# NONHUNTING MORTALITY OF FLEDGED NORTH AMERICAN WATERFOWL

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*Abstract:* A survey of nonhunting mortality of wild waterfowl was conducted by the Delta Waterfowl Research Station, Delta, Manitoba, 1963–65. Records of reported mortality ($n$ = 2,108,880) for the period 1930–64 were assembled from open literature, unpublished federal reports, and a questionnaire. In addition, nonhunting mortality band recoveries ($n$ = 25,817) for the period 1930–63 were analyzed. Data were compiled on mortality from collisions, weather, predation, pollution, diseases and poisons, and miscellaneous factors. Collision mortality ($n$ = 3,015) was 0.1 percent of the total sample and was reported most commonly from the Central Flyway. Collisions with utility wires and automobiles were the most frequent causes of mortality. Weather-related mortality ($n$ = 158,723) was attributed to 7.4 percent of the total sample. Hail was the most important factor during summer. In other seasons various factors operated in concert with cold weather. Predation ($n$ = 2,621) accounted for 0.1 percent of the total mortality reported. Losses appeared to be of similar magnitude in all flyways and peaked during summer. Mortality from pollution ($n$ = 13,944) was 0.6 percent of the total sample. Losses were concentrated on the Atlantic coast and were proportionally heavier among diving ducks (Aythyinae). Mortality from disease ($n$ = 1,873,970) was 87.7 percent of the total mortality studied. Losses were most prevalent in the Central and Pacific flyways during summer and fall. Mortality from miscellaneous causes ($n$ = 82,424) was 3.8 percent of the total sample. Losses were confined largely to the Mississippi Flyway and to the summer–fall period. The seasonal losses peaked during winter and spring.

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This paper summarizes a survey of *reported* nonhunting mortality of wild waterfowl conducted by the Delta Waterfowl Research Station, Delta, Manitoba, 1963–65. A preliminary discussion of waterfowl nonhunting mortality was given by Cornwell and Hochbaum (1962, paper presented at 24th Midwest Fish Wildl. Conf., Des Moines, Iowa), and a detailed study, including an extensive literature review, was completed by Stout (1967). Boyd (1962) provided further impetus for our study.

The objective of the survey was to review and compile qualitative evidence from the available records on nonhunting mortality in waterfowl. Hopefully, this data base will aid in the design of future quantitative studies of nonhunting mortality.

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## METHODS

Observations of nonhunting mortality were tabulated under these categories: collisions, weather, predation, pollution, disease and poisons, and miscellaneous. Data (sources defined below) were compiled on ducks, geese, and swans native to North America. Deaths not attributed to shooting were regarded as nonhunting mortality; cripple losses and deaths likely to have been confused with hunting losses were excluded

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from consideration, as were data on unfledged waterfowl.

Questionnaires were directed to approximately 800 waterfowl biologists (state, federal, private, and university) to obtain yearly summaries of observations of nonhunting mortality made during 1963 and 1964. Details on the questionnaire design and cooperators were reported in Stout (1967:61). Three hundred eighty-one questionnaires were returned and 326 contained usable data.

Long-term data for the period from 1954 to 1963 were obtained from the files of the U. S. Fish and Wildlife Service, primarily from refuge narrative and biological reports and necropsy reports.

Waterfowl band-recovery data for the period from 1930 to 1963 were secured on magnetic tape for analysis by IBM 1740 computer through the cooperation of the Migratory Bird Populations Station, Laurel, Maryland. The recovery codes used were reported in Stout (1967:63). Recoveries were tabulated by species, recovery code, year, month, sex, age, and flyway.

Observations of mortality, other than band recoveries, were punched on key-sort cards by species, cause of death, number of deaths, age, sex, year, month, locality, and flyway. Further interpretative information was written on the card.

An observation of nonhunting mortality in this paper refers to an individual anatid that died of nonhunting causes. For example, a single event may have caused the loss of several hundred waterfowl, but each death would be regarded as an observation.

Questionnaire data, unpublished reports, and literature records of nonhunting mortality were combined and subsequently will be referred to as survey data. Every effort was made to avoid duplication of records. Initially band recoveries were analyzed as a separate unit. The survey data and band recovery data sampled different populations and were largely independent measures of nonhunting mortality. The data were pooled when useful for the purpose of analysis.

Accumulated data were tabulated for analysis by mortality factor, species or broader taxonomic grouping, flyway or region, season, and sex. Many observations of mortality were incomplete with regard to one or more variables. Accordingly, totals for the various categories are not consistent among the tables, because the maximum number of complete observations has been used in each.

