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# ORGANOCHLORINES, PREDATORS AND REPRODUCTIVE SUCCESS OF THE RED-NECKED GREBE IN SOUTHERN MANITOBA[1]

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*Abstract.* I assessed factors influencing the reproductive success of Red-necked Grebes (*Podiceps grisegena*) in Turtle Mountain Provincial Park, Manitoba, during 1980 and 1981. Nesting losses were high as 78.9% of 697 eggs in 179 regularly observed nests failed to hatch. An additional 4.4% disappeared during the hatching process. Similar success rates among 137 eggs in 29 infrequently observed clutches indicated that observer presence did not adversely affect nesting success. Losses due to waves (2%) and intraspecific territoriality (6%) were minimal. Predators, particularly raccoons (*Procyon lotor*), accounted for half of the losses. Organochlorine residues contributed to many of the remaining losses. Average DDE levels (74.3 ppm, lipid weight) in 12 eggs were comparable to those reported in other recent studies, but average PCB levels (194.8 ppm) were unusually high. Average residue levels of 1 to 8 ppm were recorded for mirex, dieldrin, hexachlorobenzene, oxychlordane, heptachlor epoxide, and DDD. The average Ratcliffe Index (1.72) for 29 eggs collected during this study was significantly less than Ratcliffe Indices for 112 Red-necked Grebe eggs collected in North America prior to 1947 ($\bar{x}$ = 1.84) or for 186 eggs collected in central Alberta in the early 1970s ($\bar{x}$ = 1.86). Other indications of thin-shelled eggs included the frequent disappearance of single eggs between nest checks (9%) and cracked eggs noted in several active nests. The estimated rate of egg inviability (25%) exceeded the 5% rate considered normal for most grebes. Egg inviability contributed to at least 23% of 191 eggs in 58 successful clutches being deserted after partial clutch hatching.

A high incidence of renesting, 83.5% of 79 failed pairs, resulted in 51% of 114 breeding pairs hatching at least one young. An average of 2.5 young hatched per successful pair. This was reduced to 1.9 young per successful pair or 0.9 young per breeding pair at fledging. Fledging success was lower than recorded in most other Red-necked Grebe studies. Organochlorines, recent increases in unnatural predators, and human recreational activities have probably contributed to reduced productivity and population declines among Red-necked Grebe populations throughout North America.

*Key words: Red-necked Grebes; nesting success; productivity; DDE; PCB; organochlorines; predators.*

## INTRODUCTION

Reduced reproductive success and resultant population declines due to persistent organochlorines have been documented for many fish-eating and raptorial bird species (Hickey and Anderson 1968, Faber and Hickey 1973, Fleming et al. 1983). Many studies have correlated reduced productivity with eggshell thinning caused by DDE, a metabolite of DDT (Blus et al. 1972, Clark and Krynitsky 1983). Elevated DDE residues have occasionally been shown to induce delayed ovulation, decreased egg production, reduced hatchability, and increased embryo and hatchling mortality (Haegele and Hudson 1973, Haseltine et al. 1974, Mendenhall et al. 1983). Polychlorinated biphenyls (PCBs) generally exert less influence on eggshell thickness, but they may alter courtship and nesting behavior, decrease egg production, depress hatchability of fertile eggs, increase embryo and chick mortality, and reduce growth rates of the progeny (Dahlgren and Linder 1971; Briggs and Harris 1973; Lillie et al. 1974, 1975; Scott et al. 1975; Tori and Peterle 1983).

Population declines of the Red-necked Grebe (*Podiceps grisegena*) have been noted in North America (Riske 1976, Tate 1981) and in Europe (Wobus 1964, Ahlen 1970, Cramp and Simmons 1977). Although factors involved in these declines are unclear, the Red-necked Grebe's position at the top of aquatic food chains (Wetmore 1924, Munro 1941) makes it susceptible to ingestion of large concentrations of pollutants. Riske

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(1976) found elevated levels of PCB and DDE in Red-necked Grebe eggs from central Alberta and suggested that these residues in combination with other limiting factors contributed to a 55 to 80% reduction in reproductive success and to population declines of 50 to 75% from 1970 to 1976. The objectives of this study were to monitor reproductive success among a Red-necked Grebe population in southern Manitoba and to assess the effects of organochlorines and other potential limiting factors in a relatively unmodified and undisturbed setting.

