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Trends in Waterfowl Populations: Evidence of Recovery from Acidification

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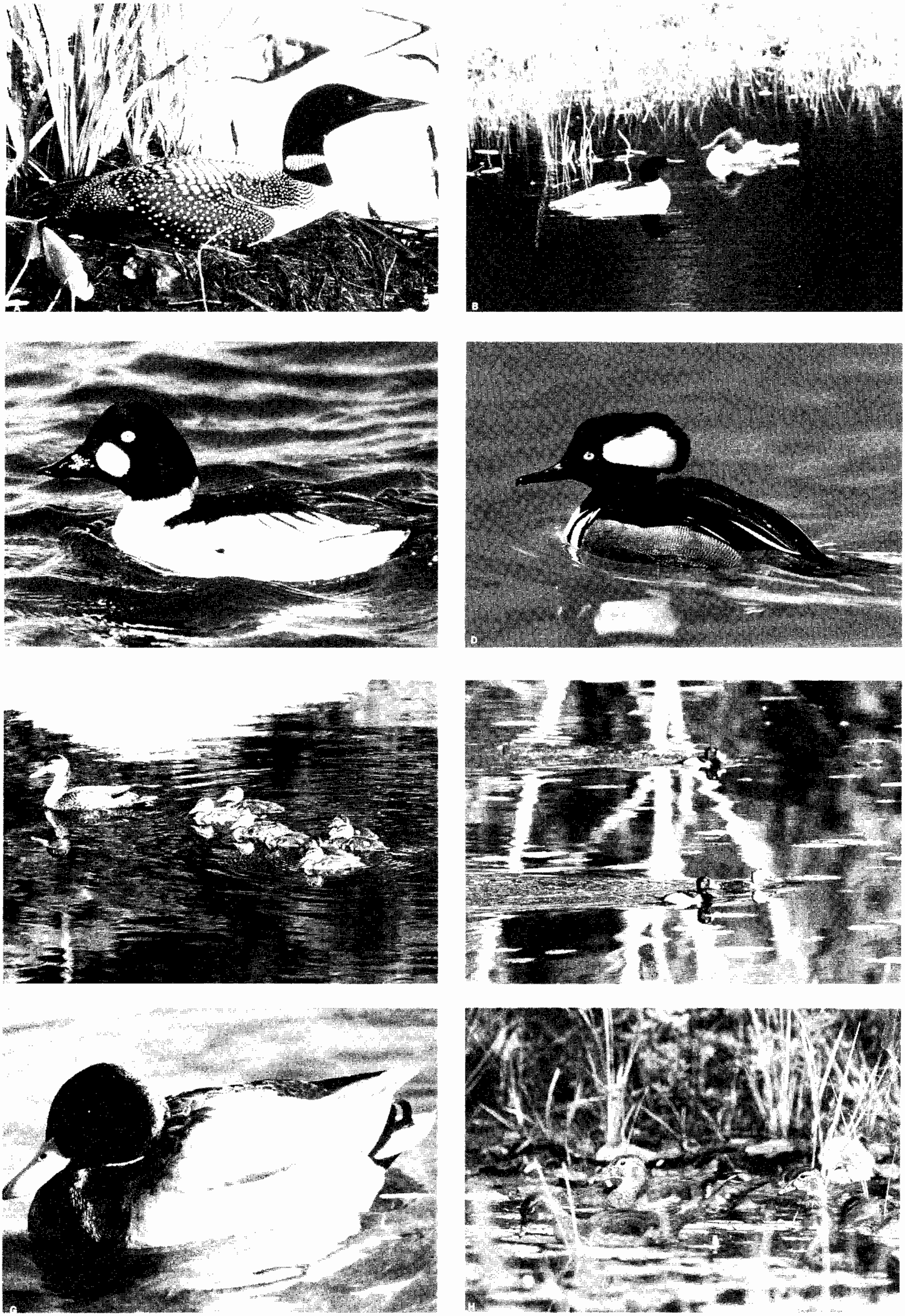
The loss and degradation of aquatic habitat has serious implications for waterfowl species breeding in the northern forests of eastern Canada, an area whose importance to continental populations is only beginning to be appreciated (NAWMP 1986). Acid rain poses a serious threat to waterfowl that rely on healthy lakes and wetlands for nest sites, protection of young, and most important, food. Both ducks and loons require high-protein, mineral-rich foods (small fish or invertebrates) for the production of eggs and rapid growth of young (Reinecke and Owen 1980). As lakes acidify, the accompanying biological changes disrupt normal prey communities. Changes in the composition, abundance, and nutritional value of prey can reduce the quality of breeding habitat (McNicol and Wayland 1992) and affect reproduction (Scheuhammer 1991). Consequently, reversal of acidification would benefit a significant waterfowl resource. An estimated 192,000 pairs of ducks and loons breed on the exposed Precambrian Shield of central and northeastern Ontario, where surface waters have a limited capacity to neutralize acidic inputs (McNicol et al. 1990).

