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Mortality of Common Mergansers in Lower Saginaw Bay

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# WINTERING STRATEGIES AND TRANSMISSION LINE MORTALITY OF COMMON MERGANSERS IN LOWER SAGINAW BAY

By

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# ABSTRACT

## WINTERING STRATEGIES AND TRANSMISSION LINE MORTALITY OF COMMON MERGANSERS IN LOWER SAGINAW BAY

By

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Age and sex specific differences in fasting endurance and behavioral dominance have been advanced as hypotheses to explain the preponderance of adult males often observed in waterfowl populations using northern wintering sites. To assess these hypotheses, numbers, habitat use, time-activity budgets, and foraging success of adult male and other common mergansers (*Mergus merganser*) observed in lower Saginaw Bay were compared among 3 winters (Nov. 1988 - March 1991). Each year, 10,000-12,000 mergansers, of which 6-15% were adult males, arrived in the area in late fall and early winter to feed on gizzard shad fry (*Dorosoma cepedianum*) that aggregated in the Karn-Weadock power plant's thermal discharge zone. More than 50% of the mergansers left the area in late January, after the shad dispersed. During 2 winters, the proportion of adult males in midwinter increased 2- to 3-fold as more than half of the adult males stayed in the area while most of the other birds departed. Adult males spent less time foraging in midwinter than other birds, as predicted by the fasting endurance hypothesis. However, there was no change in the proportion of adult males from early to midwinter during the third year, indicating that fasting endurance is not solely responsible for the age and sex distribution of wintering mergansers. There was no evidence to support the behavioral dominance hypothesis.

A collision mortality problem developed at the Karn-Weadock site as a result of migrating and wintering common mergansers flying across transmission

lines that are concentrated in flight corridors. Flight patterns were observed to identify problem corridors, and collision mortality was estimated from observed collisions and numbers of carcasses found under transmission lines that bisected flight paths. An estimated 624 collisions resulting in death and 907 resulting in serious injury occurred during the 3 winters. In December and January 1989-90 and 1990-91, an attempt was made to direct birds away from the lines by obstructing key flight paths with 1.7-m diameter, helium-filled balloons placed at transmission line height. Balloons were removed every other week to assess their effectiveness. Obstruction of flight paths caused significant ($P<0.001$) shifts in merganser flight patterns that resulted in a reduction of documented mortality from 41 fatal collisions when balloons were absent to none when balloons were present.

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## PART I: WINTERING STRATEGIES

### INTRODUCTION

Although the majority of North American waterfowl winter in southern United States and Central and South America (Bellrose 1980), populations of several species winter farther north. Most North American sea ducks [eiders (*Somateria* spp.), scoters (*Melanitta* spp.), oldsquaw (*Clangula hyemalis*), and harlequin ducks (*Histrionicus histrionicus*)] winter north of the 40th parallel along the Atlantic and Pacific coasts (Bellrose 1980, Reed 1986). Likewise, many of the black ducks (*Anas rubripes*) and canvasbacks (*Aythya valisineria*) that winter in the Atlantic Flyway remain in northern coastal habitats throughout the winter (Diefenbach *et al.* 1988, Serie *et al.* 1983). These populations exhibit fidelity to specific coastal wintering sites from year to year, and stay in their traditional wintering areas even during extended periods of extremely harsh weather (eg. Longcore and Gibbs 1988).

Other wintering waterfowl utilize inland habitats in the north. Because food availability is less stable and predictable in inland habitats than in coastal habitats during winter (Diefenbach *et al.* 1988), these birds tend to be facultative migrants (i.e., they remain in northern areas only as long as those areas provide their winter requirements). Individuals may benefit from a flexible wintering strategy such as this in several ways. Ketterson and Nolan (1976, 1979) noted that energetic costs of migration are reduced for birds that winter farther north than other conspecifics. Furthermore, wintering closer to the breeding grounds may enhance their timing of arrival on breeding grounds (Ketterson and Nolan

1976, 1979). Individuals of several species and subspecies of waterfowl have adopted the facultative migrant strategy, including mallards (*Anas platyrhynchos*) (Bellrose and Crompton 1970, Nichols *et al.* 1983, Jorde *et al.* 1984), common goldeneyes (*Bucephala clangula*) (Sayler and Afton 1981), common mergansers (*Mergus merganser*) (Bellrose 1980), giant Canada geese (*Branta canadensis maxima*) (Hanson 1965), and to a lesser extent, black ducks (Bellrose and Crompton 1970) and interior Canada geese (*B. c. interior*) (Cook 1990).

Technological and industrial development in the 20th century has resulted in the creation of numerous artificial environments, including permanent open water zones in areas well north of the traditional wintering grounds used by most waterfowl. These potential wintering areas in northern latitudes provide alternative winter habitats for some waterfowl species, particularly facultative migrants. Significant numbers of mallards, goldeneyes, and mergansers currently winter in open water zones created by hydro-electric dams (Reed and Bourget 1977, Thompson *et al.* 1988), municipal waste and water treatment operations (Cooper and Johnson 1977), and warm water discharge from power generating plants (Haymes and Sheehan 1982) and other industrial plants (Sugden *et al.* 1974, Cooper and Johnson 1977).

The facultative strategy may result in increased survival and/or reproductive success. However, physiological and ecological constraints may limit the ability of some species, or demographic groups within species, to take advantage of these habitats. Food resources must be adequate to meet the greater energetic demands that are imposed by harsh winter climate in northern latitudes. Although waterfowl species often minimize interspecific competition for food through habitat segregation (Stott and Olson 1973, White and James 1978), limited food supplies within habitat segments may result in intraspecific competition. In addition to food requirements, wintering waterfowl need favorable habitats for other activities. Requirements for roosting, resting, body maintenance activities, and courtship may not be adequately met in feeding habitats (Gray *et al.* 1987). If the energetic demands of movement between habitats are offset by survival or reproductive benefits derived (eg. greater security or space for courtship and pairing), optimal wintering areas may consist of several different habitats.

Wintering areas in northern latitudes are not equally suitable for all sex and age classes within a species, as evidenced by a general pattern of skewed sex and age ratios that has been documented in wintering populations of several species of ducks. Adult males were predominant in populations of common mergansers wintering in northcentral United States, whereas adult females and immature mergansers were more abundant farther south (Anderson and Timken 1972). Similar winter distribution patterns have been shown for common goldeneyes (Sayler and Afton 1981), mallards (Jorde *et al.* 1984), and canvasbacks (Nichols and Haramis 1980). Ketterson and Nolan (1976, 1979) hypothesized that in addition to possible differences among age and sex classes in costs and benefits associated with migration and timely arrival on breeding grounds, the social status and body size of individuals may influence wintering distribution patterns. Sayler and Afton (1981) concluded that differences in body size and weight between males and females and/or intraspecific competition for food among sex and age classes are among the causative factors underlying the skewed sex and age ratios observed in many wintering duck populations. Larger, heavier adult males require relatively less energy for maintenance than adult females and immature birds, and their position of social dominance favors them in competition for limited food resources (Sayler and Afton 1981). Perry *et al.* (1988) treated these as competing hypotheses, terming the former the fasting endurance hypothesis and the latter the behavioral dominance hypothesis. Although their studies of behavior and weight loss in stressed captive canvasbacks did not provide support for either hypothesis, they believed that their results were insufficient to conclusively refute the hypotheses.

Little is known about the factors that influence the choice of wintering sites by piscivorous species such as the common merganser. Migrating common mergansers arrive in the Great Lakes region in November and early December (Bellrose 1980). Although scattered small flocks of common mergansers traditionally wintered in open water on inland lakes and streams and along the coasts of Michigan, large groups were rare (Salyer and Lagler 1940). However, when Consumers Power Company's Karn-Weadock power generating facility commenced operations, the plant's thermal discharge created a previously unavailable open water habitat in lower Saginaw Bay during winter. Migrating and wintering mergansers began congregating at the Karn-Weadock site in response to this new habitat; several thousand common mergansers have been observed there each winter since 1976. This study was an investigation of the wintering strategies of common mergansers using that permanent open water zone. The following predictions were tested: 1) the age and sex composition of the wintering population would be skewed in favor of adult males (consistent with both the behavioral dominance and fasting endurance hypotheses); 2) adult males would displace other birds from preferred foraging habitats (predicted by the behavioral dominance hypothesis); 3) adult males would be more successful at capturing prey than other birds (predicted by the behavioral dominance hypothesis); and 4) adult males would spend less time foraging than other birds (predicted by the fasting endurance hypothesis).

## STUDY AREA

The study area is located in the vicinity of Bay City, Michigan, where the Saginaw River drains into lower Saginaw Bay (Figure 1). With the onset of winter, inland lakes, ponds, and streams that would otherwise provide suitable open water habitats for migrating and wintering common mergansers are eliminated by ice cover. Water temperatures at the mouth of the Saginaw River average 0-2°C during the winter months (December - March), and most of the river and lower bay is also often ice-covered. Small, scattered pockets of open water, created by discharges from several factories and a waste water treatment plant in Bay City, are present for most of the winter in the Saginaw River.

The Karn-Weadock facility is situated at the mouth of the Saginaw River, bordered by Saginaw Bay to the north and the Saginaw River to the west (Figure 1). Water imported from the river to cool the plant's turbines is returned to Saginaw Bay via a discharge channel. This continuous discharge of heated water, averaging 12-13°C during winter, creates a plume of permanent open water in the bay (Figure 1) that varies in size from 80-770 ha throughout the winter. The size and shape of the plume is influenced by temperature, wind velocity and direction, and water currents and wave action in the bay. The power plant's thermal discharge attracts some species of fish, including gizzard shad (*Dorosoma cepedianum*), in late fall. During November and December, young-of-the-year gizzard shad aggregate into large schools near the mouth of the Saginaw River and