## STUDY AREA AND METHODS

Turtle Mountain Provincial Park (TMPP) is located in southwestern Manitoba, adjacent to the Canada-United States border on the south and 215 km southwest of Winnipeg, Manitoba. The Turtle Mountain is actually a range of morainic hills that rise 243 to 320 m above the surrounding plains forming a knob and kettle type of topography with numerous poorly drained depressions (Cassel and Stewart 1969). Over 400 small to medium-sized lakes dot the 19,000 ha that comprise TMPP. Detailed discussions of the floral and faunal composition of TMPP were presented in Disrud (1968), De Smet and Smith (1979), and Guinan and Rewcastle (1982).

During the 1980 and 1981 nesting seasons, I observed 110 pairs of Red-necked Grebes in TMPP on a daily basis and 16 pairs at less frequent intervals. I used a waterproof felt pen to individually mark 834 eggs from 179 regularly observed and 29 infrequently observed clutches. These were monitored throughout incubation and hatching to determine their individual fates. To minimize disturbance, nesting pairs were observed from remote shoreline positions on a daily basis, but nest checks were limited to 1- to 4-day intervals during egg laying and hatching and approximately weekly intervals during other stages of incubation. Brood counts were initiated immediately after hatching and were continued for at least 1 month. The cohesiveness of family units began to break up after the first month, hence survival data until fledging (at 7 to 10 weeks of age) were available only for broods that were isolated on smaller lakes.

Because incubation was continuous beyond the second or third egg, clutches were suspected of being destroyed when a previously active nest was found unattended. These nests were examined immediately to determine why the nesting attempt failed. Depredation was suspected when eggshell fragments were found within or near a destroyed nest. Probably depredated nests included those with no trace of eggshell fragments despite the entire clutch having disappeared between nest checks. Clutches were considered deserted if the nest appeared unkempt and the eggs were cold. Wave-related losses were suspected when nests were found in a largely disintegrated condition, particularly if this followed a storm or windy weather. Because different factors were probably responsible for eggs located beside unflooded nests and one or more eggs disappearing between nest checks, these were recorded separately.

Eggs were collected from nests that had been deserted for several days or were retrieved from the water next to active or recently destroyed nests. During 1981, Ratcliffe Indices (Ratcliffe 1967) were calculated for 29 eggs after the contents were removed and the eggshells rinsed with water, air-dried for several months and weighed to the nearest 0.1 mg. The contents of these and 14 other eggs were individually frozen in aluminum foil or plastic bags. Twelve of these eggs, including two freshly-laid, two addled, and eight from nests deserted during egg laying or early incubation, were analyzed for organochlorines by the Ontario Research Foundation (Mississauga, Ontario). Organochlorine residue analyses were performed as described in Reynolds and Cooper (1975). Capillary gas chromatography combined with electron capture was used for the hexane fraction and packed column gas chromatography was used for the methylene chloride fraction.

## RESULTS

### ORGANOCHLORINE RESIDUES

Red-necked Grebe eggs from TMPP contained appreciable residue levels of PCB and DDE, plus average residue levels exceeding 1 ppm for mirex, dieldrin, hexachlorobenzene, oxychlordane, heptachlor epoxide, and DDD (Table 1). Laying dates were not significantly correlated with levels of PCBs ($r = -0.15$), DDE ($r = -0.29$), and total organochlorines ($r = -0.19$) in the eggs. Ratcliffe Indices were negatively correlated with levels of PCBs ($r = -0.31$), DDE ($r = -0.23$), and total organochlorines ($r = -0.31$) in the eggs, but none of these were significant ($P > 0.05$). Levels of PCB and DDE were highly correlated ($r = 0.97$).

