BREEDING WATERFOWL, WETLANDS ACIDITY AND FOOD RESOURCES IN THE LEPREAU RIVER WATERSHED OF SOUTHERN NEW BRUNSWICK

G. R. Parker
M. Petrie
D. Sears

TECHNICAL REPORT SERIES No. 84
Atlantic Region 1989
Canadian Wildlife Service

Environment Canada | Environnement Canada
Canadian Wildlife Service | Service canadien de la faune

Canada

TECHNICAL REPORT SERIES
CANADIAN WILDLIFE SERVICE

These reports contain technical and scientific information from projects of the Canadian Wildlife Service. They are intended to make available material that either is of interest to a limited audience, or is too extensive to be accommodated in scientific journals or in existing CWS series.

Demand for these Technical Reports is usually confined to specialists in the fields concerned. Consequently they are produced regionally and in small quantities; they can be obtained only from the address given on the title page. However, they are numbered nationally. The recommended citation appears on the back of the title page.

Technical Reports are available in CWS libraries and are listed with the DOBIS system in major scientific libraries across Canada. They are printed in the official language of the author's choice.

SÉRIE DE RAPPORTS TECHNIQUES
DU SERVICE CANADIEN DE LA FAUNE

Ces rapports donnent des informations scientifiques et techniques sur les projets du Service canadien de la faune (SCF). Ils visent à promouvoir la diffusion d'études s'adressant à un public restreint ou trop volumineuses pour paraître dans une revue scientifique ou une des séries du SCF.

Ordinairement, les demandes pour ces rapports techniques ne proviennent que de spécialistes des sujets traités. Ils ne sont donc produits qu'à l'échelon régional et en quantités limitées; leur numérotage est cependant effectué à l'échelle nationale. Ils ne peuvent être obtenus qu'à l'adresse figurant à la page titre. La citation recommandée apparaît au verso de la page titre.

Ces rapports se trouvent dans les bibliothèques du SCF et figurent aussi dans les listes du système de référence DOBIS utilisé dans les principales bibliothèques scientifiques du Canada. Ils sont publiés dans la langue officielle du choix de l'auteur.

BREEDING WATERFOWL, WETLANDS ACIDITY AND FOOD RESOURCES IN THE LEPREAU RIVER WATERSHED OF SOUTHERN NEW BRUNSWICK

G. R. Parker[1]
M. Petrie[2]
D. Sears[3]

TECHNICAL REPORT SERIES NO. 84
Atlantic Region 1989
Canadian Wildlife Service

This series may be cited as:

Parker, G. R., M. Petrie and D. Sears. 1989. Breeding waterfowl, wetlands acidity and food resources in the Lepreau River watershed of southern New Brunswick. Technical Report Series No. 84. Canadian Wildlife Service, Atlantic Region.

[1]Canadian Wildlife Service, Box 1590, Sackville, N.B. EOA 3CO.
[2]582 Squires St., Fredericton, N.B. E3B 3V4.
[3]Box 1261, Sackville, N.B. EOA 3CO.

Issued under the Authority of the
Minister of Environment
Canadian Wildlife Service

Minister of Supply and Services Canada 1986
Catalogue no. CW 69-5/84E
ISBN 0-662-17389-9
ISSN 0831-6481

Copies may be obtained from:

Canadian Wildlife Service
Atlantic Region Headquarters
P.O. Box 1590
Sackville, N.B.   EOA 3CO

ABSTRACT. Species richness (n=6) and density (20 broods/100 km^2) of waterfowl breeding on wetlands in forested habitat in southern New Brunswick were considerably lower than on more productive and abundant wetlands in similar habitat in Ontario. The Black Duck (Anas rubripes) and Ring-necked Duck (Aythya collaris) represented 60-70% of total breeding waterfowl. The abundance of aquatic invertebrates most influenced use of wetlands by broods of dabbling ducks. Moderately acidified wetlands caused changes in species composition of the invertebrate fauna but not total biomass. The presence and abundance of fish as a direct competitor for macroinvertebrates significantly influenced wetland use by broods of insectivorous waterfowl. We did not identify water acidity as affecting directly the survival of insectivorous waterfowl broods or ducklings.

