Pond ecology and its influence on Mallard use in Ontario, Canada

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Introduction

Mallard *Anas platyrhynchos* production in Ontario is substantial. Collins (1974) reported a six-fold increase between 1951 and 1971 in the numbers of mallards in the province and Dennis (1974) estimated that southern Ontario supported 0·62 Mallard pairs/km^2. However, little has been published concerning their ecology. Of the few studies conducted in the province, Mallard were included with a number of other waterfowl species (Patterson 1976), or emphasis was on population status and harvest rates (Boyd 1974). The objective of this study was to relate selected physical and biological characteristics of ponds to the temporal and spatial distributions of breeding pairs, broods, post-breeding flocks, and autumn pre-migratory flocks of Mallard frequenting a 39-pond complex in southwestern Ontario.

Study area and methods

The study area consisted of a 10 km^2 block of farmland in Brant County (80° 17′ 12″ W, 43° 16′ 40″ N), 6·5 km south of Cambridge, Ontario, Canada. Agricultural lands supporting corn, wheat, oats, and barley were interspersed with pasture and tracts of deciduous forest (*Acer*, *Tilia*, *Quercus*). Situated in depressions in both agricultural and forested areas were ponds ranging from 0·04 to 3·8 ha.

The 1977 field season gathered baseline data on pond structure and the use of the 39 ponds by Mallard. These data were then used as a basis for choosing 15 representative ponds for intensive study during 1978; the remaining 24 ponds were examined in less detail.

The habitat preferences of Mallard pairs were examined during 20 April to 6 June 1977 and 15 April to 6 June 1978; those time intervals are hereafter referred to as Period I. Ponds used by Mallard broods and post-breeding (principally adult male) Mallard were examined from 7 June to 1 August 1977 and 1978 (Period II). Period III encompassed 2 August to 27 September 1977 and 2 August to 13 September 1978 when the area was being used by autumn pre-migratory Mallard. Of the 15 ponds examined intensively in 1978, 12 were chosen for study during each of Periods I and II. Nine of the 15 were studied from April through early August 1978. Three of the remaining 6 were included during Period I, the others during Period II.

Waterfowl counts from April through September of each year were conducted weekly between 0600 and 1200 hrs. Observations were made at 2–4 points along the perimeter of each pond using a pair of binoculars and a 25x spotting scope. We avoided flushing the birds to prevent them from alighting on other ponds, thus biasing the census. We recorded the number and sex of adult Mallard and the number of ducklings in broods classified by age according to the criteria of Gollop & Marshall (1954). Lone males, pairs, and males in groups of 5 or less were considered to represent pairs during Period I (Dzubin 1969). A duck use index (DU Index) modified after Joyner (1980) was used to quantify the number of ducks or pairs observed using a pond in relation to other ponds as well as to express consistency of pond use. The DU Index represented the mean number of Mallard or pairs per census on a pond as a proportion of that on all ponds X the percentage of all counts of a pond when Mallard were recorded.

Characteristics examined for all 39 ponds included pond circumference and surface area, which were determined using aerial photographs and planimetry, shoreline development (SLD), which is the relationship between pond surface area and circumference, and was calculated according to Wetzel (1975), water chemistry, and the abundance of aquatic invertebrates and plants.

Water samples (500 ml) were taken near the pond's surface on all 39 ponds near mid-day on 14–15 June, 26–27 July, and 8–9 September 1977, and on 17–18 May, 27–29 June, and 29–30 August 1978. The 3 intervals roughly corresponded to the pre-growth, peak growth, and post-growth

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periods of the aquatic macrophyte communities in most ponds as determined in 1977. Water samples were analysed for pH, specific conductance (μmhos/cm), total and phenolphthalein alkalinity (mg/l $CaCO_3$), and total hardness (mg/l $CaCO_3$) according to standard methods (APHA Standard Methods 1971).

To estimate plant frequency within the 12 intensive study ponds examined during each of Periods I and II, local percentage frequency (LPF) measurements (Greig-Smith 1964) were taken during 30 May to 2 June and 7 to 22 July 1978 for each species encountered in each pond. Plants were sampled at 1·5 m intervals along 6 to 7 randomly selected transects extending from the pond's edge to the centre, using a 0·25 m^2 quadrat divided into 25 0·01 m^2 sections. Quadrat sampling was terminated along a transect once water depths exceeded 60 cm or, in the case of shallow ponds, after 5 quadrats were completed. An accumulated mean frequency (AMF) value for the entire plant community within the 0 to 60 cm depth interval of each pond was estimated by adding the mean LPF values for all species encountered. Identification of plants followed Fassett (1957) and Ogden (1943).