The two sources of nonhunting mortality data, survey data and band recoveries, have intrinsic biases. These limitations must be recognized and considered in evaluating the data and their meaning. For example, the survey data were more likely to reflect factors spectacular in occurrence, i.e., disease die-offs and kills associated with weather. Conversely, individual cases of predation or collisions were less likely to be reported. Band recoveries were completely dependent upon man for discovery and documentation. Obviously, the probability of a given mortality event being found and reported by man varied markedly among the factors causing mortality. In general, over the years more puddle ducks (Anatinae) have been banded and may have been recovered than diving ducks, geese, and swans. More males than females have been banded over the years (W. Crissey, personal communication).

## RESULTS AND DISCUSSION

### Collisions

The survey data and band recoveries reported as killed by collision are given in Table 1. Wire strikes and collisions with autos accounted for a majority of the casualities. The Central Flyway reported 55

Table 1. A summary of the nonhunting mortality of waterfowl by category of mortality and source of data.

| | Survey data | | Band recoveries | |
|---|---|---|---|---|
| Mortality factor | *n* | % | *n* | % |
| Collision | | | | |
| Automobiles | 539 | 23.0 | 239 | 33.0 |
| Telephone and power lines | 1,487 | 65.0 | 20 | 3.0 |
| Television and radio towers | 93 | 4.0 | | |
| Aircraft | 40 | 2.0 | 10 | 1.0 |
| Farm machinery | 95 | 4.0 | 147 | 21.0 |
| Fences and buildings | 20 | 1.0 | | |
| Other objects | 25 | 1.0 | 300 | 42.0 |
| Total | 2,299 | | 716 | |
| Weather | | | | |
| Wind | 124 | 0.1 | | |
| Hail | 148,111 | 92.9 | | |
| Ice | 1,016 | 1.0 | | |
| Cold | 9,271 | 6.0 | | |
| Heat | 7 | 0.0 | | |
| Other | | | 194 | 100.0 |
| Total | 158,529 | | 194 | |
| Predation | | | | |
| Mammalian | 1,012 | 76.0 | 898 | 70.0 |
| Avian | 252 | 19.0 | 384 | 30.0 |
| Other vertebrates | 74 | 5.0 | 1 | 0.0 |
| Total | 1,338 | | 1,283 | |
| Pollution | | | | |
| Oil | 7,911 | 58.0 | 251 | 100.0 |
| Detergents | 418 | 4.0 | | |
| Chemicals | 2,414 | 17.0 | | |
| Domestic waste | 16 | 0.0 | | |
| Other | 2,934 | 21.0 | | |
| Total | 13,693 | | 251 | |
| Diseases and poisoning | | | | |
| Botulism | 1,679,771 | 89.7 | 1,093 | 63.3 |
| Lead poisoning | 69,732 | 3.8 | 87 | 5.0 |
| Fowl cholera | 99,066 | 5.3 | | |
| Aspergilliosis | 3,860 | 0.2 | | |
| Miscellaneous diseases | 12,169 | 0.6 | | |
| Unknown diseases | | | 502 | 29.1 |
| Parasites | 2,516 | 0.1 | | |
| Poisons | | | 45 | 2.6 |
| Pesticides | 5,129 | 0.3 | | |
| Total | 1,872,243 | | 1,727 | |
| Miscellaneous factors | | | | |
| Nets | 50,451 | 83.0 | 555 | 2.6 |
| Mammal traps | 3,112 | 5.1 | 3,131 | 14.5 |
| Banding mortality | 1,994 | 3.3 | 794 | 3.6 |
| Scientific specimens | 1,799 | 3.0 | 236 | 1.1 |
| Illegal kills | 793 | 1.3 | 1,307 | 6.0 |
| Adverse environmental factors | | | 15,623 | 72.2 |
| Unknown | 1,781 | 2.9 | | |
| Uncommon | 848 | 1.4 | | |
| Total | 60,778 | | 21,646 | |
| Total mortality | 2,108,880 | | 25,817 | |

percent of the observations, with each of the other strata accounting for 7 to 13 percent (Table 2). Observation of mortality from collision is probably more likely in the Central Flyway owing to the terrain features. Losses from collision may be unrelated to season; however, the data suggest a possible diminution of casualties during spring (Mar–May) (Table 3). Puddle ducks were most evident among the reported mortality (Table 4). There was no evidence that the sexes were differentially vulnerable to fatal collision (Table 5).

Most mortality of waterfowl from collisions is attributable to man, his activities, or his physical additions to the environment. The overall importance is probably minimal. Spectacular losses of migrating passerines (Stoddard and Norris 1967) are in sharp contrast to waterfowl casualties that tend to be isolated events (Tordoff and Mengel 1956). Most of the collisional factors listed in Table 1 do not pose a serious threat to waterfowl.