TABLE 1. Organochlorine compounds found in 12 Red-necked Grebe eggs from TMPP, 1981.

| Compound | Mean (ppm, lipid wt.) | SD | Range |
|---|---|---|---|
| PCB 1254/1260; peak 2 | 194.79 | 123.91 | 8.20–368.00 |
| DDE | 74.26 | 43.49 | 8.63–125.80 |
| Mirex | 8.11 | 8.66 | 0.12–28.60 |
| Dieldrin | 2.09 | 1.65 | 0.15–4.94 |
| Oxychlordane | 2.02 | 1.27 | 0.19–4.43 |
| Hexachlorobenzene | 2.01 | 1.25 | 0.38–4.49 |
| Heptachlor epoxide[1] | 1.79 | 1.12 | 0.30–3.57 |
| DDD | 1.18 | 0.93 | 0.12–2.86 |
| $\beta$-HCH | 0.65 | 0.34 | 0.25–1.29 |
| $\alpha$-Chlordane | 0.60 | 0.49 | 0.18–1.72 |
| $\gamma$-Chlordane[1] | 0.48 | 0.37 | 0.27–1.03 |
| Pentachlorobenzene | 0.14 | 0.13 | 0–0.34 |
| 1,2,3,4-Chlorobenzene | 0.03 | 0.03 | 0–0.06 |
| DDT | 0.02 | 0.05 | 0–0.18 |
| 1,2,3,5/1,2,4,5-Chlorobenzene | 0.02 | 0.04 | 0–0.11 |

[1] Sample sizes for heptachlor epoxide and $\gamma$-chlordane reduced to 10 and 4, respectively, due to presence of an interfering peak.

PCB:DDE ratios for nine of the Red-necked Grebe eggs from TMPP approached the 3:1 ratio characteristic of birds wintering along the Atlantic coast, whereas the three eggs that contained less than 100 ppm of total organochlorines had PCB:DDE ratios similar to the 1:1 ratio characteristic of birds wintering along Pacific coastlines (Keith and Gruchy 1971, Risebrough et al. 1972, Schreiber and Risebrough 1972).

## HATCHABILITY AND EGGSHELL THICKNESS

The hatchability of Red-necked Grebe eggs from TMPP was assessed by monitoring the fate of 191 eggs in 58 successful clutches (Table 2). Among these, 21.5% were inviable. Four additional clutches (nine eggs) that were deserted after more than a month of incubation contained addled eggs. At least 44 (23.0%) of the eggs in successful clutches were deserted after partial clutch hatching. Of these, 18 were addled or undeveloped, embryos in nine had died during development, seven disappeared but were considered inviable because subsequent eggs in the clutch had hatched prior to their disappearance, and only 10 were viable. Interestingly, two of the eggs that were analyzed, the first- and third-most contaminated in terms of total organochlorines, came from clutches that were eventually successful. Both clutches also contained at least one egg that was addled and one egg in which the embryo died prior to hatching.

Ratcliffe Indices for 29 eggs in 21 clutches ranged from 1.41 to 2.00 and averaged 1.72 (SD = 0.17). Cracked eggs were found in seven active clutches and in two clutches that were deserted during late stages of egg laying. Because cracked eggs in active clutches soon vanished, the frequent disappearance of one egg between nest checks (8.3%) may have resulted from weak eggs cracking and being subsequently removed by the adults.

## REPRODUCTIVE SUCCESS

Among 697 eggs from 179 Red-necked Grebe clutches that were regularly observed, 78.9% failed to hatch (Table 3). Another 4.4% disappeared during the hatching process, thus their ultimate fate was uncertain. In 29 less frequently

TABLE 2. Percentages of viable and inviable eggs in 58 successful Red-necked Grebe clutches from TMPP, 1980–1981.

| Hatchability | $n$ | % |
|---|---|---|
| Hatched | 137 | 71.7 |
| Deserted after partial clutch hatching[1] | 10 | 5.2 |
| Located beside an unflooded nest[1] | 2 | 1.0 |
| Broken during handling[1] | 1 | 0.5 |
| Viable subtotal | 150 | 78.4 |
| Deserted after partial clutch hatching[2] | 18 | 9.4 |
| Embryo died prior to hatching[3] | 9 | 4.7 |
| Disappeared during hatching[4] | 7 | 3.7 |
| Located beside an unflooded nest[2] | 7 | 3.7 |
| Inviable subtotal | 41 | 21.5 |

[1] Contents appeared viable.
[2] Contents addled or undeveloped.
[3] Died after advancing to the cheeping or pipping stage.
[4] Subsequent eggs hatched prior to their disappearance.