In 1978, we estimated the number of potential offshore loafing sites (e.g., logs, stumps, islands) present on each of the 39 ponds. Each loafing site could support one or more ducks. In addition, the surface cover was subjectively rated as nil, sparse (pond surface open with some patches of cover), moderate (many patches of cover interspersed with some open areas), dense (surface occupied mainly with cover), and very dense (open areas absent).

Active aquatic invertebrates frequenting the water column (hereafter referred to as mobile invertebrates) were sampled over 24-hour periods at 2-week intervals on the 12 ponds examined during each of Periods I and II, 1978, using activity traps as described by Whitman (1974). To sample, 3 activity traps were placed at 3 randomly selected sites in water depths $\leqslant$43 cm in each pond. Trap contents were filtered through a U.S. Standard 20 sieve (sieve mesh = 850 μm), and the invertebrates extracted and preserved in 70% ethyl alcohol. In June and August 1977, benthic invertebrates were sampled from all 39 ponds using a brass sieve (sieve opening = 600 μm). In 1978, only the intensive study ponds were sampled for benthic invertebrates, 12 ponds on 7 May (Period I) and 12 on 5 July (Period II). In addition, 10 of the 12 intensive study ponds examined during Period II 1978 were sampled again for benthic invertebrates during Period III (23 August). Each substrate sample consisted of 3 sieve scoops for a total of 0·5 l of material, each scoop taken 1 to 2 m from the shoreline at the 3 sites previously selected for sampling with activity traps. All invertebrates were identified using Pennak (1953), Usinger (1956), Sawyer (1972), and Stewart & Loch (1973).

The mean width of the adult Mallard bottom feeding zone, defined as that portion of the pond's substrate which can be reached by an adult Mallard when tipping-up to feed (i.e., a pond depth $\leqslant$ 43 cm, Phillips 1923 in Perret 1962), was estimated for each of the 15 intensive study ponds from depth measurement taken during vegetation sampling.

Small sample sizes (ponds) precluded the use of a more sophisticated statistical approach; therefore, data were analysed using simple correlation, linear regression, and student's *t*-test (Sokal & Rohlf 1969). Invertebrate numbers were transformed using $\log x$ or $\log (x + 1)$ to correct for heteroscedasticity and non-normality (Sokal & Rohlf 1969:382, Elliott 1977:33).

Results

Physical, chemical and biological characteristics of ponds

The area and circumference of the 39 ponds ranged from 374 to 38,271 m^2 and from 76 to 1,032 m, respectively. Configuration varied from circular (SLD = 1) to long and narrow (SLD = 2·14). Six ponds contained no potential offshore loafing sites, the others had from 2 to 300. There was a positive ($r = 0{\cdot}51$, $P \leqslant 0{\cdot}001$) correlation between the number of offshore loafing sites on the 39 ponds and pond surface area. Pond surface cover included dead logs and stumps, dead and living shrub growth (mainly *Salix* sp. and *Cephalanthus occidentalis*), and emergent herbaceous vegetation.

For the intensive study ponds examined during Periods I and II, the mean width of the substrate feeding zone ranged from 1·5 m on 1 deep pond with a rapidly descending littoral zone, to feeding zones encompassing the entire pond basin (arbitrarily assigned values of 10·0 m).

Thirty-eight of the 39 ponds were classified in the medium to hardwater range

($\geq$60 mg/l $CaCO_3$, Thomas 1953), the exception having a total hardness value of 55–66 mg/l. The presence of carbonates in 10 ponds during 1977 and in 5 ponds in 1978 was indicated by high pH, from 9·1 to 10·5, when phenolphthalein alkalinity was detected. For the majority of ponds, pH ranged from 7·0 to 9·0. Bicarbonates predominated in the other ponds. In 1978, specific conductance among the 15 ponds varied from 115 to 450 μmhos/cm in Period I, 135 to 480 μmhos/cm in Period II, and from 139 to 610 μmhos/cm in Period III.

During 1977–78, 54 genera and/or species of 29 families of aquatic plants were collected within the 0 to 60 cm depth interval of the 39 ponds. The AMF for the 12 ponds examined during Period II 1978 ranged from 98·1 to 230·7, as compared to 42·0 to 219·9 for Period I. During both periods, *Lemna minor*, *Potamogeton foliosus*, *and Wolffia* spp. were most frequently encountered. Other common species encountered during both sampling periods included *Eleocharis* spp., *Spirodela polyrhiza, Chara vulgaris, P. pectinatus*, and *Najas flexilis.*

Seventy-four species and/or genera of 32 families of invertebrates were collected from the 39 ponds during 1977–78. The most abundant in activity traps were Hirudinea, Dytiscidae, Amphipoda, Hydracarina, Haliplidae, Pleidae, and Corixidae. Sieve samples were dominated by Talitridae, Chironomidae, Pelecypoda, Planorbidae, Gammaridae, Oligochaeta, Cladocera, and Heleidae.