Collision with utility wires was important. Two factors, migration and inclement weather, probably accentuate wire strikes during the fall–winter period. Others (Quortrup and Shillinger 1941, Harrison 1963) have noted the association between prevalency of wire strikes and inclement weather, particularly fog. In part, learned response to the environment (Hochbaum 1955:14) may prevent many of the potential collisions on familiar areas, viz., nesting grounds and wintering grounds. Cornwell and Hochbaum (1971) suggested removing unnecessary fences and wires from waterfowl production marshes to reduce mortality from collisions.

No quantitative data are available on waterfowl collisions with autos. Data presented elsewhere (Stout 1967:71) suggest that such mortality may be common during the breeding season and periods of disper-

Table 2. Distribution of nonhunting mortality of waterfowl according to flyway or region and source of data.

| Mortality factor | Source: Bands | Source: Survey | % |
|---|---|---|---|
| Collision (3,140)[a] | | | |
| Atlantic | 101 | 132 | 7.4 |
| Mississippi | 159 | 214 | 11.9 |
| Central | 154 | 1,565 | 54.7 |
| Pacific | 116 | 276 | 12.5 |
| Canada | 328 | 95 | 13.5 |
| Weather (158,722) | | | |
| Atlantic | 63 | 4,863 | 3.1 |
| Mississippi | 47 | 3,323 | 2.1 |
| Central | 52 | 150,020 | 94.6 |
| Pacific | 6 | 322 | 0.2 |
| Canada | 26 | | 0.0 |
| Predation (2,621) | | | |
| Atlantic | 327 | 399 | 27.7 |
| Mississippi | 283 | 291 | 21.9 |
| Central | 113 | 517 | 24.0 |
| Pacific | 116 | 132 | 9.5 |
| Canada | 443 | | 16.9 |
| Pollution (14,350) | | | |
| Atlantic | 48 | 7,249 | 50.9 |
| Mississippi | 164 | 3,121 | 22.9 |
| Central | 15 | 2,933 | 20.5 |
| Pacific | 6 | 796 | 5.6 |
| Canada | 18 | | 0.1 |
| Disease (1,874,102) | | | |
| Atlantic | 117 | 6,115 | 0.3 |
| Mississippi | 115 | 84,874 | 4.5 |
| Central | 368 | 902,490 | 48.2 |
| Pacific | 988 | 878,918 | 47.0 |
| Canada | 117 | | 0.0 |
| Miscellaneous (81,915) | | | |
| Atlantic | 3,947 | 2,040 | 7.3 |
| Mississippi | 4,836 | 54,324 | 72.2 |
| Central | 2,843 | 3,026 | 7.2 |
| Pacific | 4,344 | 1,239 | 6.8 |
| Canada | 5,316 | | 6.5 |

[a] Sample size.

Table 3. Distribution of nonhunting mortality of waterfowl according to season and source of data.

| Mortality factor | Source: Bands | Source: Survey | % |
|---|---|---|---|
| Collision (3,135)[a] | | | |
| Spring | 277 | 225 | 16.0 |
| Summer | 256 | 594 | 27.1 |
| Fall | 113 | 797 | 29.0 |
| Winter | 100 | 773 | 27.9 |
| Weather (158,693) | | | |
| Spring | 45 | 517 | 0.4 |
| Summer | 30 | 148,000 | 93.3 |
| Fall | 23 | 350 | 0.2 |
| Winter | 96 | 9,632 | 6.1 |
| Predation (2,620) | | | |
| Spring | 282 | 177 | 17.5 |
| Summer | 349 | 730 | 41.2 |
| Fall | 432 | 90 | 19.9 |
| Winter | 218 | 342 | 21.4 |
| Pollution (13,913) | | | |
| Spring | 172 | 1,447 | 11.6 |
| Summer | 5 | 25 | 0.2 |
| Fall | 11 | 3,676 | 26.6 |
| Winter | 63 | 8,514 | 61.6 |
| Disease (1,871,192) | | | |
| Spring | 162 | 18,243 | 1.0 |
| Summer | 650 | 1,252,251 | 67.0 |
| Fall | 681 | 432,142 | 23.1 |
| Winter | 233 | 166,830 | 8.9 |
| Miscellaneous (81,940) | | | |
| Spring | 7,470 | 710 | 10.0 |
| Summer | 2,769 | 2,300 | 6.0 |
| Fall | 4,839 | 52,371 | 70.0 |
| Winter | 6,437 | 5,044 | 14.0 |

[a] Sample size.

sal. Three hundred band recoveries (Table 1, other objects) were attributed either to wire strikes or auto collision, but a specific cause of death could not be assigned.