TABLE 3. The fate of 834 Red-necked Grebe eggs from 179 regularly observed clutches and 29 infrequently observed clutches from TMPP, 1980–1981.

| Egg fate | Regularly observed | | Infrequently observed | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| Hatched | 116 | 17 | 21 | 15 |
| Possibly hatched | 31 | 4 | 18 | 13 |
| Depredated | 197 | 28 | 9 | 7 |
| Probably depredated | 75 | 11 | 39 | 28 |
| Single eggs disappeared | 62 | 9 | 7 | 5 |
| More than one egg disappeared | 42 | 6 | 24 | 18 |
| Deserted during early incubation | 49 | 7 | 14 | 10 |
| Deserted; partial clutch hatching | 48 | 7 | 3 | 2 |
| Deserted; incubating adult killed | 13 | 2 | 0 | 0 |
| Deserted; partial nest depredation | 6 | 1 | 0 | 0 |
| Located beside an unflooded nest | 39 | 6 | 2 | 1 |
| Nest flooded by waves | 17 | 2 | 0 | 0 |
| Broken during handling | 2 | 0 | 0 | 0 |

observed clutches, 71.5% of 137 eggs failed to hatch, but infrequent visits resulted in more eggs (13.1%) disappearing during the hatching process.

Predators accounted for half of the nesting losses, contributing to depredated and probably depredated clutches and the desertion of eggs after partial clutch depredation or after an incubating adult was killed. Predators were also blamed for most of the losses where more than one egg disappeared between nest checks. The appearances of eggshell remains (see Rearden 1951) and circumstantial evidence suggested that raccoons (*Procyon lotor*) were a major predator (De Smet 1982). Muskrats (*Ondatra zibethica*), American Coots (*Fulica americana*), and Pied-billed Grebes (*Podilymbus podiceps*) were deemed responsible for some nesting losses, especially those that occurred during early egg-laying stages when nests frequently were left unattended. Although some observers attributed major losses by nesting grebes to depredation by crows (Rowan 1924, Simmons 1955, Cringan 1957, Wobus 1964, Riske 1976), egg-thieving by American Crows (*Corvus brachyrhynchos*) in TMPP was considered rare. Three incubating Red-necked Grebes were killed on their nests, probably by mink (*Mustela vison*) or Great Horned Owls (*Bubo virginiatus*).

Wave-related losses in TMPP were slight, accounting for only 2% of the egg losses (Table 3). Intraspecific territoriality was suspected in most incidences where eggs were located beside unflooded nests (6%); however, incidental observations indicated that some of these were accidentally displaced by the adults during nest reliefs or during nest construction (De Smet 1982).

Although 79 of 110 regularly observed pairs in TMPP failed in their initial nesting attempt, 83.5% initiated at least one and up to four renests. Overall, 50.9% of the pairs were successful in hatching at least one young. Successful pairs hatched an average of 2.5 young, but only 1.9 young remained by the time broods were 1 month old. Causes of posthatching mortality were generally unknown because few dead chicks were found. Losses during the second month were minimal; only one of 51 chicks perished among those observed until 50 days of age. Hence, reproductive success of Red-necked Grebes in TMPP was 1.8 young per successful pair or 0.9 young per breeding pair.

## DISCUSSION

### HATCHABILITY AND EGGSHELL THICKNESS

Hatchability data and Ratcliffe Indices implicate pollutant residues with the deflated productivity recorded in TMPP. One quarter of the Red-necked Grebe eggs from TMPP were considered inviable, yet other studies indicated at least 95% fertility among Eared Grebes, *Podiceps nigricollis* (Hanzak 1952), Horned Grebes, *P. auritus* (Fjeldsa 1973), Great Crested Grebes, *P. cristatus* (Harrison and Hollom 1932, Simmons 1974), and Red-necked Grebes (Wobus 1964).