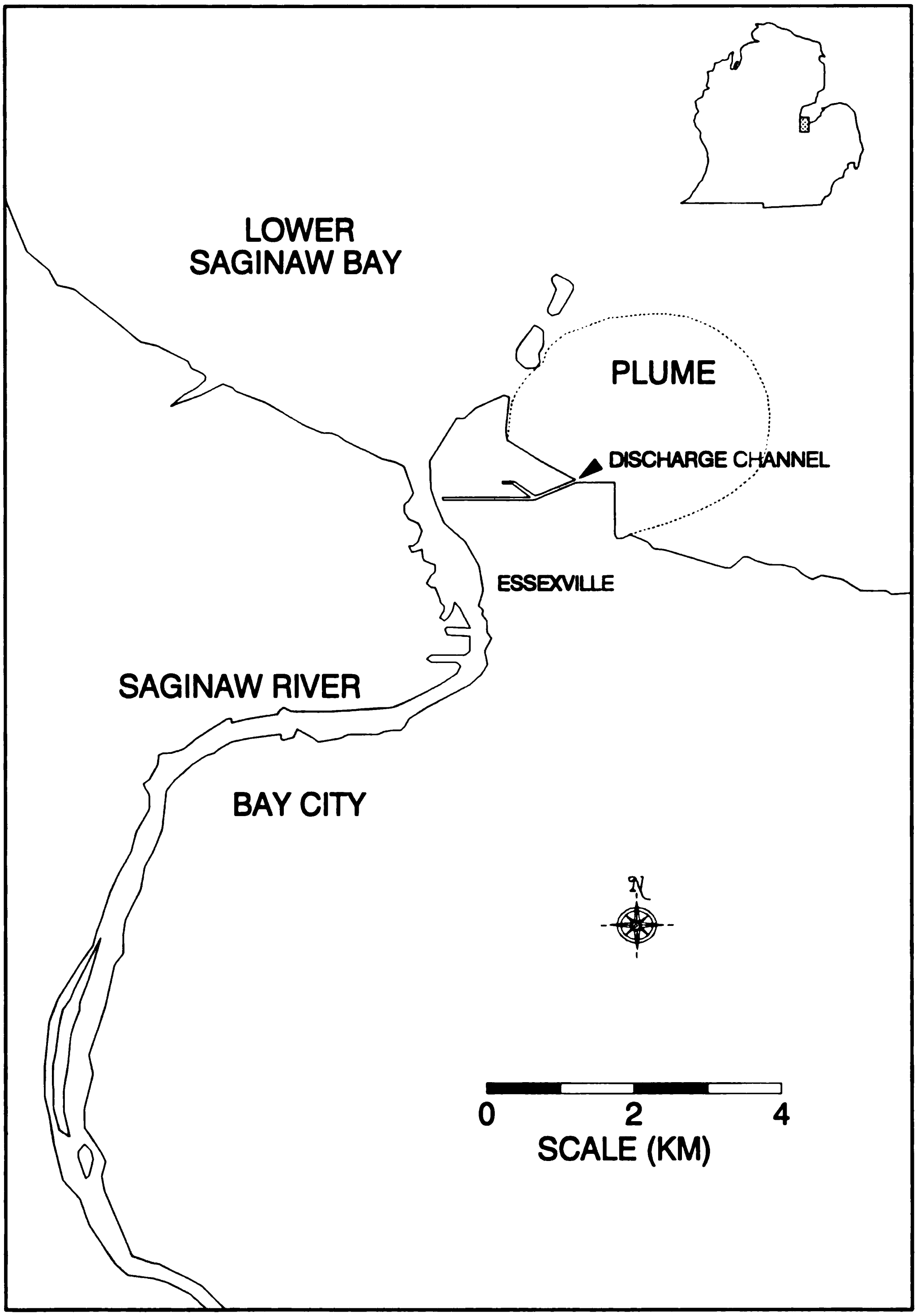


Figure 1. Lower Saginaw Bay, the Karn-Weadock (Essexville, Michigan) power generating station's discharge channel, and the warm water mixing zone (plume) created by thermal discharge from the power plant.

in the power plant's plume (Pope 1976). The timing of these shad movements coincides with the early winter arrival of migrating common mergansers.

## METHODS

Activities of common mergansers were observed 4 days/wk during the winters of 1988-89 (December-March), 1989-90 (November-March), and 1990-91 (November-March). The objectives of this study were to: 1) describe seasonal changes in population size and the age and sex composition of the population; 2) compare seasonal habitat use by adult males versus other birds; 3) construct and compare seasonal time-activity budgets for adult males versus other birds; and 4) document and compare foraging success of adult males versus other birds.

### Counts

Common mergansers in the area were counted at midday 1-4 days/wk, using binoculars or a spotting scope. During early winter 1988-89, midday counts covered the power plant's discharge channel and the plume. When other sites used by mergansers in the area were identified as the winter progressed, they were included in midday counts. As a result, by late winter midday counts were also taken at the mouth of the Saginaw River and along a 20-km segment of the river extending south from the river mouth. Midday counts in 1989-90 and 1990-91 covered all sites that were identified as potential merganser habitat in 1988-89.

Mergansers using inland habitats at night were also counted. Initial observations indicated that most of the birds in the area were spending the night in the discharge channel, therefore either evening or early morning counts were conducted 4 days/wk from vehicles parked on the dikes along the channel.

Evening counts consisted of enumerating mergansers in the channel in late afternoon and birds that flew into the channel from late afternoon until 0.5 hr after sunset. During early morning, birds swimming or flying out of the channel were counted from 1-1.5 hr before sunrise to 0.5 hr after sunrise. It was assumed that mergansers did not enter or leave the discharge channel during the night. In February and March, mergansers in the Saginaw River were counted at night from the shore $\geq$1 night/2 wk.

The sex and age composition of the population was estimated by sampling randomly selected groups of birds after counts were completed and during behavioral observations. Adult females, immature males, and immature females could not be reliably differentiated, thus birds were identified as either adult males or others. Estimates of the number of adult males present were extrapolated by multiplying the proportions of adult males in the sample groups by the corresponding total counts of mergansers.

**Habitat Use**

***Movement Patterns.*** Flights of common mergansers were documented 4 days/wk during 3 time periods: morning (0.5 hr before sunrise to 2.5 hr after sunrise); midday (2.5 hr after sunrise to 2.5 hr before sunset); and evening (2.5 hr before sunset to 0.5 hr after sunset). Three 15-min observations/time period/day were conducted from vehicles parked at the mouth of the discharge channel. Number of birds and flight direction (inland or toward Saginaw Bay) were recorded. Although movement between inland habitats (river and discharge channel) and the plume was recorded, movement within habitats was not documented. The 3 flight observations/time period/day were pooled to estimate total flights/time period/day.

*Availability*. Based on observations during the first year of the study, the discharge channel, the plume, and Saginaw River were identified as habitats suitable for common mergansers during winter. However, the availability of the plume and the river was limited by ice cover, the extent of which varied as a function of weather conditions. Changes in the amount of open water in those 2 habitats were noted when they occurred, providing estimates of percent availability throughout the winter.

*Use*. Estimates of the mean number of birds using each habitat during the day were derived from midday counts, whereas estimates of night habitat use were based on a combination of counts and flight observations. Although night counts of birds in the discharge channel were considered accurate, complete counts of mergansers in the Saginaw River often were not obtained. Therefore, when flight estimates indicated that more birds were using inland habitats at night than were actually counted there, the additional birds were assumed to be using the river. Night use of the plume was estimated indirectly by subtracting the number of birds using inland habitats at night from the total number of mergansers in the area, as determined from midday counts.

Day and night estimates were averaged to examine the factors affecting diel habitat use. The effects of year, season, and age-sex group on the number of birds using each habitat were analyzed with linear model Chi-square analogues of analysis of variance (SAS Institute Inc. 1985). When full-model analyses indicated that interaction effects were significant, subsets of the data were used to analyze the main effects.

**Behavior**

Instantaneous sampling was used to construct time-activity budgets, whereas continuous observations were used to estimate duration of dives and foraging success. Tacha *et al.* (1985) found that continuous observation of individuals gives more accurate and precise estimates of percent of time spent in various activities, especially those that occur infrequently or are of short duration, than instantaneous methods. Continuous observation also provides reliable information on the duration of various activities (Altmann 1974). However, scan sampling of groups (an instantaneous method) allows observation of many more individuals compared to the continuous method, and is therefore a more valid basis for comparisons at the population level.

Birds were observed 4 days/wk from parked vehicles, using binoculars or a spotting scope. Observation posts were established along the shores of the discharge channel (10 posts), the plume (10 posts), and Saginaw River (17 posts). Scans were only conducted when the activities of $\geq$20 birds could be reliably ascertained, thus the distance from which birds were observed varied depending on light and other visibility factors as well as water turbulence, particularly in the plume. Groups of mergansers were scanned $\geq$10 min after the vehicle was parked, and the behavior of each bird at the instant it was seen was recorded. Merganser activities were assigned to the following categories: foraging (searching for food, diving, or handling prey); resting (sleeping or inactive); locomotion (swimming); social (agonistic or courtship behavior); comfort (preening, bathing, or other body maintenance activities); and alert.

Diurnal behavior was observed during the same morning, midday, and evening time periods that were established for flight observations. In 1989-90 and 1990-91, observations of mergansers in the discharge channel and the Saginaw River were also conducted during 3 night time periods: 0.5 hr after sunset to 3.5 hr after sunset; 2300 hrs - 0200 hrs; and 3.5 hr before sunrise - 0.5 hr before sunrise. Birds in the plume were not visible from the shore at night, preventing observation of night behavior in that habitat.

To minimize the loss of independence among samples, data used in analyses were restricted to 1 scan/observation post/time period/day. For each scan, the proportion of birds engaged in each activity was calculated separately for adult males and other birds. After proportions of 0 and 1 were adjusted as recommended by Snedecor and Cochran (1980), they were converted to angles using the arc sine square root transformation. The transformed data were then weighted by the sample size (*n*) for each scan (Snedecor and Cochran 1980) prior to analysis. Univariate and multivariate analysis of variance were used to examine the effects of year, season, age/sex group, time of day, and habitat on occurrence of the various activities. As with analysis of habitat use, when full-model analyses indicated that interaction effects were significant, subsets of the data were used to analyze main effects. The Statistical Analysis System (SAS Institute Inc. 1985) was used to conduct the analyses.

When groups of undisturbed mergansers were observed from $\leq$100 m, a single bird was randomly selected for continuous observation after the scan. The duration of each of the subject's activities was recorded for 10 (1988-89) or 15 (1989-90 and 1990-91) min. Birds that flew out of sight were assumed to be flying for the remainder of the observation period, but when a subject swam out of sight the observation was aborted. An observation was also aborted if the subject was "lost" among a group of birds during the observation period. Continuous observations were not conducted at night.

**Foraging**

In 1990-91, dip netting was used to provide an index of the relative abundance of forage fish in the discharge channel over time. Species and length were recorded for fish caught during 10 dipping attempts/day at each of 2 fixed locations along the channel. Sampling was conducted at midday, 4 days/wk. Comparisons with the previous 2 winters are based on casual observations of schools of forage fish seen at the surface of the water in the discharge channel. Availability of forage fish in other habitats was not estimated.

Percent of time spent diving, duration of dives, and foraging success rates were estimated from data collected during continuous behavioral observations. Chi-square tests were used to compare foraging effort and success rates of adult males versus other birds. Crops from carcasses collected during the 1988-89 and 1989-90 transmission line mortality study (see Part II below) were used to determine food habits of migrating and wintering common mergansers. The esophagus and proventriculus of each bird was removed and preserved individually in diluted 2-propanol for later analysis. Crop contents were weighed and prey items were counted and, when possible, identified to species and measured.