Nesting duck mortality from farm machinery does not appear to be serious, although nest loss is of considerable importance. Previous authors (Milonski 1958, Ordal 1964) have reached similar conclusions.

## Weather

Waterfowl mortality associated with inclement weather represented 7.4 percent of the total sample, and hail was the most significant individual weather factor (Table 1). Mortality from weather was most represented in the Central Flyway and most was caused by hail (Table 2). These losses, spectacular and readily counted, tended to exaggerate the regional total. Mortality in each of the other geographic strata amounted to 1 to 3 percent. The latter casualties were due largely to cold weather (Tables 1, 2). Ice, cold temperatures, and wind generally acted in concert during the

Table 4. Distribution of nonhunting mortality of waterfowl by species group and source of data.

| Mortality factor | Source | | |
|---|---|---|---|
| | Band | Survey | % |
| Collisions (3,016)[a] | | | |
| Puddle ducks | 1,131 | 566 | 56.3 |
| Diving ducks | 396 | 66 | 15.3 |
| Geese | 110 | 84 | 6.4 |
| Swans | 12 | | 0.4 |
| Unidentified | | 651 | 21.6 |
| Weather (158,723) | | | |
| Puddle ducks | 149 | 3,013 | 2.0 |
| Diving ducks | 32 | 1,184 | 0.8 |
| Geese | 13 | 3,325 | 2.1 |
| Swans | | 4 | 0.0 |
| Unidentified | | 151,003 | 95.1 |
| Predation (2,625) | | | |
| Puddle ducks | 1,109 | 698 | 68.8 |
| Diving ducks | 81 | 89 | 6.5 |
| Geese | 94 | 50 | 5.5 |
| Swans | 2 | 15 | 0.6 |
| Unidentified | 1 | 486 | 18.6 |
| Pollution (3,351) | | | |
| Puddle ducks | 26 | 12 | 1.2 |
| Diving ducks | 73 | 61 | 4.0 |
| Geese | 1 | 3 | 0.1 |
| Swans | | 1 | 0.0 |
| Unidentified | | 3,174 | 94.7 |
| Disease (1,873,970) | | | |
| Puddle ducks | 1,462 | 187,929 | 10.1 |
| Diving ducks | 134 | 5,939 | 0.3 |
| Geese | 128 | 18,767 | 1.0 |
| Swans | 3 | 2,097 | 0.1 |
| Unidentified | | 1,657,511 | 88.5 |
| Miscellaneous (82,424) | | | |
| Puddle ducks | 15,054 | 2,638 | 21.5 |
| Diving ducks | 3,563 | 54,357 | 70.3 |
| Geese | 2,968 | 1,085 | 4.9 |
| Swans | 61 | 78 | 0.1 |
| Unidentified | | 2,620 | 3.2 |

[a] Sample size.

Table 5. Distribution of nonhunting mortality of waterfowl according to sex.

| Mortality factor | Bands | | Survey | |
|---|---|---|---|---|
| | M | F | M | F |
| Collisions | 271 | 256 | 219 | 224 |
| Weather | 288 | 179 | | |
| Predation | 632 | 488 | | |
| Pollution | 149 | 56 | 1,837 | 773 |
| Disease | 1,001 | 413 | 3,078 | 2,486 |
| Miscellaneous | 10,655 | 6,002 | 814 | 653 |

winter (Dec–Feb) to cause mortality not readily attributed to any individual factor (Tables 1, 3). The species composition of the casualties ascribed to weather factors was predominantly unidentified (Table 4). Male anatids (288) were more frequent in the reported losses than were females (179) (Table 5).

Factor interactions often complicate the identification of a given weather factor as the ultimate or proximate cause of death. When waterfowl habitat is covered with ice, losses result because food, shelter, and escape cover become unavailable. Observations by Trautman et al. (1939) documented ice as the ultimate mortality factor. During freezes of short duration, losses occurred among underweight, diseased, and otherwise injured waterfowl. Healthy birds died only after habitats had frozen over for long periods (Jahn and Hunt 1964:103). High winds have been reported to kill waterfowl in unusual circumstances (Rate 1957, Wooten 1954).

Scattered reports suggested hail as a frequent cause of mortality, principally affecting preflight birds. Smith and Webster (1955:374) in Alberta attributed the loss of up to 148,000 waterfowl to 2 hail storms. Fyfe (1957) presented similar observations from Saskatchewan. Hail losses were shown by Ordal (1964) to have a marked influence on duck production on a Minnesota study area where the number of broods was decreased to one-half of the 4-year average following a severe hail storm. Hochbaum (1955:167) cited an example of migrating waterfowl being killed in flight by hail.