Although a high degree of partial clutch abandonment during hatching has been observed among grebes (Hanzak 1952, Simmons 1955, Palmer 1962, Wobus 1964, Kevan 1970, Nuech-

TABLE 4. PCB and DDE residues (lipid weight basis) in Red-necked Grebe eggs from TMPP compared to residues noted in other studies.

| Study site | Year(s) | $n$ | $\bar{x}$ Residues (ppm) | |
|---|---|---|---|---|
| | | | PCB | DDE |
| Red-necked Grebe | | | | |
| Manitoba | 1981 | 12 | 194.8 | 74.3 |
| Alberta (Riske 1976) | 1971 | 46 | 42.4 | 21.4 |
| Wisconson (Faber and Hickey 1973) | 1970 | 3 | 744.6 | 646.8 |
| Alberta (Fyfe, in Riske 1976) | 1969 | 1 | — | 9.0 |
| Western Grebe | | | | |
| Utah (Lindvall and Low 1982) | 1973–1974 | 40 | 4.0 | 76.5 |
| Alberta (Riske 1976) | 1971 | 20 | 86.7 | 42.4 |
| California (Rudd and Herman 1972) | 1969 | 28 | — | 47.9 |
| Saskatchewan (Vermeer and Reynolds 1970) | 1968–1969 | 10 | — | 57.9 |
| Alberta (Vermeer and Reynolds 1970) | 1968–1969 | 10 | — | 87.2 |
| British Columbia (Fyfe, in Riske 1976) | 1968–1969 | 11 | — | 57.2 |
| California (Herman et al. 1969) | 1967 | 17 | — | 142.2 |
| Horned Grebe | | | | |
| Alberta (Riske 1976) | 1971 | 10 | 59.2 | 32.0 |
| Alberta (Fyfe, in Riske 1976) | 1969 | 4 | — | 53.0 |
| Saskatchewan (Vermeer and Reynolds 1970) | 1968–1969 | 10 | — | 88.4 |
| Eared Grebe | | | | |
| Alberta (Riske 1976) | 1971 | 20 | 6.5 | 13.2 |
| Alberta (Fyfe, in Riske 1976) | 1969 | 1 | — | 51.3 |
| Pied-billed Grebe | | | | |
| Wisconsin (Faber and Hickey 1973) | 1970 | 9 | 77.6 | 82.6 |

terlein 1975), this study is the first to link pesticide residues and egg inviabiity with this phenomenon. Even in instances where viable eggs were abandoned, inviability among previous eggs frequently contributed to their abandonment. McAllister (1963) noted that Red-necked Grebe embryos begin cheeping in the eggs 12 to 36 hr before hatching. This presumably prevents premature abandonment of viable eggs (Wobus 1964). If an inviable egg was the next egg scheduled to hatch, however, no cheeping would occur for 1 to 3 days. When this occurs the adults presumably abandon all remaining eggs to take care of previously hatched young. This phenomenon was observed on three occasions when pairs with two or three young abandoned their last two eggs. Upon examination, the penultimate egg was addled but the final egg was viable. Another pair with two young abandoned five eggs, the first two of which were addled.

Comparison of Ratcliffe Indices revealed that Red-necked Grebe eggs from TMPP were thin-shelled. The mean Ratcliffe Index from TMPP was significantly less than means of 1.84 for 112 eggs collected at various sites in North America before 1947 (Faber and Hickey 1973) and 1.86 for 186 eggs collected in central Alberta from 1971 to 1973 (Riske 1976) ($P < 0.001$). Only one other sample, seven eggs collected in Wisconsin and Ontario from 1946 to 1970 (Faber and Hickey 1973), had a similar Ratcliffe Index (1.68) to that recorded in TMPP. Cracked eggs and the high rate of egg disappearance in active clutches also implicated thin-shelled eggs and organochlorine residues as contributing to reduced reproductive success.

## ORGANOCHLORINE RESIDUES

A tendency towards lower levels of DDE and PCBs as the season progressed was observed for Red-necked Grebes in this study and by Riske (1976). This suggests that the major intake of organochlorines occurs on migration and in wintering areas, and that body burdens decline through the transfer of residues into the eggs. PCB:DDE ratios suggest that most Red-necked Grebes from TMPP winter along Atlantic coastlines, whereas Red-necked Grebes nesting in Al-

TABLE 5. Comparison of hatching and fledging success for Red-necked Grebes from TMPP compared to other sites.

| Study site | Years | $n$ | Hatching success[1] | Fledging success[2] Per successful pair | Fledging success[2] Per breeding pair |
|---|---|---|---|---|---|
| TMPP | 1980–1981 | 114 | 50.9 | 1.85 | 0.94 |
| Alberta potholes (Riske 1976) | 1970–1976 | 63 | 65.1 | 1.63 | 1.07 |
| Pine Lake, Alberta (Riske 1976) | 1971–1976 | 207 | 24.6 | 1.37 | 0.34 |
| Astotin Lake, Alberta (Kevan 1970) | 1969 | 89 | — | — | 1.14 |
| Germany (Wobus 1964) | 1962 | 20 | 53.6 | 1.96 | 1.05 |

[1] Percentage of pairs that were successful.
[2] Number of young fledged.

berta generally had PCB:DDE ratios characteristic of birds that winter along Pacific coastlines (Riske 1976).

