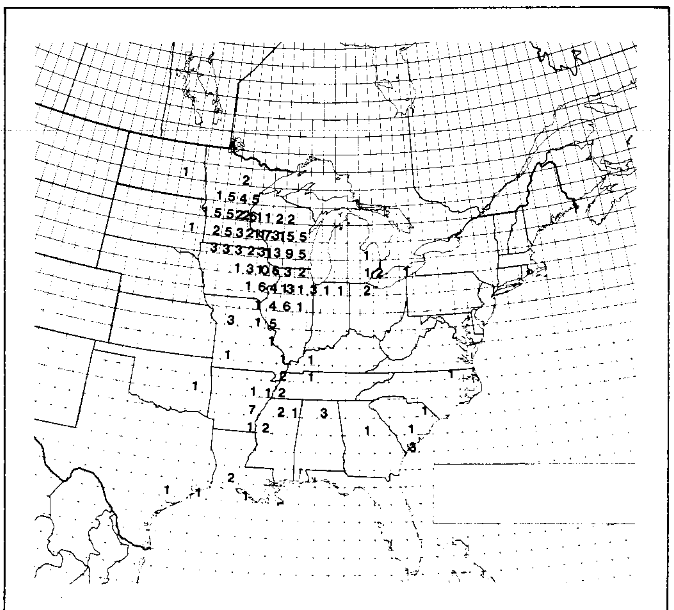




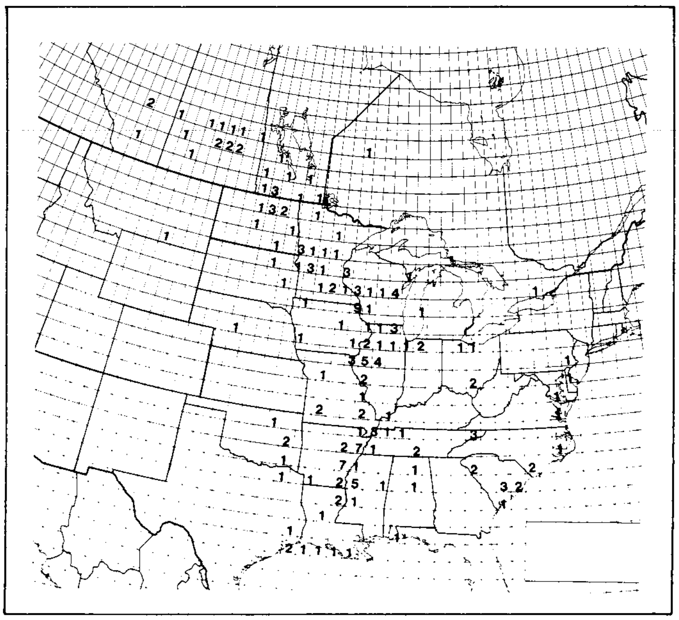
Direct recoveries — immature males banded preseason east of 90° longitude.



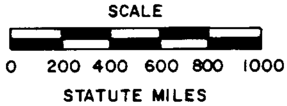
Indirect recoveries — immature males banded preseason east of 90° longitude.

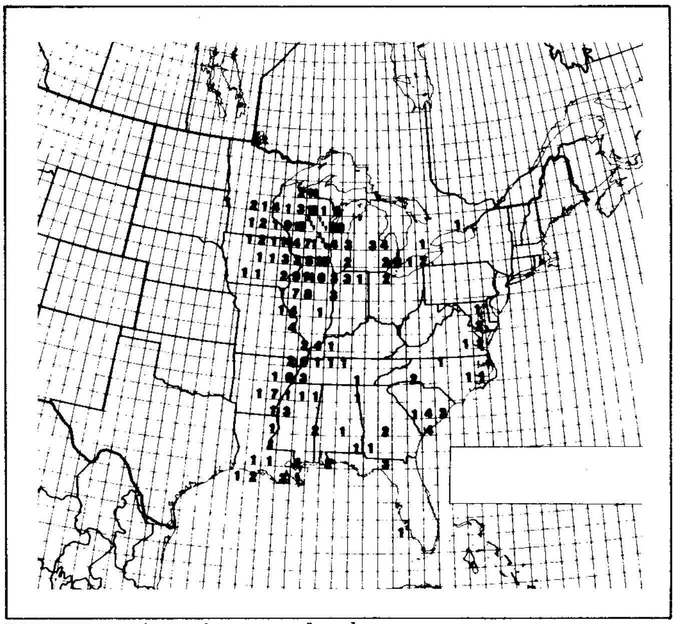


Direct recoveries — immature males banded preseason west of 90° longitude.