Waterfowl seldom if ever suffer fatal hypothermia unless accompanied by, or as a culmination of, the influence of another stressor. Most observations in the literature cite mortality as having been caused by starvation; in contrast, Roseberry (1962) suggested that predation was the principal source of mortality to upland game. Extensive observations from Great Britain and the United States supported the hypothesis that starvation is the principal cause of hypothermia in waterfowl (Boyd 1964, Harrison and Hudson 1964, Kalmbach and Coburn 1937, Trautman et al. 1939).

Waterfowl species undoubtedly differ in their resistance to cold-weather stress. Boyd (1964) showed that certain waterfowl species in Britain suffered disproportionally heavy losses to cold weather. Evidence presented by Beer (1964) suggested differences at the tribal level in resistance to cold: Dendrocygnini showed the highest mortality, Anserini showed little mortality, and other tribes were intermediate.

Canada geese (*Branta canadensis*) sustained the greatest cold losses reported in the survey. Most observations were from the Atlantic Flyway, specifically the Pea Island area of North Carolina, where studies (Cowan and Herman 1956) revealed that heaviest mortality was associated with cold weather, malnutrition owing to food of low crude protein content, and heavy parasitism by gizzard worms (*Amidostomum anseris*).

Weather factors most often may act to disturb the overall density-regulating process in waterfowl populations. However, with regard to mortality, specific factors may operate under different circumstances as either density-independent or density-proportional effects (Wagner et al. 1965).

## Predation

Predation losses represented 0.1 percent of the total nonhunting mortality reported (Table 1). Data suggested that mammals prey on waterfowl three to four times as heavily as do avian predators. Regional variation in predation was small in contrast to other categories of mortality (Table 2). Reported losses were lowest in the Pacific Flyway and highest in the Atlantic Flyway. Survey-reported predation upon waterfowl appeared to peak during summer (Jun–Aug), but band recoveries were more frequent in the fall (Sep–Nov) (Table 3). Losses were represented largely by puddle ducks in the data examined (Table 4). Predation among puddle ducks was probably more likely to be discovered and/or reported than among other anatids. More male (632) than female (488) anatids were observed killed by predators (Table 5).

Errington (1946) reviewed the early literature on vertebrate predation upon waterfowl. He concluded that so-called "surplus" birds comprised most of the mortality. Much of the literature concerned with predation upon waterfowl deals with egg and nesting losses (Bennett 1938, Low 1945, numerous others). Studies providing data on nesting female losses showed that roughly 1 percent of the ground nesters and 5 percent of the cavity nesters may succumb to predation (Keith 1961:44, Milonski 1958:223, Stotts and Davis 1960:149, Glover 1956:41). These losses alone do not appear to have a major influence on waterfowl sex ratios (Bellrose et al. 1961). Postnesting losses may be frequent among molting birds, for Oring's (1964) observations suggested high vulnerability during flightless periods.

Over 90 percent of the band recoveries attributed to mammalian predation were from puddle ducks. Although more puddle ducks were present in banded populations, the high recovery rate probably reflected the amount of time spent on the ground in nesting and other activities where vulnerability was greater. Twice as many banded geese as diving ducks were recovered.

Previous studies (Hecht 1951, Wright 1953, Bennett 1938:66) suggested low rates of avian predation during the breeding season. Little work has been done on avian predator-waterfowl relationships during winter, but scattered reports document minor losses (Sharp 1951, Imler and Kalmbach 1955).

Recent quantitative studies of red-tailed hawk (*Buteo jamaicensis*) predation in Alberta (Luttich et al. 1970:196) demonstrated that flying-age waterfowl comprised from 3.6 to 16.5 percent of the dietary biomass over the years 1965 through 1968. Predation upon flying-age waterfowl by fish and reptiles does not appear to be of any consequence (Coulter 1958, Lagler 1956, Solman 1945).

## Pollution

Data on waterfowl mortality associated with five categories of pollution are presented in Table 1. Oil pollution was a major factor according to the survey data; few band recoveries were reported, but all were attributed to oil pollution. Losses were greatest in the Atlantic Flyway (51 percent), least in the Pacific Flyway (5 percent), and similar in the Mississippi and Central flyways, 23 and 20 percent, respectively (Table 2). Little mortality was reported from Canada. Winter was the season associated with most of the waterfowl losses (Table 3). Reported observations diminished during summer and spring. Waterfowl classed as "unknown species" comprised 95 percent of the combined sample (Table 4). Mortality identified to species, largely from band recoveries, involved principally diving ducks. Mortality from pollution was largely among males (Table 5).