RÉSUMÉ. La diversité des espèces (n=6) et l'abondance (20 couvées par 100 km^2) des oiseaux aquatiques nichant dans les terres humides des habitats boisés du sud du Nouveau-Brunswick se sont avérées considérablement moindres que dans les terres humides plus productives et plus abondantes d'habitats semblables en Ontario. Les Canards noirs (Anas rubripes) et les Morillons à collier (Aythya collaris) représentaient 60 à 70 pour 100 du total des oiseaux aquatiques déterminait en majeure partie l'utilisation des terres humides par des couvées de canards de surface. Les terres humides modérément acides ont entraîné des changements dans la composition des espèces de la faune invertébrée mais non de l'ensemble de la biomasse. La présence et l'abondance de poissons comme concurrents directs des macro-invertébrés a influé dans une grande mesure sur l'utilisation des terres humides par des couvées d'oiseaux aquatiques insectivores. Nous n'avons pu déterminer si l'acidité de l'eau avait une incidence directe sur la survie des couvées d'oiseaux aquatiques insectivores ou des canetons.

TABLE OF CONTENTS

	Page
ABSTRACT	i
RESUME	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	iv
LIST OF FIGURES	vi
INTRODUCTION	1
STUDY AREA AND METHODS	2
RESULTS	3
1. Wetland Acidity and Sensitivity	3
2. Numbers of Breeding Pairs	4
3. Numbers of Broods	4
4. Waterfowl Distribution and Wetland Acidity	5
5. Waterfowl Distribution and Wetland Size	5
6. Duckling Survival	6
7. Water Acidity and Aquatic Invertebrates	7
8. Waterfowl Broods - Invertebrate Biomass	8
9. Fish Community Structure	8
10. Influence of Fish on Aquatic Invertebrates	9
11. Waterfowl Production and Aquatic Invertebrate Biomass	9
DISCUSSION	9
ACKNOWLEDGEMENTS	13
LITERATURE CITED	14

LIST OF TABLES

Table		Page
1.	Mean size, alkalinity and water color of 79 wetlands within 4 acidity classes on Lepreau study area	18
2.	The numbers and densities of waterfowl recorded on the Lepreau study area during helicopter surveys on May 6, 1986 and May 9, 1987 (1987 data in parentheses)	19
3.	The number of broods of waterfowl observed on the Lepreau study area in 1986 and 1987 and potential broods from May aerial surveys. Total broods include new broods recorded during mid-July aerial survey. Also shown are Chi-square values (excludes Green-winged Teal and Wood Duck as expected cells < 5) comparing breeding pairs counted during early May aerial survey (expected percentages) with observed brood production (percentages in parentheses)	20
4.	Estimated densities (numbers/100 km^2) of breeding pairs and broods of the 6 major species of waterfowl breeding in the Lepreau study area in 1986 and 1987 (1987 in parenthesis)......	21
5.	Distribution of waterfowl broods among wetlands of varying acidity (1986, 1987 observations combined)	22
6.	Observed and expected frequencies of waterfowl broods by wetland size classes on Lepreau study area in 1986 and 1987 ...	23
7.	Use of wetland size classes by breeding loons (1986 and 1987 combined)	24
8.	Distribution of brood sizes among age classes for the 4 most common species of waterfowl breeding in the Lepreau study area in 1986 and 1987	25
9.	Individual broods, exposure time, losses, and estimated survival rates for juvenile Black Ducks in the Lepreau study area May-July, 1986 (The Mayfield method (1975) for estimating nest success as applied to juvenile Black Duck survival in Maine by Ringelman and Longcore, 1982).............	26
10.	Individual broods, exposure time, losses, and estimated survival rates for juvenile Black Ducks in the Lepreau study area May-July, 1987 (The Mayfield method (1975) for estimating nest success as applied to juvenile Black Duck survival in Maine by Ringelman and Longcore, 1982)............	27

Table Page

11. Mean numbers and dried weights of common aquatic invertebrates for wetlands sampled within 4 acidity classes (numbers (wt. in mg)).. 28

12. Kruskal-Wallis H values for numbers and biomass (mg) for common invertebrate taxa within wetland acidity classes 29

13. The number and percentage of wetlands occupied by fish species for those wetlands sampled in the Lepreau study area, 1987..... 30