The numbers of mobile invertebrates collected in activity traps from the 15 ponds varied during and between periods. Of the 12 ponds sampled during Period I 1978, 9 exhibited an initial peak in invertebrate abundance in the spring and a decline soon thereafter. In the other 3 ponds, numbers were lowest in the spring and increased throughout the period. The average ($\pm$ S.D.) number of mobile invertebrates captured per activity trap during Period I ranged from 13·3 $\pm$ 4·7 to 275·8 $\pm$ 339·5 with a period average of 75·5 $\pm$ 124·8. Eleven of the 12 ponds sampled during Period II exhibited a peak during mid- to late June. Average numbers varied from 5·4 $\pm$ 7·5 to 201·1 $\pm$ 203·1 with a period mean of 89·3 $\pm$ 111·0. The 4 ponds supporting the highest mean densities of mobile invertebrates during Period II ($\geq$ 118/sample) were also dominated by 1 or more of the following plants; *P. foliosus*, *P. pusillus*, *P. pectinatus*, and/or *N. flexilis*.

Mallard abundance and distribution

Based on waterfowl counts during Period I, the average density of Mallard pairs on the study area was 2·3/km^2 in 1977 and 2·0/km^2 in 1978. Mallard pairs were observed at least once on all but one of the 39 ponds. For the two seasons combined the mean number of Mallard pairs per pond ranged from 0 to 0·75. There was a significant ($P \leq 0{\cdot}01$) increase in the number of pairs as pond size increased (Table 1.) However, the mean number of Mallard pairs present per hectare of surface area decreased in a hyperbolic manner so that ponds less than 0·25 ha received the highest use per hectare. No other significant relationships were evident between selected environmental characteristics and pair use.

We estimated that 18 Mallard broods hatched on the study area in 1977 and 12 in 1978. Broods were observed at least once on 13 of the 39 ponds censused weekly. Of the 9 ponds having a surface area >1 ha, 5 were used by broods, whereas only 8 of the 30 smaller ponds were used. Differences in brood use based on pond size for all 39 ponds were significant ($P \leq 0{\cdot}05$). Three of the 4 ponds >1 ha in surface area and not used by broods were deep (2–3 m), lacked surface cover, and had no islands and few loafing sites. Brood use was highest on ponds having sparse or moderate surface cover densities. Only 1 of 12 ponds with no surface cover and 1 of 2 with very dense surface cover were used by broods.

Of the 12 intensive study ponds examined during Period II 1978, the number of brood sightings increased significantly as pond size, numbers of loafing sites, and the mean number of mobile invertebrates captured per activity trap increased (Table 1). A synchrony in the initial appearance of Mallard broods in June with peaks in numbers of invertebrates in 11 of the 12 ponds suggests that an abundant, high-protein food source was present in the ponds. Krull and Boyer (1976) noted a similar synchrony with benthic invertebrate abundance in New York wetlands.

Of the 4 ponds in which the number of benthic invertebrates collected per sieve sample was > 250 per sample, 3 were used by broods during censuses, whereas broods were observed on only 2 of the 8 ponds with lower numbers of benthic invertebrates. Most benthic invertebrates, however, were probably unavailable to Class I and perhaps Class II ducklings. Pond size may have confounded the relationships between brood distribution and invertebrate densities as 4 of the 5 ponds used by broods were >1 ha in surface area, whereas only 1 of the 7 unused ponds was that large. Surface cover may have further complicated these relationships.

The aquatic macrophyte communities of the 3 ponds receiving the most frequent brood use were each dominated by 2 of 3 taxa of duckweeds (Lemnaceae) and by *P. foliosus* or *N. flexilis*. Although the two ponds used most frequently by broods also had the highest AMF for all aquatic plant species, in general brood use and the AMF of aquatic plants were inversely related (Table 1).

Post-breeding Mallard aggregated on some ponds prior to the summer moult and apparently avoided others. DU Index II values ranged from 0 to 21·18 with only 13 of 39 ponds having values ≥0·20. For the 12 intensive study ponds examined during Period II, 1978, numbers of Mallard present increased ($P \leqslant 0{\cdot}01$) as the AMF of all aquatic plant species increased.