## RESULTS

**Population Trends**

***Counts.*** Common mergansers began arriving in lower Saginaw Bay in November (Figure 2). Most of these early arrivals were observed in the plume and on the Saginaw River. In 1988 and 1989, mergansers continued to move into the

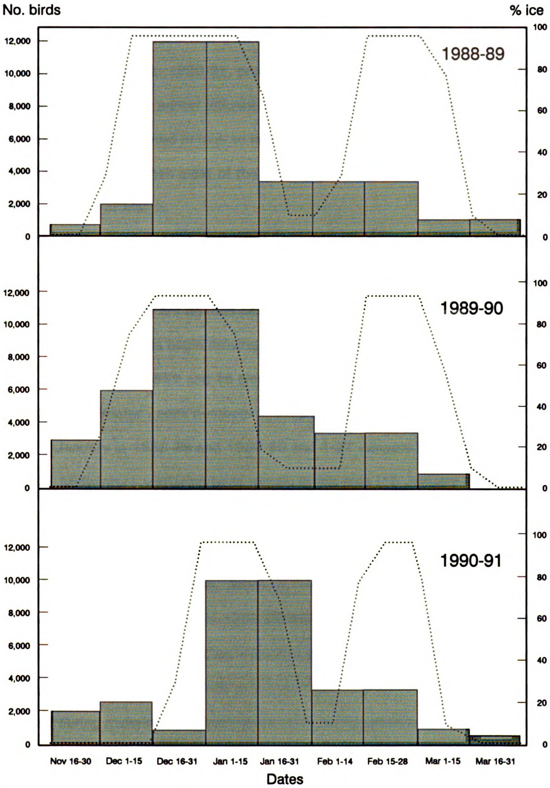


Figure 2. Maximum counts (bars) of common mergansers in relation to ice cover (dotted lines) in lower Saginaw Bay and the Saginaw River, 1988 - 91.

area in December, with peak numbers of 12,000 (1988-89) and 11,000 (1989-90) occurring in late December and early January. The peak number (10,000) did not occur until January in 1990-91, probably because unusually warm weather during late fall and early winter influenced chronology. Each year more than 50% of the mergansers departed in mid/ to late January. At least 3,400 birds remained throughout February, when most of the wintering birds left the area. All were gone by the end of March.

These counts provided the basis for partitioning the winter into 4 segments according to the chronology and status of wintering common mergansers using the area. The segments are defined as:

1) Late fall - birds begin arriving in the area (16 November - 15 December in 1988 and 1989 and 16 November - 31 December in 1990);
2) Early winter - peak numbers of birds present (16 December - 15 January in 1988-89 and 1989-90 and 1-31 January in 1991);
3) Midwinter - wintering birds remain in the area (16 January - 28 February in 1989 and 1990 and 1-28 February in 1991); and
4) Late winter - birds present during March.

***Age and Sex Composition.*** Although fewer adult males used the area during late fall and early winter in 1988-89 than in the 2 subsequent years, the proportion of adult males among early arrivals and at peak numbers was similar within years (Table 1). In 1988-89 and 1989-90, the proportion of adult males increased during midwinter as most of the adult males present during peak numbers also wintered in the area. Of those, about half remained in the area in late winter, after most of the other wintering birds had left. The pattern was different in 1990-91. The proportion of adult males remained the same from late

Table 1. Proportion and maximum number of adult males in populations of migrating and wintering common mergansers using lower Saginaw Bay from November through March.

| | Proportion | | | Number | | |
|---|---|---|---|---|---|---|
| Season | 1988-89 | 1989-90 | 1990-91 | 1988-89 | 1989-90 | 1990-91 |
| Late fall | 0.09 | 0.17 | 0.15 | 180 | 1020 | 390 |
| Early winter | 0.06 | 0.13 | 0.15 | 720 | 1430 | 1500 |
| Midwinter | 0.20 | 0.25 | 0.16 | 700 | 875 | 540 |
| Late winter | 0.40 | 0.39 | 0.42 | 400 | 390 | 420 |

fall through midwinter, indicating that most of the adult males left during the general early winter exodus of mergansers from the area. However, both the proportion and the number of adult males remaining in late winter were similar to those of the previous 2 years.

**Habitat Use**

***Movement Patterns.*** Daily movements were marked by large groups of mergansers flying between inland habitats and the plume during the morning and evening periods (Table 2). Three main patterns were evident: flights to inland habitats in the evening and back out to the plume the following morning; flights to inland habitats in the morning and back out to the plume the same evening; and no movement between inland habitats and the plume. Flights between inland habitats and the plume occurred most frequently during late fall and early winter (Table 3), primarily by mergansers spending the night in inland habitats. This pattern continued through mid/ and late winter in 1989, but comparatively little movement between habitats was observed during mid/ and late winter of 1990 and 1991.

***Availability.*** When mergansers began arriving in late fall, all suitable habitats in the area were ice-free and completely available. However, when freeze-up occurred in early to midDecember in 1988 and 1989 (Figure 2), ice cover reduced the size of the plume and virtually eliminated the river as an available habitat during early winter. Open water in the river was restricted to small, intermittently thawed pockets created by municipal and industrial thermal discharges. In 1990 freeze-up occurred in late December, but pockets of permanent open water were present in the Saginaw River throughout early winter. Thus although availability of the river was reduced by >95%, it was not

Table 2. Mean number of common mergansers flying either toward inland habitats (Inland) or toward the Karn-Weadock discharge plume in lower Saginaw Bay (Plume) during winter (Nov. - Mar.).

| | 1988-89 | | | | 1989-90 | | | | 1990-91 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inland | | Plume | | Inland | | Plume | | Inland | | Plume | |
| Time of day | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE |
| Morning | 261 | 71 | 1548 | 523 | 181 | 45 | 2352 | 1465 | 235 | 84 | 649 | 181 |
| Midday | 328 | 133 | 207 | 54 | 93 | 34 | 311 | 183 | 198 | 58 | 463 | 171 |
| Evening | 2725 | 728 | 293 | 116 | 3439 | 1056 | 530 | 149 | 1045 | 236 | 998 | 265 |
| Total | 3314 | 380 | 2048 | 341 | 3713 | 692 | 3193 | 931 | 1478 | 162 | 2110 | 211 |

Table 3. Mean number of common mergansers flying either toward inland habitats (Inland) or toward the Karn-Weadock discharge plume in lower Saginaw Bay (Plume) in the evening during winter (Nov. - Mar.).

| | 1988-89 | | | | 1989-90 | | | | 1990-91 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inland | | Plume | | Inland | | Plume | | Inland | | Plume | |
| Time of year | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE | $\bar{x}$ | SE |
| Late fall | 4310 | 2460 | 360 | 110 | 90 | 90 | 50 | 50 | 460 | 170 | 440 | 180 |
| Early winter | 3520 | 960 | 380 | 120 | 4490 | 1410 | 630 | 200 | 1800 | 420 | 1730 | 510 |
| Midwinter | 1590 | 530 | 370 | 170 | 90 | 60 | 50 | 50 | 40 | 30 | 30 | 20 |
| Late winter | 500 | 360 | 60 | 50 | 20 | 10 | 10 | 10 | 10 | 0 | 80 | 0 |

effectively eliminated as during the previous 2 years. Although the size of the plume was reduced during early winter, $\geq$200 ha of open water was present each year.

Availability of the river and plume habitats increased as the result of a midwinter thaw in late January each year (Figure 2). The Saginaw River was ice-free for at least 10 days during late January and early February each year, as was the entire plume and most of the bay that was visible from the shoreline. When cold temperatures returned, open water habitat in the bay was again confined to the plume, which was reduced in size until the spring thaw in late March. In the Saginaw River, however, pockets of permanent open water at thermal discharge sites persisted throughout the remainder of the winter during all 3 years.

*Use*. During late fall, when all habitats were completely available, >50% of the mergansers in the area used both inland habitats and the plume in 1988-89 and 1990-91. Equal numbers of birds used the discharge channel and the Saginaw River ($X^2$=0.69, 1df, $P$=0.406) (Table 4), indicating that the 2 inland habitats were equally preferred. In 1989-90, >20,000 herring (*Larus argentatus*) and ring-billed gulls (*L. delawarensis*) appeared in the study area in early November, apparently in response to unusually large and/or accessible aggregations of gizzard shad fry. The gulls exploited this food source for nearly 2 months before leaving the area in late December. The constant presence of thousands of gulls in the air and on the water at inland habitats seemed to disrupt the normal movement patterns of mergansers; of the mergansers that were observed attempting to land in the discharge channel in late fall, most were unsuccessful and returned to the plume. Thus most birds spent nearly all their time in the plume until early winter.

**Table 4. Mean number/day of common mergansers using 3 habitats in lower Saginaw Bay during winter, 1988-89 - 1990-91.**

| Year and season | Discharge channel | | Discharge plume | | Saginaw River | |
|---|---|---|---|---|---|---|
| | No. birds | % | No. birds | % | No. birds | % |
| 1988-89 | | | | | | |
| Late fall | 500 | 25 | 1000 | 50 | 500 | 25 |
| Early winter | 3275 | 27 | 8725 | 73 | 0 | 0 |
| Midwinter | 100 | 3 | 2445 | 70 | 955 | 27 |
| Late winter | 25 | 3 | 500 | 50 | 475 | 48 |
| 1989-90 | | | | | | |
| Late fall | 275 | 6 | 4200 | 93 | 25 | 1 |
| Early winter | 2775 | 25 | 7975 | 73 | 250 | 2 |
| Midwinter | 25 | 1 | 1795 | 47 | 2010 | 52 |
| Late winter | 15 | 3 | 305 | 51 | 280 | 47 |
| 1990-91 | | | | | | |
| Late fall | 275 | 15 | 1295 | 69 | 300 | 16 |
| Early winter | 75 | 1 | 7565 | 76 | 2360 | 24 |
| Midwinter | 25 | 1 | 2000 | 59 | 1375 | 40 |
| Late winter | 15 | 2 | 505 | 63 | 280 | 35 |

When merganser numbers peaked in early winter, about 50% of the birds used both inland habitats and the plume. The Saginaw River was ice-covered in early winter the first 2 years, therefore birds using inland habitat were confined to the discharge channel. However, in 1990-91 the Saginaw River was only partially ice-covered during early winter, and nearly all birds using inland habitat selected the river over the discharge channel (Table 4). In all 3 years, mergansers that remained in the area avoided the discharge channel after early winter. Movement between habitats decreased, and sedentary wintering birds showed a preference for the plume over the river during both midwinter ($X^2=442.9$, 2df, $P<0.001$) and late winter ($X^2=34.1$, 2df, $P<0.001$).

The proportion of adult males present did not differ significantly among habitats in either late fall ($X^2=1.35$, 2df, $P=0.509$), early winter ($X^2=1.78$, 2df, $P=0.410$), or late winter ($X^2=0.43$, 1df, $P=0.513$), indicating that habitat use was similar for adult males and other birds during those 3 seasons (Table 5). However, a difference ($X^2=62.6$, 1df, $P<0.001$) in habitat use between adult males and other birds was observed during midwinter; 23% of the mergansers observed in the plume were adult males compared to 17% of the birds using the river (Table 5). Thus in midwinter, adult males preferred the plume whereas one or more of the other age-sex groups preferred the river.