Efforts to reduce sulfur dioxide emissions are aimed at protecting sensitive aquatic habitats. Where improvements to water quality are expected, little is known about the response of biological communities, because most research has documented aspects of decline. A notable exception is recent evidence of biological changes that have accompanied chemical improvements of acidic lakes near Sudbury after reductions in local smelter emissions (Keller et al. 1992a). Such evidence confirms that damaging effects of acidification can be reversed; already, some biotic communities in recovering lakes are becoming more typical of those found in non-acidic lakes. Sudbury area lakes provide a unique opportunity to monitor biological recovery across a broad range of initial chemical conditions.

Waterfowl are being studied as indicators and integrators of the biological responses to reduced acid deposition and chemical recovery observed in Sudbury area lakes. As fish and invertebrate prey return to lakes, the quality of breeding habitat for some species is expected to improve. This chapter examines trends in waterfowl populations breeding in the Sudbury area as possible evidence of reversibility of acidification. Relationships between the distribution, density, and productivity of waterfowl and various habitat parameters including pH are examined. Finally, present knowledge is used to predict future responses of waterfowl to the environmental effects of additional abatement programs.



Waterfowl and Habitat Parameters

Waterfowl that commonly breed near Sudbury are shown in Figure 16.1 and include, for this exercise, the Common Loon (*Gavia immer*), as well as the following ducks: Common Merganser (*Mergus merganser*), Common Goldeneye (*Bucephala clangula*), Hooded Merganser (*Lophodytes cucullatus*), American Black Duck (*Anas rubripes*), Ring-necked Duck (*Aythya collaris*), Mallard (*Anas platyrhynchos*), and Wood Duck (*Aix sponsa*). Aspects of their breeding biology are summarized in Table 16.1.

Studies of waterfowl breeding populations, habitat quality, and aquatic food webs were conducted in the Sudbury area between 1983 and 1993. This study area covers approximately 17,000 km^2, generally corresponding to the area southwest and northeast of Sudbury (Fig. 16.2), defined by Neary et al. (1990) as the zone influenced by past sulfur emissions from Sudbury smelters (see Chapter 3). Surveys of breeding populations were undertaken in 4-km^2 plots located throughout this zone between 1985 and 1993 (Ross 1987) (Fig. 16.2). Numbers of wetlands and estimates of open water area were determined for each plot (Fig. 16.3). Data from 363 lakes sampled in the early 1980s (Neary et al. 1990) were used to map lake pH distributions in the area; survey plots were then assigned a pH class.

The ecology of waterfowl breeding in the acid-stressed area north of Lake Wanapitei has been studied since 1983. A total of 174 lakes and wetlands was surveyed or sampled to varying degrees in the Wanapitei study area (see Fig. 16.2). These lakes varied substantially in pH (3.9–7.6) and fish and invertebrate populations (Bendell and McNicol 1987, in press). The relative production of waterfowl breeding at Wanapitei was compared among pH classes based on the most recent pH reading, usually 1993.

Simple correlation was used to examine relationships between waterfowl populations and habitat parameters. For plots within the Sudbury study area, no significant correlations were evident among habitat parameters (Table 16.2). Average numbers of wetlands were higher in central plots compared with the northeast and far southwest, where fewer but larger lakes predominate (Fig. 16.3). North of Sudbury, high wetland densities coincide with high open water areas, a situation that might arise if large numbers of small lakes were found in close proximity. Large areas northeast and southwest of Sudbury contained surface waters with pH less than 6 in the early 1980s (Fig. 16.3).

After emission reductions in the 1970s, acidic lakes distant from Sudbury showed marked increases in pH and alkalinity and declines in sulfate between 1980 and 1987 (Keller et al. 1992b) (see Chapter 5). Similar trends were evident in small lakes monitored for waterfowl near Wanapitei (McNicol and Mallory 1994). However, further improvements to water quality have not been observed since 1987, nor are any expected until additional abatement measures are implemented.

The invertebrate communities in these lakes are strongly influenced by the presence or absence of fish (McNicol and Wayland 1992). Approximately 25% of lakes sampled at Wanapitei in 1993 continue to have pH less than 5 and are fishless. This abundance of small (<8 ha), fishless, acidic lakes is a unique feature of the Wanapitei area. In the absence of fish predation, these small acid lakes contain large populations of a few types of acid-tolerant invertebrate taxa. Larger lakes (>8 ha), ranging in pH between 5 and 6.3, often support acid-tolerant fish species, such as yellow perch (*Perca flavescens*), which, coupled with acid stress, reduce invertebrate prey abundance and diversity (Bendell and McNicol 1987, in press).

FIGURE 16.1. Waterfowl species that commonly breed in the Sudbury area: (**A**) Common Loon, (**B**) Common Merganser, (**C**) Common Goldeneye, (**D**) Hooded Merganser, (**E**) Black Duck, (**F**) Ring-necked Duck, (**G**) Mallard, (**H**) Wood Duck. (Photos for A, B, E–H by Michael W.P. Runtz; photos for C and D by Jim Flynn.)

Table 16.1. Habitat requirements of waterfowl species found in the Sudbury area.