Post-breeding ducks were attracted to ponds with moderate, sparse, or no surface cover and avoided ponds with dense or very dense surface cover. Ponds having the widest bottom feeding zones were used most frequently by post-breeding Mallard during Period II, although this relationship was not always consistent. One pond was used frequently by Mallard in 1977, due in part, to an adjacent wheat field harvested on 18 July. Most post-breeding Mallard left the study area to moult. Evidence of flightless Mallard was recorded on only 2 ponds, both of which possessed moderate densities of pond surface cover.

Of the 30 ponds that retained water in August (Period III), 17 had DU Index III values >0·20. All 6 ponds >2·5 ha in surface area had DU Index III values >0·20, whereas only 11 of 24 ponds <2·5 ha in surface area received at least this amount of duck use. Of the ponds receiving the most extensive duck use during Period III, the fewest number of potential offshore loafing sites was 10 and the highest was 300. Ponds having no offshore loafing sites generally received little use by pre-migratory Mallard during Period III, whereas ponds with numerous loafing sites were readily used (Table 1). Five of 6 ponds with sparse surface cover and 6 of 11 ponds with nil surface cover had DU Index III values ≥0·20. Of the 6 ponds with moderate surface cover and 6 ponds with dense, 33% or 2 each had DU Index III values ≥0·20. In general, pre-migratory Mallard congregated on ponds close to harvested grain fields and flocks were often observed leaving these ponds and alighting in fields less than 200 m away.

Table 1. Simple correlation coefficients relating extent of duck use (duck use indices)[a] by adult Mallard and their broods to variables estimated for 15 ponds in Ontario, 1978.

	Use by adults during period[b]			Brood sightings during
Variable	I	II	III	Period II
Pond surface area (m^2)	0·66**	0·34	0·43	0·71**
Pond circum. (m)	0·62	0·30	0·38	0·69**
Shoreline development (SLD)[c]	0·16	−0·05	0·01	0·28
No. potential offshore loafing sites	0·22	0·46	0·58*	0·51*
Mean width feeding zone (m)[d]	0·48	0·40	0·17	0·34
Aquatic plants (AMF)[e]	−0·04	0·76**		−0·83**
Avg. no. mobile invertebrates per activity trap[f]	−0·30	0·35		0·61*

[a] Mean number of Mallards on a pond (all censuses) as a percentage of the mean for all ponds.
[b] Period I = 15 April–6 June, Period II = 7 June–1 August, Period III = 2 August–13 September 1978.
[c] An index to shoreline length/surface area.
[d] The width of the substrate feeding zone was measured to a pond depth of 43 cm.
[e] AMF (accumulated mean frequency) according to Greig-Smith (1964); measurements taken with a 0·25 m^2 quadrat divided into 25 0·01 m^2 sections.
[f] Activity traps described by Whitman (1974).
* $P \leqslant 0{\cdot}05$, ** $P \leqslant 0{\cdot}01$.

Discussion

Mallard pair densities on the study area were higher than the 0·62 pairs/km^2 reported for southern Ontario by Dennis (1974). Undoubtedly the large number of ponds served as a major attractant to breeding Mallard.

The mean number of pairs using a pond for Period I never exceeded 1 (range = 0 to 0·75). Comparable results have been reported for Manitoba (0·6–1·0 pairs per pond, Pospichal *et al.* 1954) and in Saskatchewan (0·09–0·93 pairs per pond, Stoudt 1964 in Dzubin 1969). Although the absolute number of pairs that used a pond through Period I increased slightly as pond size increased, as also reported by Patterson (1976) and Dzubin (1969), ponds less than 0·25 ha in surface area supported the highest overall densities of Mallard pairs per hectare. The even distribution of Mallard pairs on the study area suggests that intraspecific aggression may have been the principal mechanism regulating the numbers of Mallard pairs using the 39-pond complex (Dzubin 1969, Joyner 1980).

During Period I, breeding pair densities comparable to those reported in other regions as well as the even distribution of Mallard pairs on the study ponds suggest that the number of ponds on the study area was an important factor restricting the size of the breeding population of Mallard. The numbers of breeding waterfowl including Mallard, at Redvers, Saskatchewan, were directly dependent on the number of available wetlands (Stoudt 1971), although Pospahala *et al.* (1974) suggested that the number of breeding ducks in the prairie-parkland area may also be a function of the size of the continental breeding population and other habitat factors. The Brant County study area may support more breeding Mallard than were present in 1977 and 1978 since some tolerance to crowding has been recorded in this and other waterfowl species (Smith 1971). Although Dzubin (1969) suggested that crowded pairs of Mallard may have relatively low brood production, the arguments for density-dependent regulation of production remain speculative. Dzubin & Gollop (1972) felt that, overall, spacing mechanisms play only a minor role in regulating pair abundance and influencing continental production.