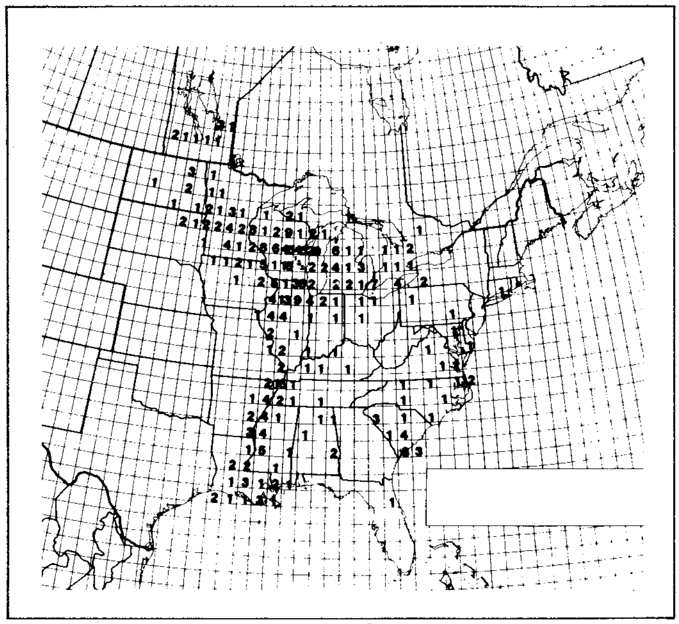


Indirect recoveries — immature males banded preseason west of 90° longitude.

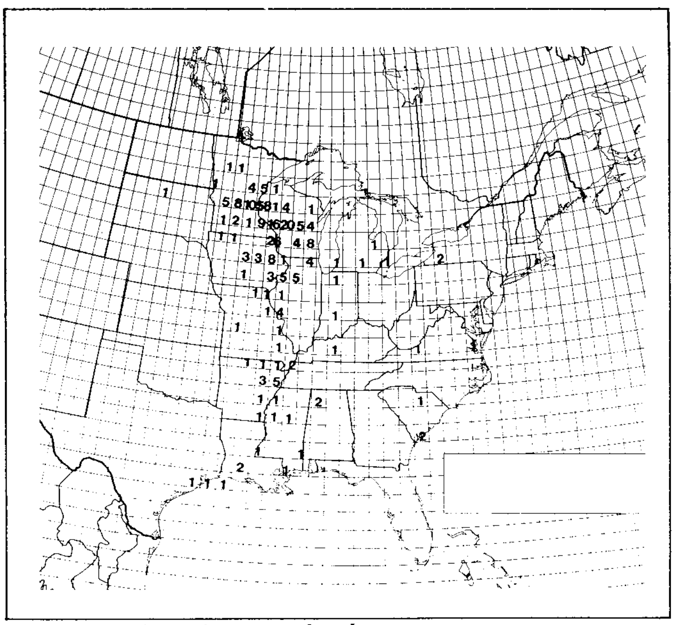




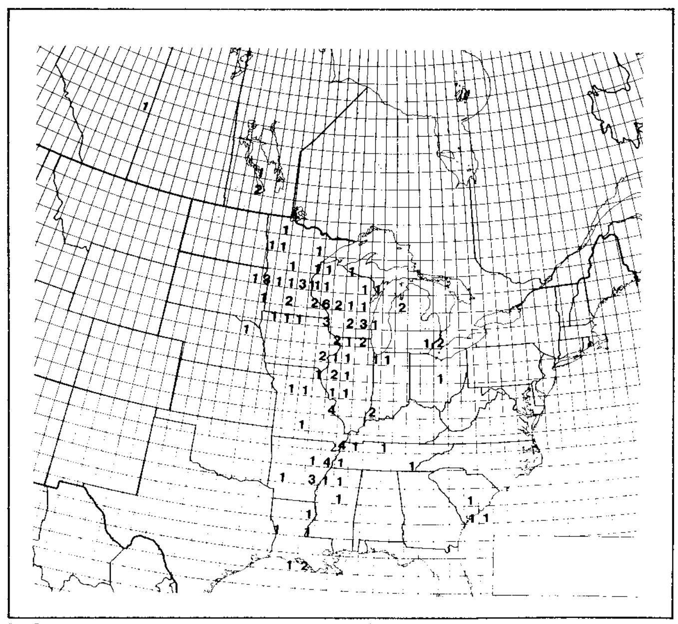
Direct recoveries — immature females banded preseason east of 90° longitude.