Species	Diet	Nesting habitat	Brood-rearing habitat
Common Loon	Small to medium-sized fish	Ground (prefers islands) near water	Lakes; medium-to-large, meso- to oligotrophic
Wood Duck	Adults—plant matter Ducklings—invertebrates	Tree cavity	Wetlands; small, meso- to eutrophic with marshy cover
Black Duck	Adults—plant matter Ducklings—invertebrates	Ground in heavy cover	Wetlands; small, meso- to eutrophic with shoreline cover
Mallard	Adults—plant matter Ducklings—invertebrates	Ground in heavy cover	Wetlands; small, eutrophic with marshy cover
Ring-necked Duck	Adults—plant matter Ducklings—invertebrates	Ground in heavy cover near water	Wetlands; small, meso- to eutrophic with shoreline cover
Common Goldeneye	Mostly invertebrates	Tree cavity	Lakes; small-to-medium, oligotrophic
Hooded Merganser	Small fish and invertebrates	Tree cavity	Wetlands; small, meso- to oligotrophic with shoreline cover
Common Merganser	Small to medium-sized fish	Tree cavity	Rivers and medium-to-large lakes

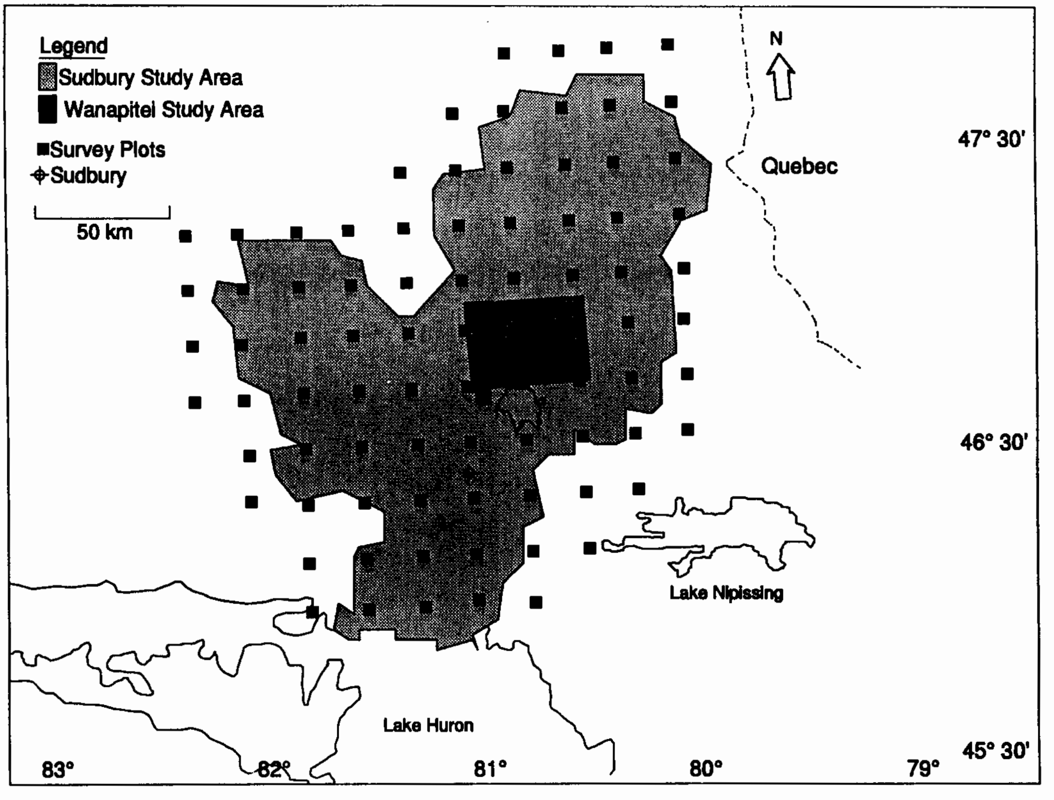


Figure 16.2. Map of northeastern Ontario showing outlines of the Sudbury study area (from Neary et al. 1990) and the Wanapitei study area (from McNicol et al. 1987a). Waterfowl and habitat survey plots (2 × 2 km) that fall inside the Sudbury area ($N = 57$) or within 20 km ($N = 26$) are also identified.