Previous studies of oil pollution (Hawkes 1961, Erickson 1963) reported the greatest regional losses of waterfowl on the coasts of North America, principally the Atlantic coast. Eighty-nine percent of the survey observations were from the Atlantic Flyway. Observations on oil mortality are given by Hadley (1930) and Lincoln (1936). Wilson (1960, unpubl. rep., New York Dept. Environ. Conserv., Albany) showed that significant numbers of waterfowl harvested in the eastern portion of Lake Erie were contaminated by oil, but direct evidence of mortality was not cited.

Band recoveries associated with oil pollution were more than three times more common in the Mississippi Flyway than the Atlantic Flyway. Hunt and Cowan (1963) discussed the hazards of oil pollution to waterfowl wintering on the Detroit River-Lake Erie complex. F. B. Lee (Unpublished data) also observed extensive waterfowl losses to oil in the vicinity of Red Wing, Minnesota. An oil spill on the Mississippi River in 1963 (Jessen 1963, p. 5 *in* Minutes of Technical Section, Mississippi Flyway Council, St. Louis, Mo.) was estimated to have killed 10,000 waterfowl; of 2,000 examined casualties, 85 percent were scaup (*Aythya affinis* and *A. marila*) and 95 percent were males. Hartung and Hunt (1966) suggested that oil losses were still important in the Detroit River area. Pacific Flyway recoveries of oil-contaminated birds were insignificant, although Richardson (1956:20) reported up to 2,000 white-winged scoters (*Melanitta deglandi*) were killed by a single oil spill.

Occurrence of oil spills on waterways or coasts does not follow any observable seasonal cycle but is random, because most pollution is man-made (Erickson 1963) and in part accidental. Rather, the seasonal movements of waterfowl determine their vulnerability and mortality in the randomly appearing foci of oil pollution. Thus migration may make waterfowl especially vulnerable to oil spills. Hartung (1967) showed that the probability of survival following oil contamination is related directly to the fat reserves of cold-stressed ducks. During the breeding season, only five band recoveries were reported.

Diving ducks sustain most of the casualties attributed to oil pollution. Eiders (*So-*

*materia* sp.), scoters, and oldsquaws (*Clangula hyemalis*) long have been implicated in these losses (Hadley 1930). Of the total band recoveries, 47 percent were scaup and 20 percent canvasback (*Aythya valisineria*). The black duck (*Anas rubripes*) is probably the most vulnerable of the puddle ducks to oil losses, for it commonly winters on salt water (Wright 1954:109).

Various chemicals and detergents were reported to have killed waterfowl (Table 1, survey data). Major losses (84 percent) were from the Central Flyway where mine pollution was prevalent. Most of the observations were made during the winter season. Mortality appeared to be concentrated on the wintering grounds.

Waterfowl mortality caused by sundry forms of pollution was greatest during the spring (96 percent) (Stout 1967:151). Water pollution by unknown agents also killed mainly diving ducks.

The tendency of pollution to cause mortality during winter and spring (after shooting losses) and prior to the breeding season would be of concern only in those species that otherwise might be reduced to low numbers. Any variation in the number of returning breeding birds then would be of importance.

## Diseases and Poisoning

Disease mortality was 87.8 percent of the total nonhunting mortality studied, and band recoveries accounted for less than 1 percent of the diseased sample (Table 1). Botulism was the major pathogen represented in the survey data and band recoveries. Fowl cholera and lead poisoning also were significant factors. Disease and poisoning casualties were greatest in the Central and Pacific flyways, 48.2 and 47 percent, respectively (Table 2); fewest losses were reported from the Atlantic Flyway. Study of the seasonal dynamics of waterfowl losses

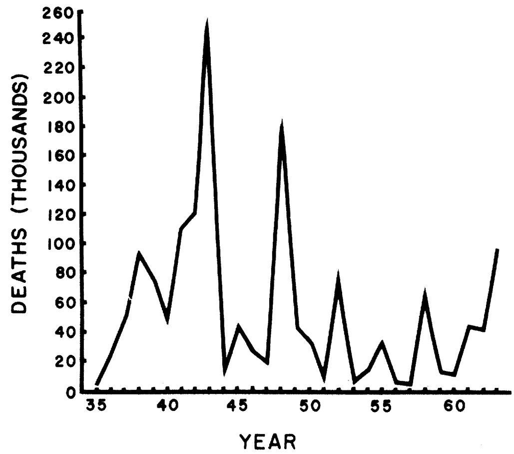

Fig. 1. Trend of waterfowl mortality from botulism principally on federal refuges, 1935–63; survey data and band recoveries combined.

revealed a unimodal peak in summer and a gradual decline until the following summer (Table 3). Most of the reported mortality (88 percent) was not identified to species (Table 4). Puddle ducks were over 95 percent of the identified sample. Male anatids were reported more frequently than females in the disease sample (Table 5).