**Behavior**

Four hundred three scans of common mergansers in all habitats (Table 6) were used to estimate the percent of time birds spent in each of the 6 behavioral categories. Because most attempts to scan birds at night failed due to high densities of very active birds and/or poor lighting, few observations of nocturnal

**Table 5.** Proportion of adult males (*P*) in groups of common mergansers observed in 3 habitats in lower Saginaw Bay from November - March, 1988-91. Sample size (*n*) represents total common mergansers identified during multiple independent observations.

| | Discharge channel | | Discharge plume | | Saginaw River | |
|---|---|---|---|---|---|---|
| Time of year | *P* | *n* | *P* | *n* | *P* | *n* |
| Late fall | 0.12 | 574 | 0.15 | 3118 | 0.15 | 909 |
| Early winter | 0.09 | 4773 | 0.11 | 6272 | 0.13 | 4833 |
| Midwinter | 0.28 | 153 | 0.23 | 4384 | 0.17 | 7127 |
| Late winter | 0.28 | 46 | 0.40 | 1970 | 0.41 | 810 |

Table 6. Number of behavioral observations (scans) of fall migrating and wintering adult male (AM) and adult female and immature (Other) common mergansers in lower Saginaw Bay, Dec. 1988 - Mar. 1991.

| | | Number of birds observed | | |
|---|---|---|---|---|
| Season and habitat | Scans | AM | Other | Total |
| Late fall | | | | |
| Channel | 10 | 60 | 640 | 700 |
| Plume | 24 | 301 | 1511 | 1812 |
| River | 11 | 147 | 667 | 814 |
| Total | 45 | 508 | 2818 | 3326 |
| Early winter | | | | |
| Channel | 54 | 164 | 2249 | 2413 |
| Plume | 50 | 809 | 4401 | 5210 |
| River | 34 | 668 | 4004 | 4672 |
| Total | 138 | 1641 | 10654 | 12295 |
| Midwinter | | | | |
| Channel | 24 | 80 | 699 | 779 |
| Plume | 53 | 1270 | 2968 | 4238 |
| River | 87 | 1249 | 7090 | 8339 |
| Total | 164 | 2599 | 10757 | 13356 |
| Late winter | | | | |
| Channel | 6 | 17 | 173 | 190 |
| Plume | 33 | 698 | 1074 | 1772 |
| River | 17 | 412 | 598 | 1010 |
| Total | 56 | 1127 | 1845 | 2972 |
| Total | 403 | 5875 | 26074 | 31949 |

behavior were quantified. Therefore only diurnal time-activity budgets were estimated; observations of night activities are presented qualitatively.

***Daily and Seasonal Activity Patterns.*** During the day, mergansers were most active (foraging and locomotion) during the morning and least active (resting) at midday (Figure 3). Much of the locomotory activity consisted of swimming between dives, and was therefore associated with foraging. Diurnal activity patterns of adult males were similar to those of adult females and immatures (Age/sex x time of day interaction effect; $F=2.81$, 2df, $P=0.061$ for social activity; $F \leq 0.92$, 2df, $P \geq 0.397$ for all other activities).

Time-activity budgets also varied among seasons (Figure 4). Foraging activity was constant during late fall and early winter, dropped off significantly in midwinter ($F=9.93$, 3df, $P=0.0001$), and returned to its previous level in late winter. An inverse relationship between resting and locomotion was apparent; mergansers spent more time resting ($F=8.34$, 3df, $P=0.0001$) and less time in locomotory activities ($F=9.06$, 3df, $P=0.0001$) during early and midwinter than in late fall and late winter. Seasonal variations in time allocated to comfort, social, and alert behavior were not consistent from year to year.

The percent of time birds engaged in foraging, resting, locomotory, and comfort activities did not differ between adult males and other birds in late fall and early winter (Table 7), but the patterns of behavior diverged thereafter. In both mid/ and late winter, adult males devoted more time to locomotion and social behavior and less time to foraging than did other birds (Figure 5, Table 7). Resting time was similar for all birds in midwinter, but adult males spent less time resting than other birds in late winter (Figure 5, Table 7). Much of the mid/ and late winter increase in locomotory and social activity by adult males was due to

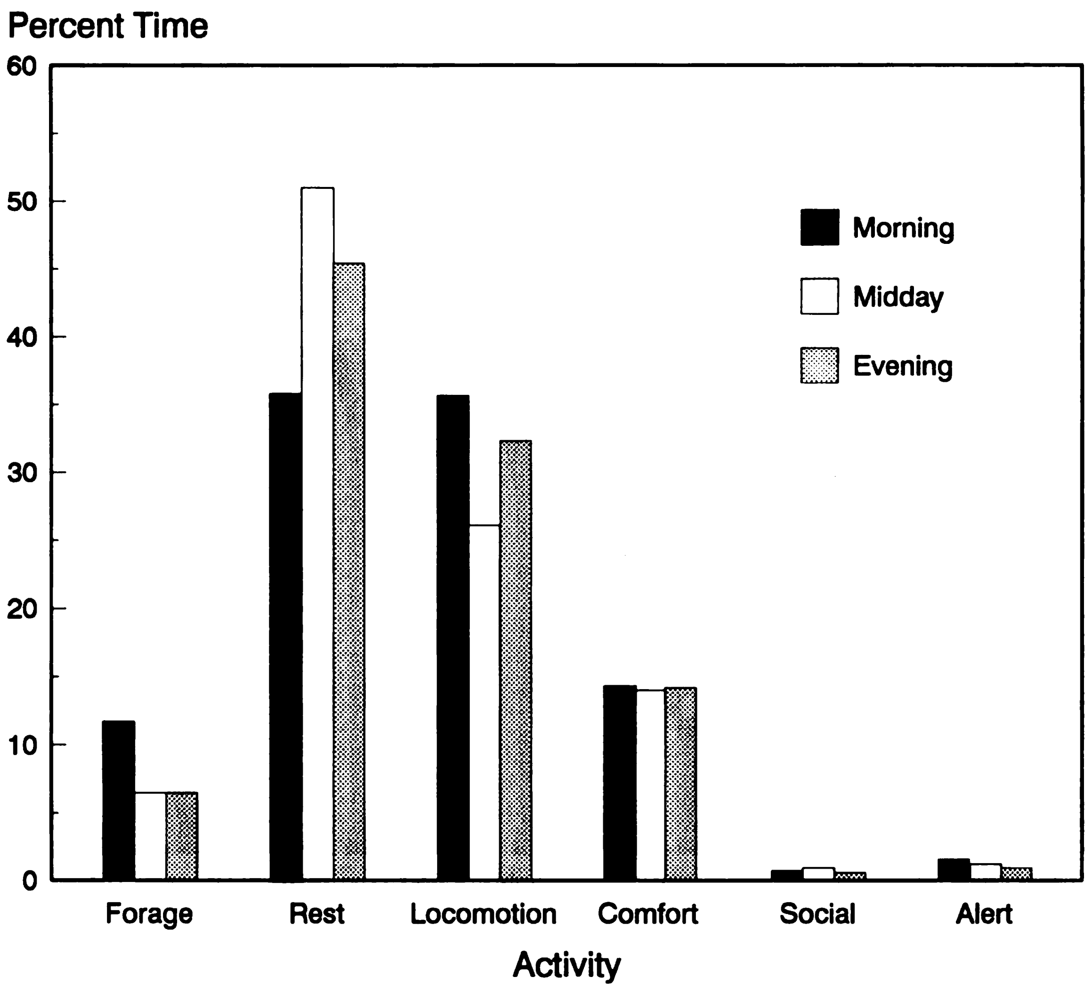


Figure 3. Diurnal time-activity budgets of common mergansers in lower Saginaw Bay during winter (November - March), 1988-89 - 1990-91.

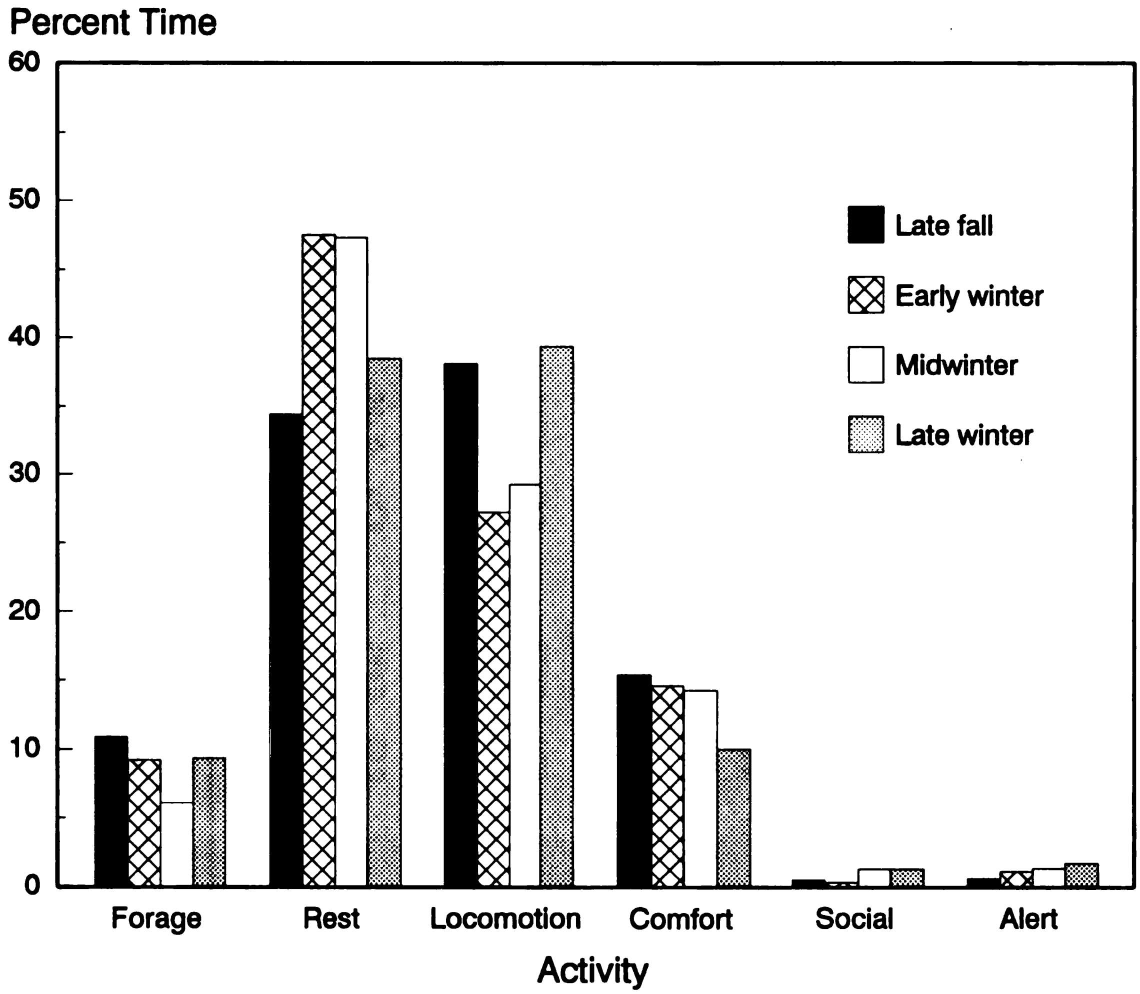


Figure 4. Seasonal time-activity budgets of migrating and wintering common mergansers in lower Saginaw Bay during winter (November - March), 1988-89 - 1990-91.