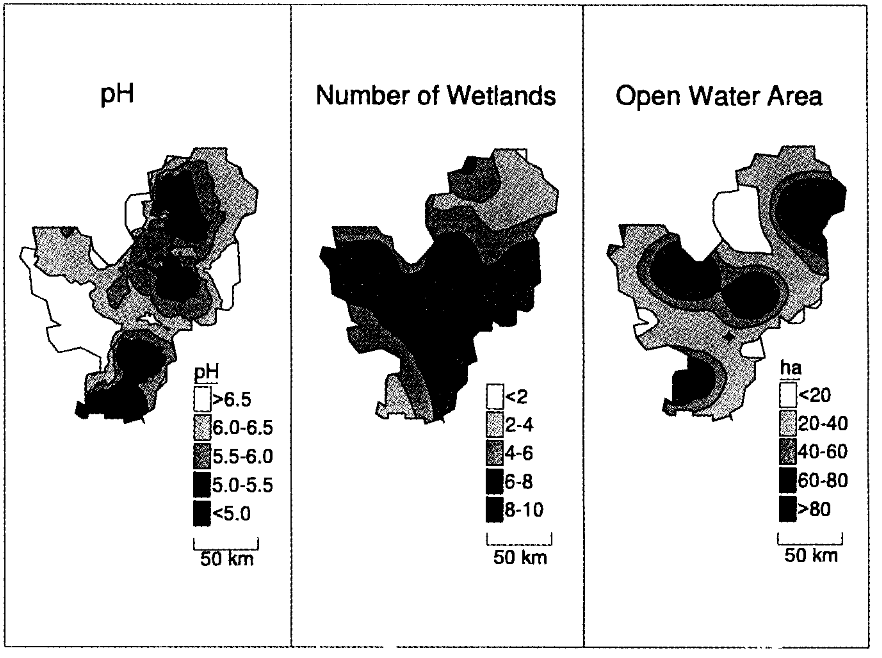


FIGURE 16.3. Maps of the distribution of pH, number of wetlands, and open water area (derived from 83 4-km^2 plots) in the Sudbury area. The pH map was derived from 363 lakes (from Neary et al. 1990). Maps were constructed using the POTMAP use of SPANS (Intera Tydac 1991). Sudbury is shown by ⊕.

TABLE 16.2. Relationships between the densities of eight waterfowl species breeding in the Sudbury area and habitat parameters, based on 5-year average densities for 57 plots, expressed as Spearman rank correlation coefficients.

	Habitat parameter		
	pH	No. wetlands	Open Water Area (ha)
No. wetlands	0.04		
Open Water Area	0.10	0.19	
Common Loon	0.26*	0.37**	0.78**
Common Merganser	−0.08	−0.11	0.31*
Common Goldeneye	−0.29**	0.16	0.11
Hooded Merganser	0.07	0.61**	0.20
Black Duck	−0.06	0.45**	0.06
Ring-necked Duck	−0.20	0.45**	0.06
Mallard	−0.02	0.18	−0.15
Wood Duck	−0.11	0.08	−0.03

* $P < .05$; ** $P < .01$.

Waterfowl Species Accounts

The following accounts discuss patterns in species' distribution, density, and productivity in the context of recovery of Sudbury area lakes. The results of the surveys are illustrated in Figures 16.3 to 16.6 and Tables 16.1 and 16.2.

Common Loon

This well-known species is common on large oligotrophic lakes, where it feeds primarily on small fish. Loons and other piscivores are at risk from acidic precipitation due to reduced availability and quality of fish prey as lake pH declines. Because they are long-lived and return to the same lake each year, loons breeding on acidic lakes may experience impaired reproduction from elevated levels of mercury in fish prey (Scheuhammer 1991). Studies have shown that loons breed less frequently on acidic lakes (DesGranges and Darveau 1985; McNicol et al. 1987a) and that nest attempts on these lakes are often unsuccessful due to higher chick mortality (Alvo et al. 1988). The dominant factor influencing loon breeding distribution and success across Ontario is lake area (Wayland and McNicol 1990). At Sudbury, breeding densities correlate strongly with