Except for a few local case histories, information on year-to-year variation in mortality caused by botulism is not available. A great quantity of data was abstracted from U. S. Fish and Wildlife Service files, and the long-term trend (29 years) of botulism losses (Fig. 1) showed marked fluctuations every 2 to 5 years. This cycle may be generated by population fluctuations of the invertebrates that harbor the botulism toxin (Jensen and Allen 1960) or by changes in the number of susceptible waterfowl.

The great significance of botulism as a mortality factor in the Pacific and Central flyways was corroborated by the survey; in addition, losses were found to be common in the Mississippi Flyway and limited in the Atlantic Flyway (Reilly and Boroff 1967).

Puddle ducks made up 92 percent of the band recoveries attributed to botulism. The pintail (*Anas acuta*) was the most common species among the band recoveries (44 percent) and in the survey (49 percent). Quortrup and Shillinger (1941) and Hammond (1950) also supported this conclusion. The diving ducks, geese, and swans suffered occasional botulism losses, but nothing comparable to the puddle ducks (Bossenmaier et al. 1954).

The results of the study on lead poisoning (Table 1) supported in several respects the definitive work of Bellrose (1959). The survey indicated the Mississippi Flyway to be the major site of mortality (76 percent); the Central Flyway made up an additional 21 percent. Survey observations were predominantly from winter (79 percent), as also reported by Bellrose (1959:284). The mallard (*A. platyrhynchos*) accounted for 54 percent (47) of the band recoveries and 60 percent (42,135) of the survey observations. Few deaths of banded birds (87) were attributed to lead poisoning. Additional data on the species composition of losses by flyway and season were reported in Stout (1967:168). Overall importance of lead poisoning as a mortality factor affecting waterfowl was estimated by Bellrose (1959:286) as a 2–3 percent annual loss of the total population. This appears to be the best estimate available.

Fowl cholera was generally limited to the Central and Pacific flyways (Quortrup et al. 1946, Rosen and Bischoff 1949). Outbreaks in the Mississippi Flyway were unusual (Vaught et al. 1967), and serologic evidence supports this conclusion (Donahue and Olson 1969). The first published report for the Atlantic Flyway was Gershman et al. (1964); however, Locke et al. (1970) found fowl cholera among waterfowl on the Chesapeake Bay.

Outbreaks of fowl cholera were associated consistently with winter (Quortrup et al. 1946, Rosen and Bischoff 1950, Petrides and Bryant 1951). Gershman et al. (1964) reported the only instance of an outbreak during the breeding season. Survey and band recovery data were inadequate to demonstrate differential losses to fowl cholera by species.

After contamination with the cholera agent, a given area seems to remain a focus in which an outbreak may recur. For example, the Muleshoe area in Texas has had a long history of fowl cholera, and as recently as 1956–57, 60,000 waterfowl were estimated to have died there (Jensen and Williams 1964:339). Data given by Rosen (1969) showed cholera mortality to be density-independent.

An extensive amount of information on waterfowl losses attributed to miscellaneous and unknown diseases and parasites was given by Stout (1967:185, 196). The nature of the data does not lend itself to discussion here.

Pesticide kills of waterfowl were largely seasonal and concentrated during spring migration. Coincidence of mortality, spring migration, and the application of toxic chemicals to agronomic crops also was reported from England (Cramp and Conder 1960, Cramp et al. 1962). The English studies showed the principal losses to be among birds feeding on vegetation. The band recoveries reported here were primarily of vegetation-eating species (94 percent). Geese were especially vulnerable. Direct mortality caused by pesticides appears to be among the breeding stock and superimposed on the losses over winter. More subtle effects may be operating on the breeding biology (Heath et al. 1969), and the impact could be far greater than the direct mortality (Longcore et al. 1971, Friend and Trainer 1972).

Botulism losses are probably the best documented of the nonhunting mortality factors. Areas regularly experiencing waterfowl losses to botulism tend to be watched carefully. Accordingly, the survey data have underestimated the magnitude of other nonhunting mortality compared to botulism losses.

Disease may be an important factor limiting waterfowl numbers. Conclusive evidence to support the presumption of disease acting on waterfowl as a density-dependent factor is not available. Lack (1954:166) speculated that North American waterfowl populations might be controlled in part by disease.

## Miscellaneous

Miscellaneous mortality was 3.8 percent of the total nonhunting mortality; however, 83.8 percent of the total band recoveries were included in this category (Table 1). Waterfowl drowned in fish nets represented 83 percent of the survey data sample and 2 percent of the band recoveries (Table 1). Waterfowl losses attributed to mammal traps, banding procedures, scientific collections, and unknown factors were of similar magnitude in the survey sample (Table 1). A major portion of the band recoveries (15,623) was reported as killed by adverse environmental factors (Table 1). Miscellaneous mortality was associated strongly with the Mississippi Flyway (72 percent); the remaining geographic strata reported losses of the same proportion (Table 2). Mortality was associated largely with fall (70 percent) (Table 3), and diving ducks composed 70 percent of the sample (Table 4). Considerable disparity was apparent in the frequency with which the sexes were reported killed by miscellaneous factors (Table 5).