Table 7. Test statistic (*F*) and *P*-value results of analyses of variance testing for differences in behavior of common mergansers between adult males and other birds, among habitats, and between adult males and other birds within habitats (A/s x H).

| Season & Source | df | Forage | | Rest | | Locomotion | | Comfort | | Social | | Alert | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *F* | *P* | *F* | *P* | *F* | *P* | *F* | *P* | *F* | *P* | *F* | *P* |
| **Late fall** | | | | | | | | | | | | | |
| Age/sex | 1 | 0.07 | 0.792 | 0.34 | 0.562 | 0.00 | 0.952 | 0.00 | 0.990 | 16.78 | <0.001 | 28.52 | <0.001 |
| Habitat | 2 | 0.06 | 0.939 | 1.38 | 0.258 | 1.32 | 0.272 | 0.42 | 0.656 | 2.95 | 0.058 | 2.26 | 0.110 |
| A/s x H | 2 | 0.19 | 0.827 | 0.14 | 0.874 | 0.02 | 0.982 | 0.27 | 0.766 | 0.50 | 0.610 | 0.79 | 0.455 |
| **Early winter** | | | | | | | | | | | | | |
| Age/sex | 1 | 0.63 | 0.429 | 0.22 | 0.637 | 0.18 | 0.671 | 0.06 | 0.804 | 39.55 | <0.001 | 10.07 | 0.002 |
| Habitat | 2 | 1.07 | 0.344 | 1.22 | 0.298 | 0.07 | 0.929 | 4.40 | 0.013 | 6.80 | 0.001 | 0.01 | 0.992 |
| A/s x H | 2 | 0.07 | 0.930 | 0.06 | 0.939 | 0.02 | 0.977 | 0.53 | 0.587 | 0.41 | 0.662 | 0.24 | 0.786 |
| **Midwinter** | | | | | | | | | | | | | |
| Age/sex | 1 | 5.74 | 0.017 | 2.72 | 0.100 | 11.34 | 0.001 | 8.60 | 0.002 | 104.45 | <0.001 | 10.09 | 0.002 |
| Habitat | 1 | 16.40 | <0.001 | 0.19 | 0.663 | 2.97 | 0.086 | 0.52 | 0.473 | 22.91 | <0.001 | 4.56 | 0.034 |
| A/s x H | 1 | 0.70 | 0.405 | 3.93 | 0.049 | 7.08 | 0.008 | 6.79 | 0.010 | 11.99 | <0.001 | 1.13 | 0.289 |
| **Late winter** | | | | | | | | | | | | | |
| Age/sex | 1 | 4.63 | 0.034 | 4.93 | 0.029 | 10.55 | 0.002 | 1.12 | 0.294 | 29.22 | <0.001 | 0.23 | 0.632 |
| Habitat | 1 | 0.35 | 0.554 | 1.28 | 0.261 | 0.01 | 0.934 | 0.06 | 0.800 | 0.56 | 0.458 | 1.32 | 0.254 |
| A/s x H | 1 | 0.07 | 0.790 | 0.36 | 0.550 | 0.30 | 0.583 | 0.00 | 0.954 | 0.15 | 0.696 | 0.78 | 0.379 |

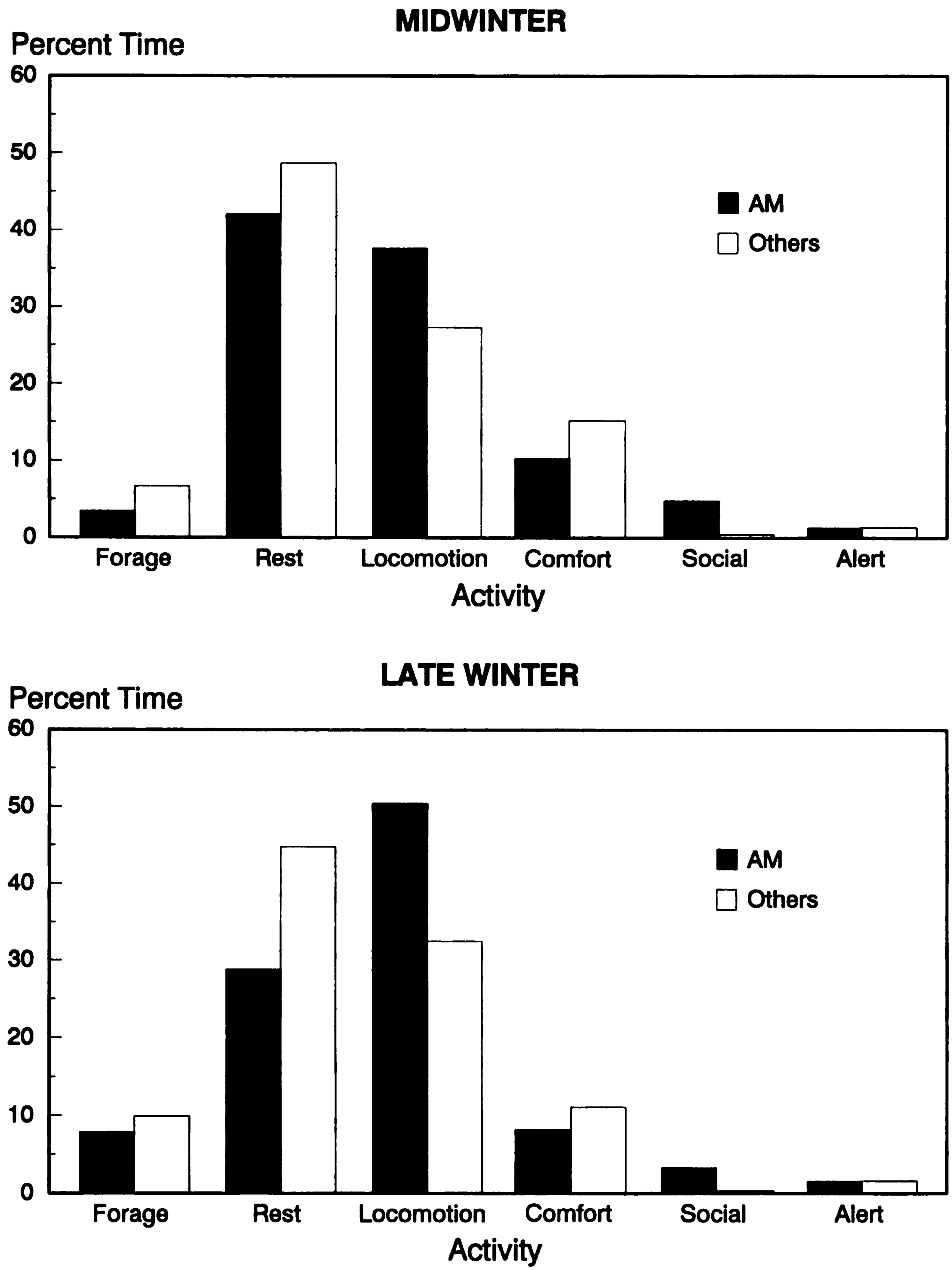


Figure 5. Time-activity budgets of adult male (AM) versus adult female and immature (Others) common mergansers in lower Saginaw Bay during mid/ and late winter, 1989 - 1991.

participation in courtship parties, some of which were observed each year by midFebruary.

In late fall and early winter 1988-89 and early winter 1989-90, thousands of birds using the discharge channel at night periodically engaged in what can best be described as feeding frenzies. These episodes were observed only during the first 1-2 hours after nightfall, and may have occurred in other habitats as well. Adult males and other birds appeared to be equally active, and many of the birds seen diving exhibited food handling postures upon reemerging at the water surface. These late fall and early winter feeding bouts did not occur in 1990-91. During all 3 years, nocturnal foraging activity was rarely seen in mid/ and late winter.

***Habitat Effects.*** Time-activity budgets of mergansers were similar among habitats during late fall and early winter (Table 7, habitat main effect), and behavior of adult males did not differ from that of other birds in any habitat during those seasons (Table 7, age/sex x habitat interaction effect). In midwinter, both adult males and other birds spent more time foraging and alert in the Saginaw River than in the discharge plume (Figure 6, Table 7). The midwinter increase in social activity by adult males occurred mainly in the plume (Figure 6), as courtship parties of up to 6 adult males vied for the attention of a single adult female. Differences in late winter time-activity budgets between adult males and other birds were not attributable to habitat effects (Table 7). However, by late winter many of the adults had paired, and most pairs were observed in the river. Thus most of the social activity in the river involved pairs, whereas social behavior in the plume primarily consisted of interactions between members of courtship parties.

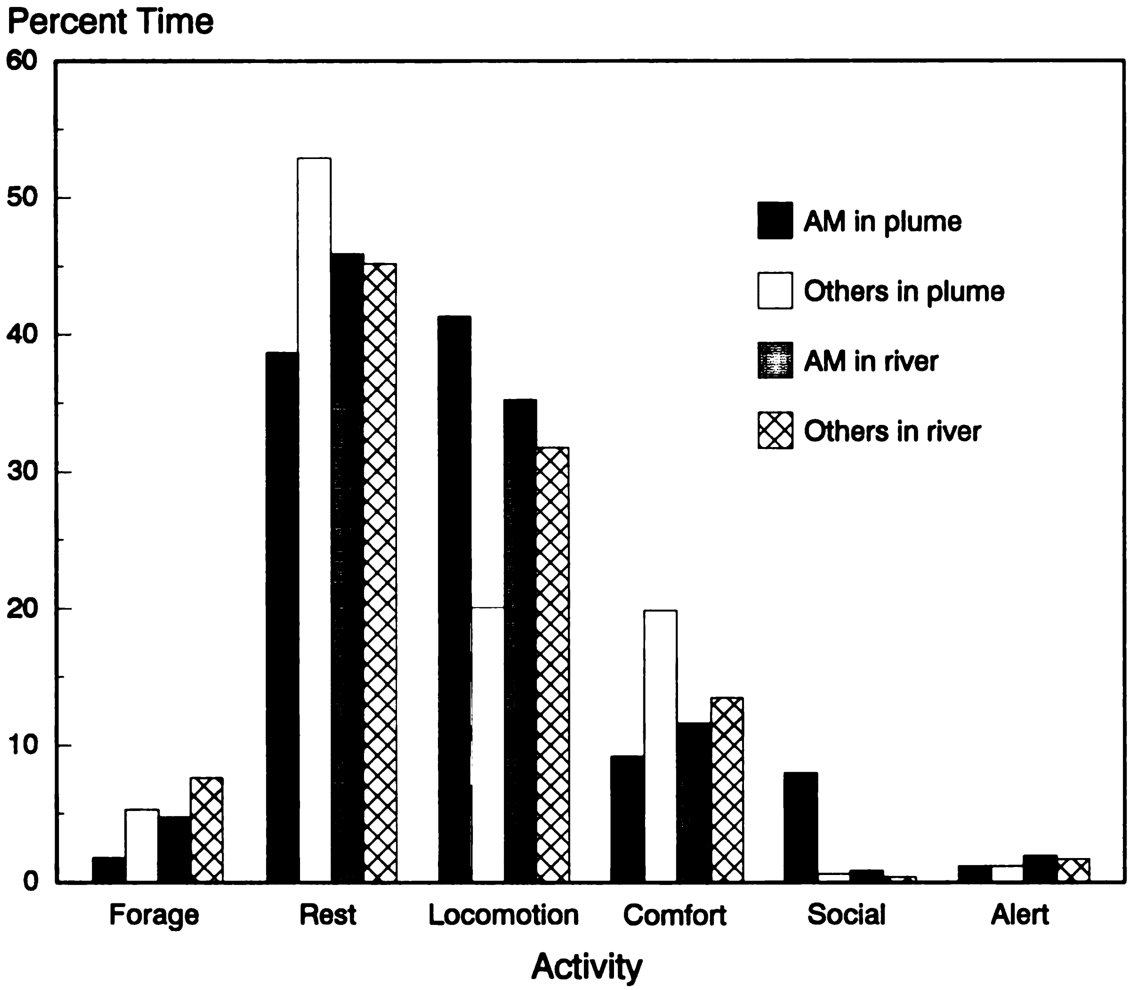


Figure 6. Midwinter time-activity budgets of adult male (AM) versus adult female and immature (Others) common mergansers using 2 habitats in lower Saginaw Bay, 1989 - 1991.