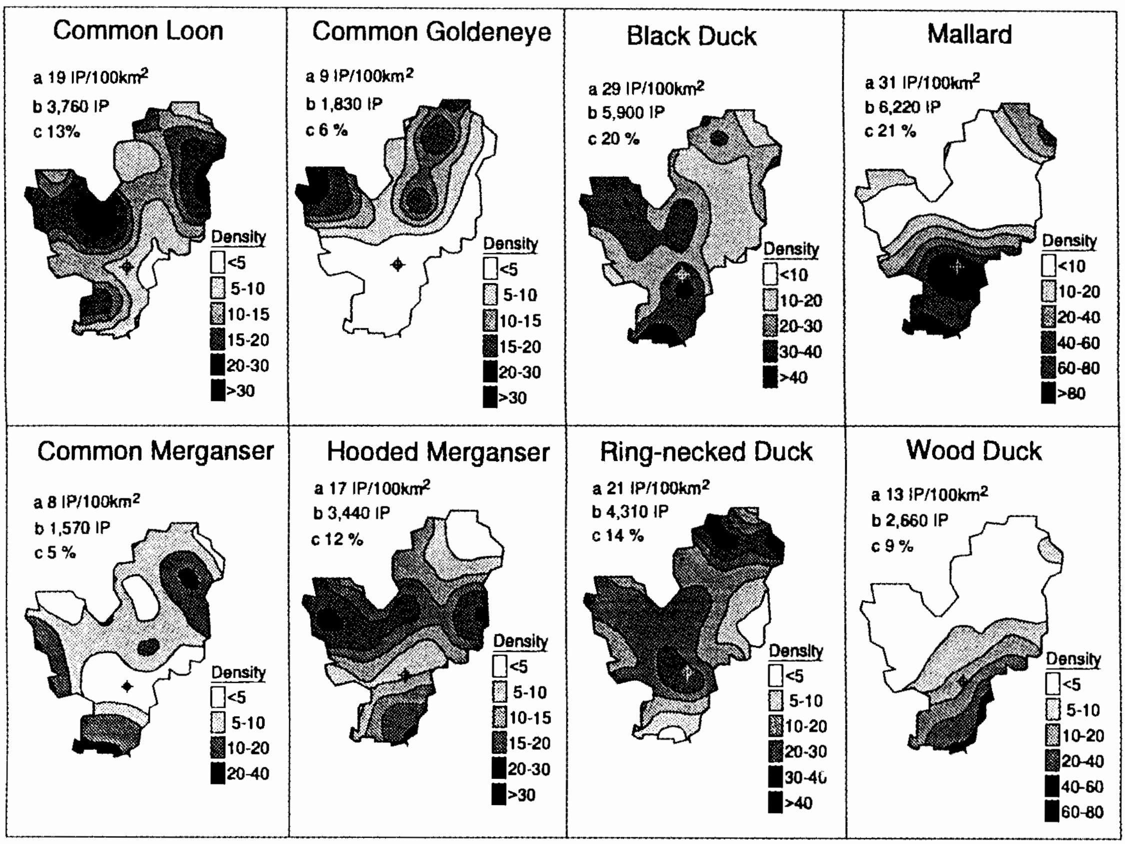


FIGURE 16.4. Maps of the distribution and density (indicated pairs per 100 km^2) of eight waterfowl species breeding in the Sudbury area, based on 5-year average densities for 83 survey plots (from Ross 1987). The location and number of pairs were determined using helicopter surveys conducted during nest initiation in May 1985, 1987–89, and 1993. Maps were constructed using the POTMAP use of SPANS (Intera Tydac 1991). Estimates of (*a*) mean density, (*b*) total number of indicated breeding pairs (*IP*), and (*c*) percentage of total waterfowl count are included for each species. Sudbury is shown by ⊕.

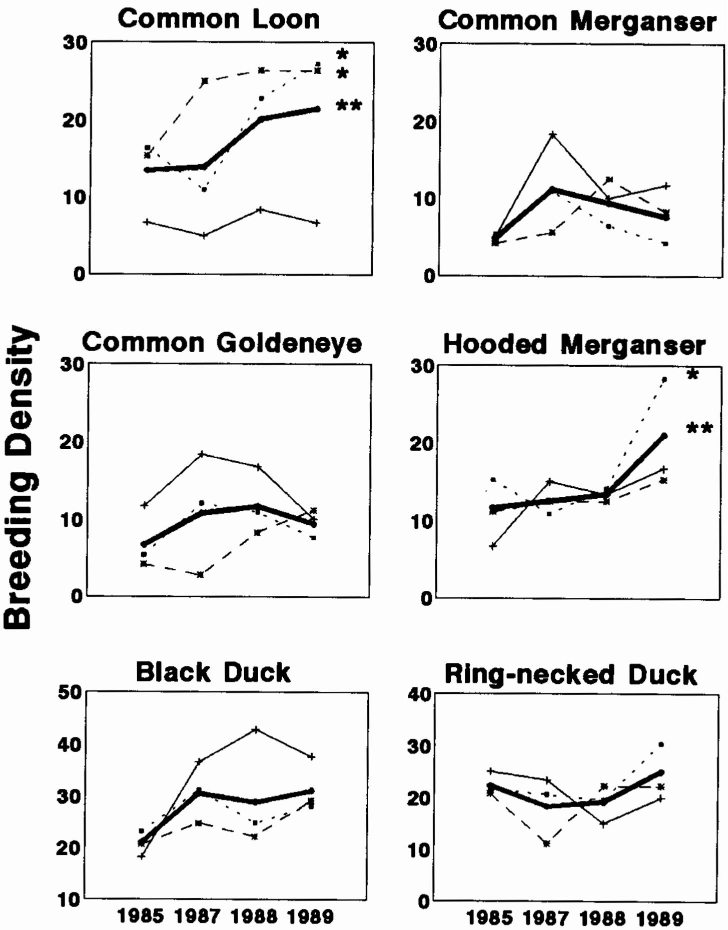


Figure 16.5. Trends in the average density (indicated pairs per 100 km^2) of six waterfowl species breeding in 56 plots within the Sudbury study area surveyed in 4 years between 1985 and 1989 (*thick line*). Also presented are trends for plots assigned to broad pH classes: less than 5.5 (+ — +; $N = 15$), 5.5–6.3 (* — *; $N = 18$), greater than 6.3 (■ · · · · ■; $N = 23$). Statistical tests are based on non-parametric trend analyses (* – $P < .05$; ** – $P < .01$) from Ross et al. 1984).

open water area, reflecting its preference for larger water bodies, but also correlate with pH. Loons are abundant in the northwest (Lake Onaping area), far northeast (Lady Evelyn area), and southwest (Lake Panache area), where average pHs are generally greater than 5.5. Loons have a very localized distribution in the immediate vicinity of Sudbury, where appropriate nesting lakes are rare. Northeast of Sudbury, near Lake Chiniguchi, suitable breeding habitat is available (i.e., large lakes), but few loons are recorded. Extremely acidic lakes (pH <5.5), typical of the general area, are used infrequently by loons.