Undoubtedly, several factors simultaneously influenced habitat selection by the Mallard broods. They were attracted to the larger ponds (>1 ha) on which they may be less accessible to mammalian predators. Pond surface cover may have been as important to broods as was pond size. Berg (1956) suggested that pond size was more important to broods in Montana than emergent vegetation. However, the importance of escape cover to broods is illustrated by their use of only the largest ponds (at least 48 cm deep and greater than 2 ha in surface area) lacking emergent vegetation in South Dakota (Evans & Black 1956). Brood distribution in 1978 was associated with food abundance (aquatic macrophytes, invertebrates) but the relationships were unclear. Furthermore, on many of the ponds used by broods, much of the aquatic food sources was presumably inaccessible due to relatively deep pond basins. Thus, the abundance and availability of aquatic food may have been less important to Mallard broods on the Brant County study area than were pond size and the presence of surface escape cover. However, Mallard ducklings are highly adaptable in their foraging behaviour. Chura (1961) reported that 67 to 86% of the invertebrates consumed by Class I Mallard ducklings were of terrestrial origin. This food source would be largely independent of pond fertility.

In contrast to the behaviour of breeding pairs, post-breeding Mallard appeared free of intraspecific strife (Hochbaum 1944). As a result they formed flocks and used wetlands that provided abundant food and resting areas, especially those supporting dense stands of *P. foliosus*, *P. pectinatus*, *P. zosteriformis*, *P. natans*, and *N. flexilis*. Since few grain crops were harvested during Period II, Mallard probably obtained much of their food from the ponds.

However, there appeared to be no association between pond use by post-breeding Mallard and the densities of aquatic invertebrates. Although protein from invertebrates may be necessary for the production of new feathers by moulting birds, the protein obtained through the consumption of aquatic vegetation and seeds satisfies the nutritional demands of non-moulting adult Mallard, with the exception of laying females which require a high protein diet (Krull 1970). The data did show a positive relationship between pond use and the AMF of all plant species within ponds. Furthermore, post-breeding Mallard tended to select ponds with wide-bottom feeding zones.

Autumn pre-migratory birds, on the

other hand, were less selective of biologically productive ponds since waste grain apparently constituted a major portion of their diet. Many ponds were used then solely as resting areas. This is reflected by the high use during Period III of ponds possessing large numbers of potential loafing sites.

Hochbaum (1944), Sowls (1955), and Cowardin (1969) pointed out the importance of loafing sites for ducks during the spring. Mallard may have been attracted to 4 ponds due to the large number of loafing sites. However, despite the presence of a large number of loafing sites, 3 other ponds received little duck use during Period III, possibly due to the 100% coverage of the shoreline with woody vegetation. Other evidence also indicated that pre-migratory Mallard avoided ponds with wooded edges. Possibly, at that time of year, Mallard preferred ponds with loafing areas that allowed a good view of the surrounding land (Keith 1961).

The occasional use of ponds with wide-bottom feeding zones suggests that autumn pre-migratory birds remained somewhat dependent on wetlands for food. However, the majority of the Mallard on the study area in August and September appeared to obtain much of their food from nearby grain fields.

Habitat selection by birds is itself complex, being governed by instinctive and learned responses to stimuli from the environment, con-specifics, and other species. The seasonal changes in sociability within a waterfowl population further complicate the study of this phenomenon. For example, Mallard pairs appeared to select ponds that would result in minimized harassment by other pairs. Pond quality seemed to be of lesser importance. Also, the flocking of post-breeding and pre-migratory Mallard will affect the interpretation of waterfowl censuses. Birds may select a pond simply because other ducks were already present. Although waterfowl social behaviour is an important component of waterfowl ecology, it is difficult to quantify in relation to habitat selection.

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Summary

This study, conducted near Cambridge, Ontario, associated selected characteristics of ponds with pond use by Mallard *Anas platyrhynchos* from April through September 1977–78. Use by Mallard pairs was positively related to pond size; however, the spacing of pairs on ponds suggested that pond use was probably regulated by behavioural mechanisms. Mallard broods frequented ponds with some surface cover; abundance of food appeared less important. Post-breeding Mallard used ponds supporting an abundant and accessible variety of plant foods. Autumn pre-migratory Mallard used ponds with numerous loafing sites and close to grain fields.

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