**Foraging**

***Food Availability.*** Large schools of gizzard shad fry (50-80 mm long) were frequently seen at the water surface and in the shallows of the discharge channel in early December of both 1988 and 1989. Most of the shad apparently left the channel in midDecember; no concentrations of fish were seen in late December or thereafter. Schools of shad fry were not seen in the channel in 1990-91, suggesting that fewer were present than in the previous 2 years. Despite this, 79 fish, 58 (73%) of which were gizzard shad fry, were caught during 32 days of dip net sampling from 11 December 1990 - 28 February 1991. During that period, forage fish were most abundant in midDecember, and none were caught after 3 January (Figure 7).

***Foraging Effort and Success.*** Continuous observations of 294 mergansers indicated that the percent of time they devoted to daytime foraging activities did not differ ($P>0.25$) for the entire winter between adult males (8.5%) and other birds (9.5%). However, adult males stayed submerged longer during dives than other birds. The mean duration of 363 dives by adult males was 14.2 sec (SE=0.4 sec) compared to 11.1 sec (SE=0.2 sec, $n=809$ dives) for other birds. The maximum observed time submerged was 55 sec for adult males and 40 sec for other birds. Despite this apparent advantage, adult males did not have greater foraging success than other birds ($X^2=0.23$, $P>0.50$); adult males captured prey during 18 of 363 observed dives (5.0% success rate) compared to 35 captures in 809 dives (4.3%) for other birds. Daytime success rates were higher ($X^2=22.07$, $P<0.001$) for birds foraging in the Saginaw River (11.2%) than for those foraging in the plume (3.0%) or the discharge channel (3.5%).

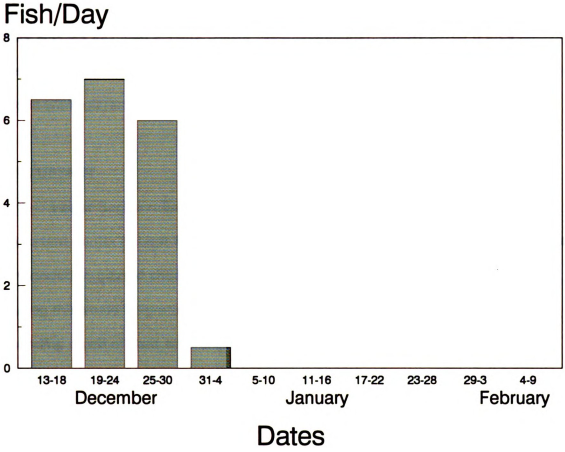


Figure 7. Number of forage fish caught using dip nets in the Karn-Weadock (Essexville, Michigan) power plant's discharge channel during late fall and early winter, 1990-91.

***Food Habits*****.** Crops of 146 mergansers collected in late fall and early winter were examined; 84 (58%) contained some fish ($\bar{x}=25.0$ g, SE=2.8 g) and the remaining 62 (42%) were empty. Six of 9 (67%) adult male crops examined were empty compared to 56 of 137 (41%) for other birds. Although prey species included alewife (*Alosa pseudoharengus*), yellow perch (*Perca flavescens*), and shiners (*Notropis* spp.), 270 (94%) of 287 identifiable fish in the crops were gizzard shad, >90% of which were young-of-the-year.

## DISCUSSION

Lower Saginaw Bay at the mouth of the Saginaw River has become an important winter habitat for common mergansers in recent years as the birds have responded to gizzard shad fry concentrations that occur there annually in late fall. During this study, migrating mergansers remained in the area for up to 6 weeks, spending much of their time engaged in foraging activities. Birds apparently left the area only after the shad dispersed in Saginaw Bay or became inaccessible when they moved under the ice pack. Thus the duration of the stopover seemed to be based solely on food availability.

Common mergansers are primarily sight hunters (Sjoberg 1987) and therefore probably spend little time foraging at night. However, the Karn-Weadock discharge channel provided an ideal nocturnal feeding site because it is shallow, confined, and partially illuminated by street lamps and other lights around the power plants. When gizzard shad aggregations moved into the channel, the available light combined with an extreme density of prey apparently made the channel a preferred night feeding site. Mergansers using the discharge channel had better foraging success than migrating and wintering common mergansers collected by Timken and Anderson (1969) during fall and winter. They examined 165 crops, 24% of which contained fish, that were removed from birds shot in Nebraska, South Dakota, and Minnesota; at the Karn-Weadock site, 58% of the mergansers killed by collisions with transmission lines near the channel had fish in their crops. Although the collection methods differ, both samples were taken from low-flying birds killed near feeding areas. Comparison with Timken and Anderson's (1969) results suggests that the discharge channel was a very high quality feeding site during late fall and early winter.

There were no significant differences in habitat selection, behavior, or foraging success between adult males and other mergansers during late fall and early winter. This suggests that adult males did not exclude other birds from optimum habitats, nor did they disrupt the foraging of other birds, either through aggression or competition.

Mergansers that remained in lower Saginaw Bay in midwinter shifted their emphasis from moving between habitats and feeding to energy conservation, spending less time foraging and more time resting than they did in late fall and early winter. There was no evidence of the large aggregations of gizzard shad fry seen in late fall and early winter, thus foraging effort was apparently directly influenced by food availability. Again, there were few differences in habitat selection, behavior, and foraging success between adult males and others. Adult males exhibited a greater preference for the plume than other birds, but spent most of their time resting there. Contrary to the prediction of the behavioral dominance hypothesis, they did not displace other birds from preferred feeding habitats or otherwise outcompete other birds for food resources. However, adult males did spend less time in foraging activities than other birds. This indicates that adult males needed less food for maintenance than adult females and immatures, as predicted by the fasting endurance hypothesis.

In late winter, foraging effort by all mergansers increased to levels equal to those observed in late fall and early winter. Differences in behavior between adult males and other birds were a result of increased courtship activity among adults. Most of the courtship activity by adult males occurred in the plume, indicating that unpaired females preferred open space, perhaps to facilitate their selection of mates. In contrast, paired adults preferred more secluded areas available in the Saginaw River.

Available habitats apparently provided all the requirements of wintering common mergansers: abundant and accessible food in late fall and early winter (primarily in the discharge channel), adequate food in mid/ and late winter (the plume and Saginaw River), secure resting habitat (primarily the plume), space for courtship in mid/ and late winter (the plume) and seclusion for pairs (Saginaw River). Despite this, each year most birds left the lower Saginaw Bay area in mid/ to late January. In 1988-89 and 1989-90, the proportion of adult males in the midwinter population increased 2- to 3-fold as more than half of the adult males stayed in the area while most of the other birds presumably resumed their migration. There was no evidence in support of the behavioral dominance hypothesis as an explanation for this, either before or after migrating birds left the area. However, in 1990-91 the age and sex composition of the migrating and wintering populations were the same, indicating that the fasting endurance hypothesis alone is also inadequate for predicting annual winter distributions of mergansers.

During the first 2 winters of the study, most birds arrived in the area when their food source (gizzard shad fry) was most abundant and accessible. This was not the case in the third winter; shad fry aggregations were much reduced from the previous 2 years, and most birds arrived in the area after the shad had dispersed in the bay. Despite this, the size of the wintering population of mergansers was similar to those in 1988-89 and 1989-90. This suggests that the condition of birds upon arrival had some influence on whether they remained in the area throughout the winter.

Anderson *et al.* (1974) observed that transient common mergansers spent little time feeding during brief stops en route to wintering grounds. Presumably the condition of each bird on arrival in lower Saginaw Bay was a function of the distance it traveled to get there. Although most of the breeding range of common mergansers lies well north of the Great Lakes (Bellrose 1980), numerous pairs breed in northern Michigan (Brewer *et al.* 1991) and throughout the northern Great Lakes region (Bellrose 1980). Those southern-breeding birds and their offspring have less distance to travel to reach lower Saginaw Bay than birds that breed farther north in Canada, consequently they should arrive in better condition. Furthermore, condition may be positively related to foraging success when thousands of birds feed in a confined area, as was often the case in the discharge channel. If so, southern-breeding mergansers would likely be in better condition than northern-breeding birds in midwinter, and would be better equipped to survive the rest of the winter in lower Saginaw Bay.

The change in the proportion of adult males from early to midwinter in 1988-89 and 1989-90 suggests that in some years, the fasting endurance hypothesis is consistent with the observed wintering strategies. Although adult males were not more successful or efficient foragers than other birds, they apparently were able to assimilate and/or conserve energy more efficiently when food was abundant. This advantage probably resulted in rapid enhancement of their condition during late fall and early winter relative to other birds and, coupled with their lower energy requirement during mid/ and late winter, allowed most of the adult males to remain throughout the winter.

However, the sex and age composition of the 1990-91 midwinter population suggests that the fasting endurance hypothesis does not hold true for mergansers in lower Saginaw Bay if food is scarce when they arrive in early winter. When this occurs, the condition of a bird upon arrival may be the principal determinant of whether it stays the entire winter or continues migration. Thus an individual's wintering strategy may depend to a large extent on where it spent the preceding summer.

Future research on this subject should consider migration distance as well as energetic and behavioral aspects of wintering waterfowl, but should also focus on quantifying the reproductive benefits (or lack thereof) of wintering in northern latitudes. This would provide the basis for a cost-benefit analysis that could generate testable predictions involving several hypotheses of wintering strategies.

## PART II: TRANSMISSION LINE MORTALITY

### INTRODUCTION

As increasing numbers of migrating and wintering common mergansers began congregating at the Karn-Weadock site, a collision mortality problem developed as a result of birds flying across the transmission lines that are concentrated in the area. Numerous cases of birds colliding with transmission lines have been recorded in the United States (Stout and Cornwell 1976, Avery *et al.* 1980) and abroad (eg. Ogilvie 1967, McNeil *et al.* 1985). Although in some instances many individuals are killed (eg. Malcolm 1982), collision mortality is usually not considered a major factor at the population level for most species. For example, Stout and Cornwell (1976) reported that collisions accounted for 0.07% of the documented nonhunting mortality of ducks in North America from 1930-1963. However, the significance of collision mortality is greater for some populations. Collisions have been identified as the primary cause of mortality of fledged whooping cranes (*Grus americana*) (Lingle 1987) and of mute swans (*Cygnus olor*) in Great Britain (Ogilvie 1967).

The probability of colliding with a transmission line may be affected by the biology of the bird, weather, and type and location of the transmission line. The numerous potential factors involved, variability among species and sites, and lack of comprehensive data complicate attempts to assess the significance of collision mortality. Proposed methods of alleviating the problem are currently in the experimental evaluation stage (eg. Morkill and Anderson 1991). The purpose of this study was to design a method of reducing collision mortality of common mergansers at the Karn-Weadock site. The initial goal was to determine the magnitude of the collision problem, the timing and locations of collisions, and the factors that influence collision rates at the site. This information provided a basis for designing a treatment, the testing and evaluation of which was the objective of the study.

## STUDY AREA

The Karn-Weadock property consists of about 500 ha of low, level land. Most of the northwest half of the property is developed for power plant facilities and a series of ash settling ponds (Figure 8). The discharge channel cuts through the middle of the property, and the southeast half of the site consists primarily of wetlands dominated by common reed (*Phragmites australis*). Gravel roads on an extensive dike system provide access to most of the site. Most of the collision mortality occurs at the transmission lines that extend across the ash ponds, the discharge channel, and the wetlands (Figure 8). These lines bisect flight paths that are used by mergansers traveling back and forth between the discharge channel and the plume.