Common Loon numbers have increased near Sudbury in recent years (Fig. 16.5). Although average breeding densities in acidified areas (pH <5.5) have not changed and remain low, populations in medium (5.5–6.3) and high (>6.3) pH areas have increased substantially. Presumably, increases in local breeding populations are related to recovery in water quality and biological communities (see Chapter 5), especially to the west and far north of Sudbury, where pHs in the early 1980s were greater than 5.5. As the fish prey base in large lakes improves and habitat suited for nesting and raising chicks becomes more available, increased immigration, coupled with enhanced productivity, has ultimately led to the increased recruitment to local breeding populations witnessed recently.

Common Merganser

In summer, this fish-eating species favors clear lakes, rivers, and streams of the Precambrian Shield. As with loons, mergansers display an

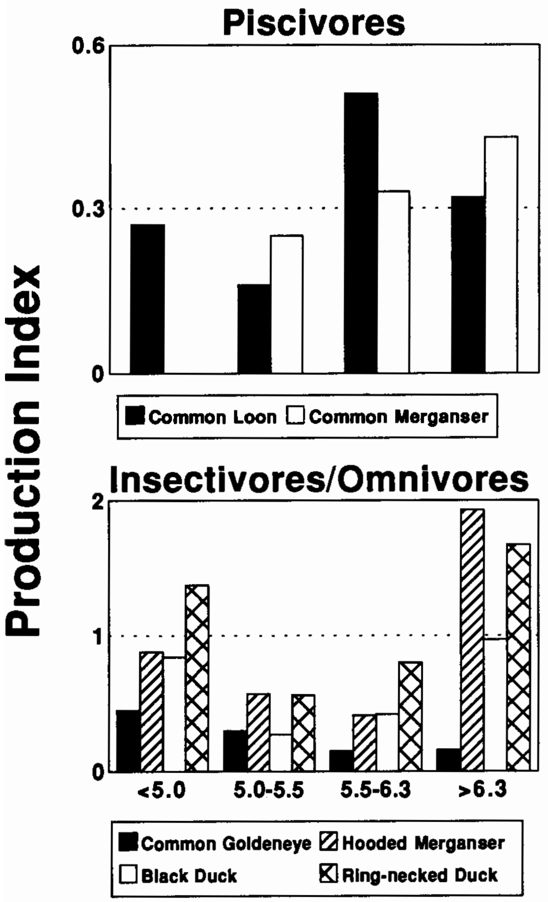


FIGURE 16.6. Comparisons of relative production of young (% class 2 broods/% indicated pairs) for piscivores (Common Loon, Common Merganser) and insectivores (Common Goldeneye, Hooded Merganser) or omnivores (Black Duck, Ring-necked Duck) using 174 lakes in the Wanapitei study area. Indicated pair data were collected in 1983, 1985–86, and 1993, and brood data were collected in 1983–87 and 1993. Data were then pooled across years per lake, and lakes were scored as used or unused by each species. Number of lakes in each pH class: less than 5 ($N = 43$), 5–5.5 ($N = 39$), 5.5–6.3 ($N = 46$), greater than 6.3 ($N = 46$).

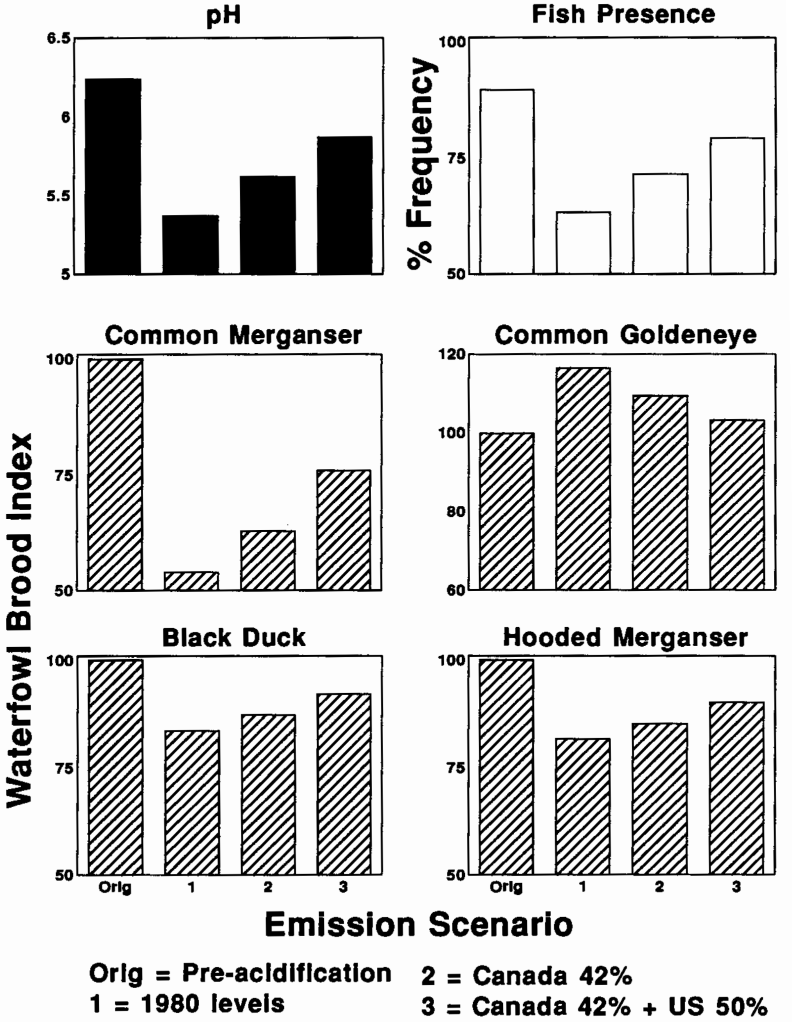
obvious preference for lakes greater than pH 6 that contain fish (McNicol et al. 1990). However, these two fish-eating species differ in their breeding habits; loons raise only one or two young, which are restricted to their nesting lake, whereas Common Mergansers attempt to raise many ducklings that are highly mobile and can move to lakes with a greater food supply.