Indirect recoveries — immature females banded preseason east of 90° longitude.



Direct recoveries — immature females banded preseason west of 90° longitude.



Indirect recoveries — immature females banded preseason west of 90° longitude.

B: Mallard and Total Duck Harvests in Wisconsin

Hunting Season	Unadjusted Duck Harvest Estimate[a]	Adjusted Duck Harvest Estimate[a]	Unadjusted Mallard Harvest Estimate[b]	Adjusted Mallard Harvest Estimate[b]
1932	632.2	474.2	192.9	144.7
1933	714.0	535.5	210.2	157.6
1934	346.2	259.6	128.3	96.2
1935	408.6	306.4	167.7	125.8
1936	528.7	396.5	196.3	147.2
1937	444.7	333.5	165.9	124.4
1938	1,132.8	849.6	454.5	340.9
1939	1,123.8	849.6	452.7	339.5
1940	938.8	704.1	409.2	306.9
1941	621.8	466.4	229.6	172.2
1942	671.6	503.7	250.1	187.6
1943	541.0	405.8	199.7	149.8
1944	377.6	283.2	111.6	83.7
1945	934.2	700.6	433.7	325.3
1946	545.3	409.0	180.8	135.6
1947	340.2	255.2	111.2	83.4
1948	537.1	402.8	171.3	128.5
1949	783.6	587.7	(286.0)	(214.5)
1950	399.8	299.8	(145.9)	(109.4)
1951	652.8	489.6	(238.3)	(178.7)
1952	864.5	716.1	(315.5)	142.5
1953	637.5	651.9	(232.7)	188.4
1954	595.0	604.1	(217.2)	207.2
1955	770.5	637.3	(281.2)	220.5
1956	584.2	479.2	(213.2)	194.1
1957	636.6	459.3	(232.3)	197.5
1958	566.2	402.1	(206.7)	189.8
1959	-	315.9	-	115.3
1960	551.3	428.5	241.5	145.7
1961	392.9	310.6	178.4	151.7
1962	257.8	210.6	97.2	77.6
1963	369.2	294.1	127.7	98.2
1964	527.2	417.1	189.3	151.2
1965	618.1 (564.4)	472.8 (423.3)	134.7	108.0
1966	757.8 (741.8)	582.1 (556.4)	244.0	186.6
1967	653.1 (858.9)	545.2 (644.2)	206.4	175.9
1968	374.4 (599.0)	302.3 (419.2)	111.9	94.7
1969	703.4	557.3	195.5	158.8
1970	739.0	575.1	238.7	190.5
1971	803.8 (762.0)	654.2 (571.5)	275.7 (261.4)	225.4 (196.0)
1972	- (688.2)	558.5 (516.2)	- (235.4)	191.1 (176.6)

[a]1932-51 duck harvest estimates are from Wisconsin Conservation Department hunter mail surveys and 1952-72 estimates were obtained from Martin and Carney (1977) by ÷ the annual mallard harvest estimate by the percent mallards in the total estimated Wisconsin duck harvest. The 1932-51 estimates are multiplied by .75 to adjust for hunter response bias. ( ) equal concurrent Wisconsin Department of Natural Resources harvest estimates during 1965-72.

[b]1932-48 mallard harvest estimates are from Wisconsin Conservation Department hunter mail surveys. The 1949-51 estimates represent 36.5% of the annual harvest estimate for total ducks, or the mean species composition (represented by mallards) of the 1932-48 estimates. Mallard harvest estimates for 1952-72 are from Martin and Carney 1977. ( ) equal concurrent Wisconsin Department of Natural Resources hunter mail survey results in 1971 and 1972. The 1932-51 harvest estimates were adjusted for response bias using .75.

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About the Authors

James R. March holds both a B.S. and M.S. from the University of Minnesota, and received his PhD in Wildlife Ecology from the University of Wisconsin-Madison in 1976. He is a former waterfowl biologist with the Wisconsin Department of Natural Resources and is currently leader of their Farm Wildlife Research Group.

Richard A. Hunt received his B.S. and M.S. degrees from the University of Wisconsin-Madison. He began employment with the Wisconsin Department of Natural Resources in waterfowl research in 1950, and has been leader of waterfowl-related studies since 1960.

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