## METHODS

### Daily Movements And Flight Patterns

Preliminary observations suggested common mergansers flying to or from the discharge channel suffered most of the collision mortality. As described previously, birds using the channel were counted either during early morning or evening, and at midday. Those daily counts were used to provide biweekly estimates throughout the winter of the mean number of mergansers at risk.

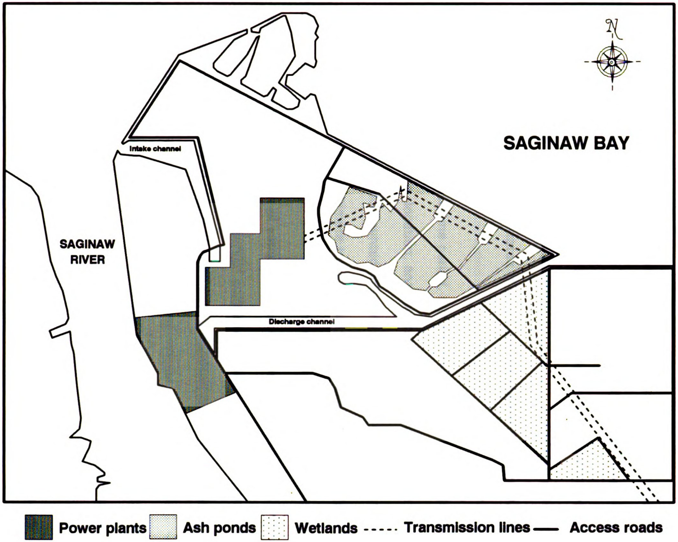


Figure 8. The Karn-Weadock (Essexville, Michigan) power generating facility at the mouth of the Saginaw River.

Flight observations were conducted near transmission lines from designated points along the discharge channel. For all common mergansers seen crossing transmission lines, flock size, flight direction (toward the power plants or toward Saginaw Bay), altitude ($\leq$ or $>2$ m above the lines), and flight path (over the ash ponds, over the discharge channel, or over the wetlands) was recorded. Flight observations were separated by time period, altitude, and flight path. Data collected during the 3 15-min observation segments/time period/day were pooled and used to estimate daily flight rates (flights/day) for each subcategory.

**Collision Mortality**

Before and after each time period, the area was searched for collision victims. Species, sex, age, location, and estimated time of collision were recorded for each carcass found. Documented mortality (DM) was adjusted for scavenging bias and crippling bias to estimate total collisions (James and Haak 1979). Some carcasses were replaced after examination to provide an estimate of scavenging bias based on the proportion of sample carcasses removed within 48 hr. Crippling bias was estimated based on observed collisions. Cripples were considered to be birds that struck lines and fell, but were not found dead during the subsequent search. Birds that struck a line and kept flying without appearing to be injured were not considered cripples. Scavenging and crippling bias estimates (SB and CB, respectively) were calculated using James and Haak's (1979) equations, where

$$SB = 1 \,/\, (1 - \text{proportion of sample carcasses removed})$$

and

$$CB = 1 \,/\, (1 - \text{proportion of crippled collision victims}).$$

Estimated mortality (EM) was then calculated as

$$EM = DM \times SB$$

and total collisions (TC) were estimated by

$$TC = EM \times CB.$$

Collision rates (collisions/flight) were then calculated based on total collision estimates and estimates of total flights derived from flight rates. Collision victims that fell into the discharge channel were rarely detected and recovered before they floated out to the bay. Therefore mortality on the channel flight path was estimated based on the calculated collision rate for the ash pond flight path.

**Factors Affecting Collision Rates**

Correlation analysis was used to evaluate the relationships among weather conditions, the number of mergansers using the discharge channel, and the number of collisions within specific time periods. Weather conditions for the area were obtained from the National Weather Service, Saginaw River Station, located $<1$ km from the study site. Visibility, wind velocity and direction, air temperature, and barometric pressure are recorded every 2 hr at the station. Percent cloud cover was recorded at the study site.

**Experiment**

Observations during the first year of the study suggested that birds often could not see the transmission lines as they approached them, which sometimes resulted in collisions. Thus the goal of the experiment was to alter the flight patterns of mergansers by forcing them to avoid the transmission lines where most collisions occurred. However, objects could not be attached to existing lines to increase their visibility, because of the potential for excessive additional stress on the lines and support structures that might result from ice storms. Instead, a series of 1.5-1.7-m diameter, helium-filled balloons was erected to create visible obstacles in key areas. The balloons were tethered in a position at transmission line height at 40-m intervals across the treatment area. Because most of the collisions occurred as birds flew from the discharge channel toward the bay, balloons were placed inland from the transmission lines. The treatment area during the first year was most of the ash pond flight path and was expanded to include the channel flight path the second year. The test was conducted in 2-wk blocks; balloons were placed in the treatment area for a week and removed the following week. Chi-square tests were used to evaluate the effects of the treatment on flight paths mergansers selected, their flight altitudes, and collision mortality.

## RESULTS

### Counts

In 1988 and 1989, most of the area froze up in early to midDecember (Figure 2). The only open water remaining in the bay was the plume created by the plant's thermal discharge, thus confining mergansers to the plume in early winter. During late December, most of these birds visited the discharge channel every night to feed and roost, and use of the channel was also high in early January (Figure 9). In 1990-91, freeze up was delayed until early January, and birds began arriving in the area about 2 weeks later than in the previous 2 winters. As a result, early winter use of the discharge channel was reduced. Mergansers virtually stopped using the channel during the midJanuary thaws that occurred each winter, and did not resume using the channel after the area froze again in early February. Their avoidance of the channel coincided with the disappearance

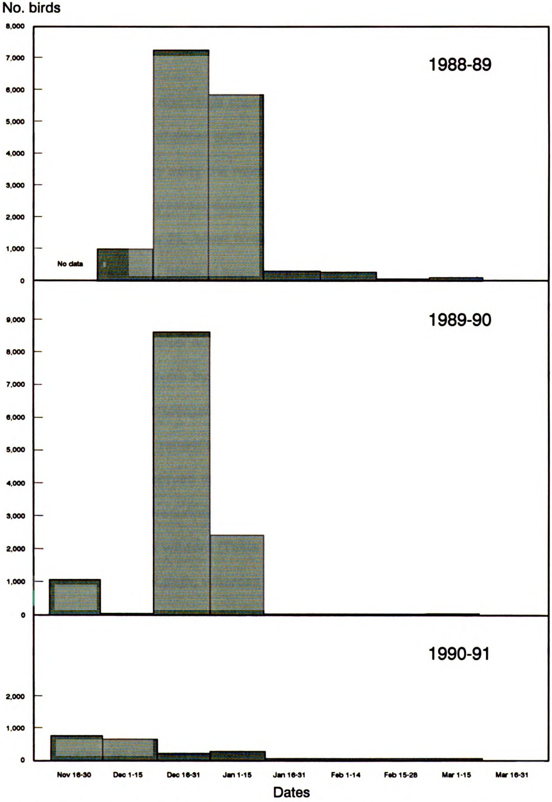


Figure 9. Mean number/day of common mergansers using the Karn-Weadock (Essexville, Michigan) power plant's discharge channel at night.

of the large aggregations of gizzard shad that were present during late fall and early winter.

**Flight Patterns**

When use of the discharge channel was highest (November-January), mergansers flew to the channel each evening, spent the night there, and flew back out to Saginaw Bay early the next morning. Flight intensity across transmission lines was greatest during early morning and evening, and lower for the midday period (Table 2). Most birds leaving the channel flew out during the first 0.5 hr after sunrise, often in large flocks of up to 2000. The evening pattern was different, as smaller groups of 5-50 mergansers flew to the channel from 1 hr before sunset to 0.5 hr after sunset. Most of the low altitude flights observed in 1988-89 and 1989-90 were by birds flying out of the channel in the morning, but a large proportion of the mergansers moving between the plume and the channel at midday also crossed transmission lines at low altitudes (Table 8). Few low altitude flights were observed during 1990-91. The ash pond and channel flight paths were used most frequently in 1988-89, but use of the wetland flight path increased in subsequent winters (Table 9). Most of the low altitude flights occurred on the channel path, whereas mergansers rarely flew low over the ash ponds (Table 9). Although some low altitude flights occurred over the wetlands, mergansers were never observed flying through or under transmission lines on that flight path.

**Collision Mortality**

Documented collision mortality of birds at the site included 210, 105, and 28 common mergansers in 1988-89, 1989-90, and 1990-91, respectively (Table 10). Over 95% of the mortality occurred from midNovember through midJanuary,

Table 8. Estimated number of low altitude ($\leq$2m above transmission lines) flights/day by common mergansers crossing transmission lines at the Karn-Weadock power plant site during late fall and early winter (Nov. - Jan.).

| | 1988-89 | | 1989-90 | | 1990-91 | |
|---|---|---|---|---|---|---|
| Direction and time of day | No. | % of total flights | No. | % of total flights | No. | % of total flights |
| Toward power plant | | | | | | |
| Morning | 44 | 17.0 | 31 | 17.1 | 3 | 1.3 |
| Midday | 38 | 11.5 | 26 | 28.0 | 1 | 0.7 |
| Evening | 87 | 3.2 | 65 | 1.9 | 2 | 0.2 |
| Total | 189 | 5.7 | 122 | 3.3 | 6 | 0.4 |
| Toward plume | | | | | | |
| Morning | 368 | 23.8 | 445 | 18.9 | 3 | 0.4 |
| Midday | 57 | 27.6 | 6 | 2.0 | 2 | 0.4 |
| Evening | 11 | 3.6 | 46 | 8.7 | 2 | 0.2 |
| Total | 436 | 21.3 | 497 | 15.6 | 7 | 0.3 |

Table 9. Mean number of flights/day and percent low altitude ($\leq$2 m above transmission lines) flights by common mergansers using the Karn-Weadock power plant site during late fall and early winter (Nov. - Jan.).

| | 1988-89 | | | 1989-90 | | | 1990-91 | | |
|---|---|---|---|---|---|---|---|---|---|
| Flight path | $\bar{x}$ | SE | % low altitude | $\bar{x}$ | SE | % low altitude | $\bar{x}$ | SE | % low altitude |
| Ash pond | 2056 | 478 | 1.5 | 1648 | 450 | 0.8 | 1365 | 155 | 0.2 |
| Channel | 2506 | 527 | 23.3 | 3686 | 894 | 17.3 | 732 | 94 | 1.1 |
| Wetland | 800 | 388 | 0.9 | 1572 | 222 | 1.8 | 1491 | 150 | 0.1 |
| Total | 5362 | 940 | 11.6 | 6906 | 1157 | 9.8 | 3588 | 316 | 0.4 |

Table 10. Estimated number of transmission line collisions by common mergansers at the Karn-Weadock power plant site during late fall and early winter (Nov. - Jan.) versus mid/ and late winter (Feb. - Mar.).

| | 1988-89 | | | 1989-90 | | | 1990-91 | | |
|---|---|---|---|---|---|---|---|---|---|
| Season and flight path | Documented mortality | Estimated mortality | Estimated collisions | Documented mortality | Estimated mortality | Estimated collisions | Documented mortality | Estimated mortality | Estimated collisions |
| Nov. - Jan. | | | | | | | | | |
| Ash pond | 135 | 156 | 209 | 56 | 65 | 87 | 27 | 31 | 41 |
| Channel | 40 | 170 | 604 | 33 | 117 | 416 | 1 | 26 | 93 |
| Wetland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 32 | 37 | 49 | 16 | 18 | 24 | 0 | 0 | 0 |
| Total | 207 | 363 | 862 | 105 | 200 | 527 | 28 | 57 | 134 |
| Feb. - Mar. | | | | | | | | | |
| Ash pond | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Channel | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wetland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 2 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 3 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |

primarily on the channel and ash pond flight paths. No collisions were observed on the wetland flight path, nor were any carcasses found there.