14. Mean size (ha) for wetlands with and without fish within water acidity classes (sample size in parenthesis)............ 31

15. Mean numbers of fish trapped on wetlands of variable levels of acidity... 32

16. Comparative mean dried weights (mg) of aquatic invertebrates from wetlands with and without fish 33

LIST OF FIGURES

Figure		Page
1.	Proportionate changes in numbers of invertebrates for common taxa on wetlands of different water acidity....................	34
2.	Proportionate changes in weights of invertebrates for common taxa on wetlands of different water acidity....................	35
3.	Relationship between brood abundance and aquatic invertebrate biomass	36
4.	Relationship between waterfowl production and aquatic invertebrate biomass on fishless lakes sampled on Lepreau study area..	37

INTRODUCTION

The importance of aquatic invertebrates in the spring diets of adult breeding waterfowl and young ducklings has been well documented (for a review see Swanson et al. 1979; Swanson and Meyer 1973). The physiological requirements for concentrated sources of dietary protein by laying females and rapidly growing young ducklings has been experimentally demonstrated (Krapu and Swanson 1975).

Most food studies on waterfowl relied upon food item identification in stomach and esophageal contents (Mendall 1949; Sugden 1969; 1973; Reinecke 1979; Swanson et al. 1979; Reinecke and Owen 1980), and assumed that breeding waterfowl were selecting for wetlands rich in invertebrates. Studies in Maine (Mendall 1949; Coulter 1955; Reinecke 1979; Reinecke and Owen 1980) confirmed the high dependency of laying female Black Ducks and young ducklings on aquatic invertebrates. In New Brunswick, Renouf (1972) documented preference by breeding Black Ducks for active beaver ponds but made no mention of food resource availability. Hughson (1971) identified aquatic invertebrates as one factor influencing the distribution of breeding Black Ducks in southwestern Nova Scotia.

Recently, studies of the impacts on the environment of acid rain have revealed intricate correlations between changing water chemistry and presence and abundance of aquatic invertebrates, fish and breeding waterfowl (Kelso et al. 1986; DesGranges and Darveau 1985; McNicol et al. 1987; and others). These studies have shown that water acidity affects fish populations adversely, and, at moderate acidity levels, reduced predation by fish allows increases in acid-tolerant invertebrates and consequent increases in insectivorous-omnivorous species of waterfowl. Only McNicol et al. (1987) studied actual distributions of naturally occurring pairs and broods of waterfowl and related those observations to relative environmental measurements. Other researchers have studied growth and behaviour of captive ducklings on experimentally acidified ponds (DesGranges and Rodrigue 1986; Haramis and Chu 1987) and selected ponds with specific characteristics (Hunter et al. 1986). DesGranges and Darveau (1985) correlated the distribution of breeding waterfowl with wetlands parameters, including water acidity from extensive aerial surveys in parts of Quebec.

No previous studies in Atlantic Canada had examined distributions of breeding waterfowl and broods relative to water acidity even though much of the region was identified as having been affected by, or as being highly sensitive to, the effects of acid rain (Hawkins and Spavold-Tims 1984; Kerekes et al. 1986). The mean monthly pH of precipitation in New Brunswick is in the range of 4.2-5.0 (Atmospheric Environment Service 1980; Environment New Brunswick 1982). Sergeant et al. (1981) found that 65% of the precipitation events in southwestern New Brunswick had pH between 4.0 and 5.0 and 26% between 3.0 and 4.0. Studies of terrestrial (Cowell et al. 1981; Shiltz 1981) and aquatic (Clair et al. 1982; Hawkins and Tims 1984) ecosystems identified portions of southwestern New Brunswick as among the most sensitive in the province to acidification.

The objectives of this study were to document the distribution and productivity of waterfowl in a region of the Maritimes geologically sensitive to the impact of acid rain and to measure the relationship that might exist between waterfowl populations, water acidity and aquatic invertebrate resources.