Mortality of waterfowl from commercial fishing nets frequently has been reported (Schorger 1947, Ellarson 1956:105, Jahn and Hunt 1964:102, Bartonek 1965). The survey indicated that the Mississippi Flyway was the principal site of the mortality (99 percent). Losses tended to be most common among wintering populations (McMahan and Fritz 1967), particularly among redheads (*Aythya americana*) and oldsquaws.

Mammal trapping, largely for muskrats (*Ondatra zibethicus*), takes a heavy annual toll of waterfowl. Of the band recoveries, 64 percent were from Canada; 88 percent of the survey reports were from the Mississippi Flyway. Jahn and Hunt (1964:172) reported 1 duck/500 trap-nights in Horicon Marsh, Wisconsin, in 1952. Losses were most common during spring (Mendall 1958: 213, Wright 1954:26).

A major portion of the band recoveries (60.5 percent) was attributed to adverse environmental factors and grouped in this section on miscellaneous mortality (Table 1). If these recoveries could have been ascribed to specific mortality factors the results might have modified some of our conclusions with regard to other mortality factors. Furthermore, the fact that these recoveries (15,623) could not be qualified as to cause of death emphasized the serious limitation imposed on any study of nonhunting mortality, i.e., determination of the cause of death.

Other miscellaneous factors listed in Table 1 were further detailed by Stout (1967) and will not be discussed here. Generally the miscellaneous mortality was associated with man and his activities. The importance of such losses may be expected to grow in the future.

## Seasonal Distribution of Band Recoveries

The seasonal trend of nonhunting mortality band recoveries from 1930 to 1963 is shown in Fig. 2. Recoveries of geese and swans peaked in December and January, diving ducks in March, and puddle ducks in

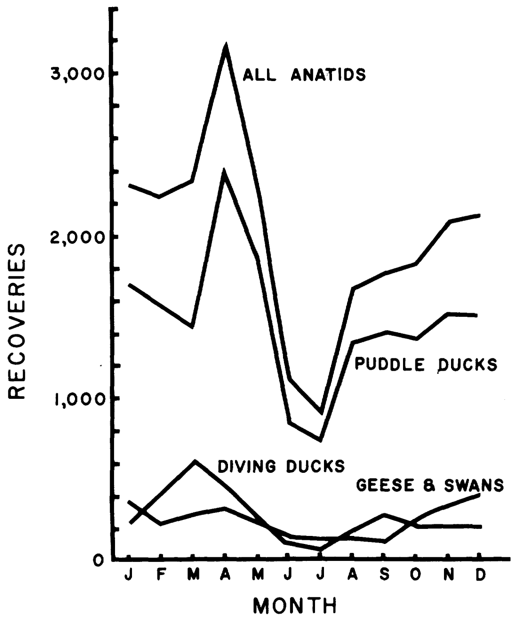


Fig. 2. The seasonal trend of nonhunting mortality of waterfowl according to band recoveries, 1930–63 ($n$ = 25,817).

April. Band recoveries were minimal in July for diving ducks and puddle ducks. Observed mortality of geese and swans was low during the summer months and minimal in September. Recoveries of puddle ducks showed a marked seasonal effect, whereas losses of geese and swans varied slightly by season.

The observed seasonal trend of nonhunting mortality has important implications with regard to annual mortality. Implicit in the harvesting policy for North American waterfowl is the notion that insignificant mortality occurs following the hunting season. That is, nonhunting mortality is assumed to be largely replaced by shooting losses. Some nonhunting mortality is replaced by shooting losses, but we believe the data suggest that important winter and spring losses occur after hunting mortality has reduced the populations.

Buss et al. (1952) discussed spring mortality in ring-necked pheasant (*Phasianus colchicus*) populations and concluded that these losses were the most critical of the year. Similarly, Stewart and Manning (1958) regarded spring and summer mortality as important sources of variation in whistling swan (*Cygnus columbianus*) populations. Conversely, Jahn and Hunt (1964) found winter mortality of waterfowl to be minor in Wisconsin. Mendall's (1958) work on ring-necked ducks (*Aythya collaris*) suggested spring and summer as key periods of mortality. Jennings (1961) plotted the seasonal distribution of death of wild birds ($n = 1{,}000$) examined over a 7-year period. His observations showed a sharp but steady rise in number of deaths from March until a peak was reached in June.

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