Fewer than 1600 pairs of Common Mergansers nest in the Sudbury area, with especially low breeding densities (less than five pairs per 100 km^2) recorded near Sudbury, where fish populations continue to be stressed (see Chapter 5). Although production in the acid-stressed Wanapitei area was strongly related to pH, no population trends were evident among any pH classes. Breeding densities were only correlated with open water area, confirming their preference for larger water bodies (McNicol et al. 1987a). Breeding distributions were influenced by two main factors: (1) preference to breed near very large inland lakes (Lady Evelyn, Temagami, Onaping, Wanapitei, and Panache) and near Georgian Bay, and (2) preference for large river systems, such as the Spanish. Both patterns support the tendency of broods to move progressively downstream to brood-rearing habitat after hatch.

Common Goldeneye

The Common Goldeneye is one of the few species that can exploit acidified environments associated with industrial regions (Gilyazov 1993). Early studies indicated that goldeneyes compete with fish for similar invertebrate prey (Eriksson 1979), which influences their distribution (McNicol et al. 1987a) and partially explains the negative correlation with pH ob-

FIGURE 16.7. Predicted responses of pH, fish presence, and four waterfowl species in the Sudbury study area to several emission control scenarios. Waterfowl brood indices are scaled to original (pre-acidification) values.



served in the Sudbury area (Table 16.2). Here, goldeneyes are at the southern limit of their breeding range, but pockets of small, fishless, acid lakes support local concentrations of nesting pairs. The population fluctuated between 1985 and 1989, with no consistent trend. However, goldeneye breeding densities did increase on lakes where recovery should be rapid (pH 5.5–6.3), perhaps because invertebrate prey abundance and diversity increased, but fish have not yet invaded.

Research on goldeneyes at Wanapitei has confirmed that, given a variety of small oligotrophic lakes to choose from, fishless, often clustered lakes are preferred during all stages of breeding (Mallory et al. 1993, 1994; Wayland and McNicol, 1994). These associations are clearly linked to the rich supply of preferred invertebrate prey found in fishless lakes in the area, most of which are very acidic (pH <5.0) (McNicol et al. 1987b; McNicol and Wayland 1992). As pH improves and fish return to many of these lakes, the Common Goldeneye is the only species whose population is expected to decrease in the Sudbury area as a direct result of acidity shifts (Fig. 16.7).

Hooded Merganser

This merganser prefers small beaver-influenced lakes and wetlands in northeastern Ontario and is often associated with non-acidic, naturally fishless lakes (Blancher et al. 1992). Unlike goldeneyes, adult Hooded Mergansers can forage on small fish; however, their young rely exclusively on conspicuous aquatic insects and thus compete with fish for prey (McNicol et al. 1987b). Hooded Mergansers are common near Sudbury (3440 pairs), especially in central and southeastern areas, but rarely occur in the far northeast. Their distribution only correlates with number of wetlands, with higher breeding densities in plots containing large numbers of small lakes (Table 16.2). Significant increases in populations were noted and were most consistent in high and low pH areas (see Figs. 16.4 and 16.5). Unlike goldeneyes, this species appears to produce more young at pH extremes at Wanapitei. At low pH, young may have an easier time finding relatively abundant invertebrate prey consisting of few species, and at high pH they can find abundant diverse prey. In mid-range pHs, fish predation and pH effects reduce invertebrate prey availability. The plastic nature of its feeding habits, combined with its broad ecological niche, may allow this species to take full advantage of any habitat improvement after recovery.