Forty collisions were observed directly. Although in most cases it could not be determined which line a bird struck, collisions with both conductor and ground lines were observed. All of the observed collisions were suffered by birds flying toward the bay. Six of 8 (75%) collisions over the ice-covered ash ponds resulted in mortality, whereas only 9 of 32 (28%) of the birds that struck lines over the channel and dikes were killed. Therefore different crippling bias adjustments were used to estimate total collisions for the ash pond (CB = 1.333) and channel (CB = 3.556) flight paths. Of 114 carcasses that were placed under transmission lines, 16 (14%) were removed by scavengers (SB = 1.163). Documented mortality and adjustments for recovery, scavenging, and crippling biases produced estimates of 870, 527, and 134 common mergansers killed or wounded by collisions during the 3 winters (Table 10). This amounted to about 7%, 5%, and 1% of the peak population of common mergansers in the area in 1988-89, 1989-90, and 1990-91, respectively.

**Factors Affecting Collision Rates**

Mergansers appeared to make every effort to avoid the power lines if they could see them. The collisions happened when birds did not see the lines at all or, more commonly, saw them too late to take effective evasive action. Adult males and other mergansers were equally susceptible; the number of adult male collision victims did not differ from that expected (based on the proportion of adult males among birds observed in the discharge channel) during either late fall ($X^2 = 0.43$, 1df, $P > 0.50$) or early winter ($X^2 = 2.15$, 1df, $P > 0.10$), when most collisions occurred. Although most collisions occurred in the morning, collision rates (collisions/flight) were highest during midday (Table 11). There were very few collisions by birds flying into the channel in the evening. The number of mergansers using the discharge channel was positively correlated with the number of documented collisions, especially during the early morning ($r^2=0.46$, $n=58$, $P<0.001$) and midday periods ($r^2=0.49$, $n=49$, $P<0.001$). The correlation was weaker for the evening period ($r^2=0.15$, $n=51$, $P=0.005$). No consistently significant relationships were found among weather conditions and flight patterns or collisions.

**Experiment**

In 1989-90, the balloon treatment was tested for 32 days during December and January: 12 days with balloons present in the test area and 20 days with balloons absent. The test was terminated when mergansers stopped using the discharge channel. The following winter, the test covered 8 weeks from late November through midJanuary: 27 days with balloons in the expanded treatment area and 28 days without balloons. During both test years, the proportion of mergansers using treatment area flight paths was lower when balloons were present (Table 12). Balloons had the most pronounced effect on flight path selection during early morning [$X^2=155.0$ (1989-90) and 102.4 (1990-91), 1df, $P<0.001$)] and midday [$X^2=70.7$ (1989-90) and 70.2 (1990-91), 1df, $P<0.001$)]. Of the mergansers that selected treatment area flight paths, fewer flew at low altitudes when balloons were present (Table 13). The difference was much greater during 1989-90 ($X^2=21.2$, 1df, $P<0.001$) than in 1990-91 ($X^2=3.5$, 1df, $P<0.10$). Documented collision mortality in the treatment areas was also significantly reduced when balloons were present ($X^2=7.0$, 1df, $P<0.01$). No collision victims were found in the treatment areas during either test

Table 11. Estimated collision rates [(collisions / flight) x 100] of common mergansers crossing transmission lines at the Karn-Weadock power plant site during late fall and early winter (Nov. - Jan.) versus mid/ and late winter (Feb. - Mar.).

| | November - January | | | February - March | | | All winter | | |
|---|---|---|---|---|---|---|---|---|---|
| Time of day | 1988-89 | 1989-90 | 1990-91 | 1988-89 | 1989-90 | 1990-91 | 1988-89 | 1989-90 | 1990-91 |
| Morning | 0.217 | 0.178 | 0.109 | 0.011 | 0.000 | 0.000 | 0.156 | 0.178 | 0.017 |
| Midday | 0.351 | 0.512 | 0.075 | 0.000 | 0.000 | 0.000 | 0.244 | 0.506 | 0.072 |
| Evening | 0.022 | 0.017 | 0.007 | 0.000 | 0.000 | 0.000 | 0.014 | 0.017 | 0.007 |
| Mean | 0.124 | 0.014 | 0.046 | 0.003 | 0.000 | 0.000 | 0.085 | 0.104 | 0.045 |

Table 12. Estimated number of flights/day by common mergansers using treatment area and other flight paths during late fall and early winter (Nov. - Jan.).

| Year and time of day | Balloons present | | | | | | Balloons absent | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tmt area | | Other paths | | All paths | | Tmt area | | Other paths | | All paths | |
| | Flights | % | Flights | % | Flights | % | Flights | % | Flights | % | Flights | % |
| 1989-90 | | | | | | | | | | | | |
| Morning | 44 | 1 | 4661 | 99 | 4705 | 100 | 63 | 7 | 793 | 93 | 856 | 100 |
| Midday | 115 | 19 | 494 | 81 | 609 | 100 | 35 | 73 | 13 | 27 | 48 | 100 |
| Evening | 14 | 3 | 454 | 97 | 468 | 100 | 107 | 15 | 624 | 85 | 731 | 100 |
| Total | 173 | 3 | 5609 | 97 | 5782 | 100 | 205 | 13 | 1430 | 87 | 1635 | 100 |
| 1990-91 | | | | | | | | | | | | |
| Morning | 216 | 35 | 403 | 65 | 619 | 100 | 539 | 62 | 336 | 38 | 875 | 100 |
| Midday | 207 | 28 | 527 | 72 | 734 | 100 | 156 | 57 | 118 | 43 | 274 | 100 |
| Evening | 832 | 61 | 532 | 39 | 1364 | 100 | 351 | 55 | 285 | 45 | 636 | 100 |
| Total | 1255 | 46 | 1462 | 54 | 2717 | 100 | 1046 | 59 | 739 | 41 | 1785 | 100 |

Table 13. Estimated number of flights/day by common mergensers through the treatment area during late fall and early winter (Nov. - Jan.).

| Year and time of day | Balloons present | | | | | | Balloons absent | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High altitude | | Low altitude | | Total | | High altitude | | Low altitude | | Total | |
| | Flights | % | Flights | % | Flights | % | Flights | % | Flights | % | Flights | % |
| 1989-90 | | | | | | | | | | | | |
| Morning | 43 | 97.7 | 1 | 2.3 | 44 | 100.0 | 40 | 63.5 | 23 | 36.5 | 63 | 100.0 |
| Midday | 114 | 99.1 | 1 | 0.9 | 115 | 100.0 | 33 | 94.3 | 2 | 5.7 | 35 | 100.0 |
| Evening | 14 | 100.0 | 0 | 0.0 | 14 | 100.0 | 101 | 94.4 | 6 | 5.6 | 107 | 100.0 |
| Total | 171 | 98.8 | 2 | 1.2 | 173 | 100.0 | 174 | 84.9 | 31 | 15.1 | 205 | 100.0 |
| 1990-91 | | | | | | | | | | | | |
| Morning | 215 | 99.5 | 1 | 0.5 | 216 | 100.0 | 538 | 99.6 | 2 | 0.4 | 540 | 100.0 |
| Midday | 206 | 100.0 | 0 | 0.0 | 206 | 100.0 | 152 | 97.4 | 4 | 2.6 | 156 | 100.0 |
| Evening | 831 | 100.0 | 1 | 0.1 | 832 | 100.0 | 349 | 99.4 | 2 | 0.6 | 351 | 100.0 |
| Total | 1252 | 100.0 | 2 | 0.2 | 1254 | 100.0 | 1039 | 99.2 | 8 | 0.8 | 1047 | 100.0 |

year when balloons were present, compared to 41 carcasses found when balloons were absent. Outside the treatment areas, 4 collision victims were found when balloons were present and 13 when balloons were absent.

## DISCUSSION

Most collisions occurred as birds flew toward the bay, apparently because transmission lines were less visible to birds flying in that direction. Collision rates were highest during midday, indicating that more light did not necessarily increase the visibility of the lines. Likewise, weather conditions had no detectable influence on collision rates. The positive correlation between collisions and number of mergansers using the discharge channel suggests that vulnerability to collisions did not decrease as birds became more familiar with the area.

Mergansers often did not appear to notice the lines until they were too close for effective evasive action. The birds frequently flared as they crossed transmission lines, rather than during their approaches. In contrast, dabbling ducks and gulls usually flared before reaching the lines, or reduced their flight speeds and avoided the lines while flying through them. Thus mergansers were especially susceptible to collisions because of their inability to detect transmission lines from a distance combined with their lack of maneuverability during flight.

The attempt to divert flying mergansers away from the transmission lines at the site was partially successful. Some birds responded to the presence of balloons by increasing their approach altitudes and others moved to different flight paths. These changes in merganser flight patterns resulted in a significant decline in mortality. Morkill and Anderson (1991) observed similar avoidance reactions by sandhill cranes flying toward transmission lines that had been marked by aviation balls. They too documented significantly less mortality at lines that were marked compared to unmarked lines.

There were some deficiencies in the balloon method that are not reflected by the data. The obstruction of the channel flight path was not enough to divert some mergansers. The reduction of low altitude flights over the treatment area when balloons were present was much greater during the first test year. This suggests that the balloons were more effective on the ash pond flight path than on the channel path. Low-flying individuals and small flocks that ignored the balloons and flew through transmission lines over the channel were observed several times. Thus some undetected collisions probably did occur over the channel while balloons were present during the last winter of the study. This problem could probably be corrected by increasing the density and varying the heights of obstacles along the channel flight path.

Although balloons were useful because they could be set up and removed at will, they are not practical as a long-term solution to the collision problem. Balloons are not durable enough to withstand stress produced by high winds. The average life span of a balloon during this study was $<4$ days, and replacing balloons was costly and time consuming. However, a seasonally (November-January) permanent series of similar obstacles, placed inland from the transmission lines that bisect the ash ponds and discharge channel, would probably be equally effective in reducing collisions at the site.

Beaulaurier (1981) suggested that attaching highly visible markers to transmission lines where numerous collisions occur is the most cost-effective technique for reducing collision mortality. The method does produce the desired result, as demonstrated by Morkill and Anderson (1991). However, in some circumstances safety and/or economic considerations preclude direct attachment of objects to the lines. In this study, placement of markers near transmission lines provided an "early warning system" that obtained results that compared favorably to those of Morkill and Anderson (1991). Although this method presents more logistic problems and is more costly than attaching objects to transmission lines, it is a viable alternative that should be considered in cases where the transmission lines can not be modified.

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