DDE levels similar to those found in Red-necked Grebe eggs from TMPP have been reported in the eggs of several other grebe species, but PCB levels approaching those found during this study have rarely been noted (Table 4). The only exception was three Red-necked Grebe eggs from Wisconsin (Faber and Hickey 1973) that contained levels of PCB and DDE many times greater than those found in TMPP. DDE levels in Western Grebe (*Aechmophorus occidentalis*) eggs from California were almost twice those noted in TMPP and were deemed responsible for abnormally high rates of hatchling mortality (Herman et al. 1969). In another study where DDE levels similar to those recorded in TMPP may have contributed to reduced nesting success among Western Grebes, Lindvall and Low (1980) recorded 1.7 young per successful pair, which they incorrectly equated to Rudd and Herman's (1972) average of 1.7 young per breeding pair among normally reproducing populations.

Average PCB concentrations in Red-necked Grebe eggs from TMPP were 1.6 times the level that Dustman et al. (1971) suspected as contributing to reproductive problems. The high incidence of egg disappearance during incubation and hatching, cracked eggs, embryonic mortality, partial clutch abandonment during hatching and a reduction in eggshell thickness all attested to inhibition of reproduction by organochlorines. Other aspects of the breeding cycle, including courtship and nesting behavior, egg production and chick survival were not noticeably affected by organochlorines (De Smet 1983). Lengthy incubation periods among grebes in TMPP (De Smet 1983), however, may have resulted from behavioral changes brought on by pesticide burdens.

## REPRODUCTIVE SUCCESS

Nest depredation and the effects of organochlorine pollutants have rarely been identified as limiting factors among grebes. Nevertheless, these two factors contributed to at least three-quarters of the nesting losses incurred by Red-necked Grebes during this study. Nesting success was enhanced by a determined renesting effort and few losses due to waves or human recreational activities. Many studies have found wave-related losses to be prevalent among grebes (Munro 1941, Speirs et al. 1944, Hanzak 1952, Glover 1953, McAllister 1958, Chabreck 1963, Broekhuysen and Frost 1968, Burger 1974, Nuechterlein 1975, Riske 1976), yet waves accounted for only 2% of the losses in TMPP. Human recreational activities, a serious threat on large lakes (Riske 1976), were virtually nonexistent on the small to medium-sized nesting lakes in TMPP. Similar hatching success in regularly and infrequently observed clutches suggested that observer presence had little influence on reproductive success of Red-necked Grebes in TMPP.

Hatching and fledging success rates in TMPP were intermediate between those noted on Pine Lake, Alberta, and those recorded in other Red-necked Grebe studies (Table 5). The abnormally low hatching and fledging success of Red-necked Grebes on Pine Lake was attributed to a combination of human recreational activities, wave-related losses and organochlorines (Riske 1976). Hatching and fledging success in TMPP was less than those recorded on central Alberta potholes, at Astotin Lake, Alberta, or in Germany. Other sources noted even higher fledging rates among Red-necked Grebes from Eurasia; 1.6 young per breeding pair in Sweden (Ahlen 1970) and 2.8 young per successful pair in Russia (Markuze 1965, in Fjeldsa 1973).

A combination of factors are probably responsible for recent declines of the Red-necked Grebe in North America. Although organochlorine levels have declined since the 1970s (Fleming et al. 1983), Red-necked Grebes are still ingesting sufficient concentrations on their wintering range or during migration to inhibit reproductive success. Recent increases in the range of the raccoon (Lynch 1971, Cowan 1973), have exposed some Red-necked Grebe populations to a new, highly efficient wetland predator. Human recreational activities are an ever-increasing threat to grebe populations in larger lakes. When these factors are combined with natural depredation and wave-related losses, a decrease in reproductive success and population declines are inevitable.

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