American Black Duck

The Black Duck is closely related to the Mallard but is highly adapted to boreal conditions (Ross 1987). Although similarly abundant at Sudbury, its distribution is different from that of the Mallard. It is found throughout the area and shows a strong correlation to numbers of wetlands per plot (Table 16.2), a reflection of its preference for smaller breeding ponds (McNicol et al. 1987a). Its population has shown an upward tendency, consistent with recent patterns for northeastern Ontario. This trend probably reflects reductions of hunter bag limits instituted during the study in response to an overall population decline detected over the past 30 years (NAWMP 1986). Interestingly, the sharpest rise occurs in the lowest pH range. Although an explanation is presently being sought, this tendency suggests that additional birds are being forced into less desirable habitat.

Ring-Necked Duck

This ground-nesting species prefers small productive wetlands and marshes in the boreal region and is common in the Sudbury area (4300 pairs), particularly in the northeast. Ring-necked Ducks have a diverse diet (Bellrose 1980; McNicol et al. 1987b), and production of young is highest in lakes at each pH extreme (pH <5.0; pH >6.3), similar to the pattern for other insectivores and omnivores. Again, this may be due to the combined effects of fish predation and pH on invertebrate prey in lakes between pH 5 and 6.3. Its distribution, however, only correlates with wetlands numbers (Table 16.2). Given the lack of any relationship to pH, it is not surprising that Ring-necked Duck populations remained relatively stable in all pH classes during this study.

Wood Duck

This tree-nesting species prefers more southerly marshes, swamps, and small lakes (Bellrose 1980). At the northern limit of its present range near Sudbury, it is virtually absent in more boreal habitat to the north and west but is common in the southeast where it is keying on nutrient-rich clay substrates (Wickware and Rubec 1989). The Wood Duck has risen in numbers during the study, but this appears unrelated to pH changes. Instead, this reflects the sharp population increase this species has undergone in southern Ontario (Dennis et al. 1989), which has led to expansion at the edges of its range into appropriate habitat created by increasing amounts of beaver flowage in Ontario.

Mallard

The Mallard is the most widely distributed waterfowl species in the world and the most abundant duck in the Sudbury area. It is a marsh-dwelling species with a high tolerance of human activity and has a distribution very similar to the Wood Duck's, showing the same regional association with clay-dominated soils and a lack of relationship with other habitat variables. It selects the most fertile breeding habitat (Merendino 1993), which is the least likely to be affected by pH depression. The local population is stable, and trends in all three pH ranges appear similar.

Future Implications for Waterfowl

Most research on effects of acidification on waterfowl has focused on habitat and food chain relationships. However, waterfowl breeding in affected areas must be monitored over a long period to reliably establish whether a consistent trend of improvement in populations is occurring as lake chemistries recover. Nonetheless, we can use existing knowledge to make predictions on how species will respond to various emission control scenarios. The Waterfowl Acidification Response Modelling System (WARMS) is composed of an underlying acidification model (Jones et al. 1990) and fish and waterfowl models derived from data collected in the Sudbury and Algoma regions (Blancher et al. 1992). WARMS uses pH, lake area, dissolved organic carbon, total phosphorus, and fish presence to predict independent waterfowl species responses to changing lake chemistry. It provides estimates of pre-acidification, current and eventual (steady-state) values for pH, fish presence, and waterfowl breeding parameters under various emission scenarios.

WARMS predictions for pH, fish presence, and selected waterfowl species in the Sudbury area (based on 227 lakes) (Neary et al. 1990) for the following emission scenarios—(1) pre-acidification (background) levels of sulfur dioxide, (2) 1980 levels of sulfur dioxide, (3) Canadian emissions reduced by about 42% (by 1994), and (4) scenario 3 with about a 50% reduction in U.S. emissions (by year 2000)—are shown in Figure 16.7. Fish presence, pH, and waterfowl broods are all lower currently and under future scenarios than calculated values before lake acidification (except goldeneyes). However, as sulfur dioxide emissions decline, lake pH is predicted to improve dramatically. This is expected to result in the return of fish to many lakes where fish were lost due to acidification. The return of fish should provide more suitable foraging conditions for fish-eating species, such as the Common Merganser, when numbers of lakes supporting broods are expected to increase substantially.

Conditions for Black Ducks and Hooded Mergansers should also improve, although not of the magnitude of the Common Merganser. Increases in broods of these two species will be related to shifts in invertebrate assemblages (e.g., return of high-quality prey) resulting from chemical improvements and not strictly fish presence. Broods of the insectivorous Common Goldeneye are expected to decline toward pre-acidification levels, as fish return to many lakes and reduce the supply of invertebrate foods.

Even under the strongest emission reduction scenario (Canada 42% + United States 50%), WARMS predicts that waterfowl populations in the Sudbury area will not return to their pre-acidification levels. However, under any reduction in sulfur dioxide emissions, populations of all local waterfowl species should remain stable or move toward pre-acidification levels. Continued monitoring of Sudbury area lakes is required to refine these predictions, establish rates of recovery, and most important, verify that current abatement programs will indeed restore the capacity of sensitive aquatic habitats to sustain healthy populations of plants and animals, including waterfowl.

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