STUDY AREA AND METHODS

We chose the upper portions of the Lepreau and New River drainage basins ($\geq$ 10 km from the coast) in southwestern New Brunswick (referred to as the Lepreau study area) to study the distribution and densities of breeding waterfowl and broods. Clayton et al. (1977) placed the Lepreau area at the southern edge of the St. Croix Highlands physiographic region, part of the northern terminus of the Appalachian Mountain System. Most of the study area lies between 200 and 300 m, asl. Soils are variable-textured glacial drift, mostly sandy and stony loams to clay loams with humo-ferric podzol soil profile development. Rowe (1972) placed the forests of the study area within the Southern Upland Forest Section of the Acadian Forest Region. At the higher elevations and on well-drained slopes with deep soils tolerant hardwood species typified by sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*) and yellow birch (*Betula lutea*) predominate. At lower elevations those species are mixed with, and often replaced by, red maple (*A. rubrum*), white birch (*B. papyrifera*), balsam fir (*Abies balsamea*), red spruce (*Picea rubens*) and white pine (*Pinus strobus*). The climate of the region is influenced by the proximity of the Bay of Fundy, with mean summer and winter temperatures of approximately 15°C and -5°C, respectively. Precipitation is greatest in the autumn and winter and may reach 100-115 cm with frequent foggy conditions (Putnam 1940).

The Lepreau study area encompassed approximately 630 km^2. Recent forest harvesting operations have made most wetlands available by vehicle although to reach some sites required considerable effort by foot and/or canoe. In early May of 1986 and 1987 aerial surveys by helicopter established distributions of breeding waterfowl within the study area. All waterfowl were plotted to wetlands on topographic map sheets. From mid-May through mid-July of 1986 and 1987, two 2-man field crews surveyed all wetlands a minimum of 4 times. Ground surveys relied on several methods (eg. approach on foot and prolonged observation; canoe; walking shorelines) to observe adult waterfowl and broods upon different wetland types. Waterfowl were classified to species, sex and for broods number of ducklings and approximate ages based upon body size and feather development (Gollop and Marshall 1954).

Water samples from lakes, streams and ponds were collected in 1986 by helicopter; the same areas were resampled in 1987 from the ground. The sample was chosen to provide representation of wetlands of various size and type throughout the study area. In 1987 several new wetlands were sampled based upon waterfowl observations from the previous year (i.e. several small ponds of high waterfowl productivity not surveyed in 1986). Water samples were analysed by the Inland Waters Branch, Environment Canada, Moncton, New Brunswick. In 1987, using distribution of waterfowl broods from 1986, 34 wetlands were selected for sampling of aquatic invertebrates and fish. This subsample was stratified according to waterfowl use in 1986 i.e. 1) $\geq$ 2 broods (high use) 2) 1 brood (moderate use), 3) no broods (low use). Each of these wetlands was sampled 4 times for aquatic invertebrates from mid-May through mid-July. Each invertebrate sample represented a composite of 10 sweeps of a long-handled net (43 cm deep with 9 meshes per centimetre, on a D-frame with 625 cm^2 area, and a 122-cm handle) at each of 3 sites on the wetland. Sample sites were evenly distributed around the wetland periphery. Sample sites were $\leq$ 1 m deep and, when possible, supported floating or emergent macrophytes (not always possible on rocky oligotrophic lakes). Each sweep represented a figure-8 through the water column.

Sweep-net samples were sorted on the day of collection and invertebrates were stored in 70% ethyl alcohol. Invertebrates were later identified and sorted to family; the importance of invertebrate taxa in each sample was measured by numbers of individuals and dried weights. Samples were dried in a laboratory heating oven. Fish were sampled on wetlands by 3 cylindrical wire-mesh traps (6-mm wire mesh; 1.0 m x 0.30 m; 40-mm openings at each end) baited with dog biscuits and left for 48 h. The numbers and lengths of larger species were recorded and the specimens were released. Most minnows were frozen for later identification.

Duckling loss was calculated by the Mayfield method (Mayfield 1975). The standard error (SE) of Mayfield's survival rate estimator ($\underline{s}$), and subsequent 95% confidence limits of $\underline{s}$ are after Johnson (1979), an approach applied to juvenile Black Duck survival in Maine by Ringelman and Longcore (1982).

RESULTS

We observed waterfowl at least once on 149 wetlands within the Lepreau study area. Wetland, in the context of this study, refers to any distinguishable body of water and associated riparian habitat and might include distinct sections of rivers, bogs, beaver flowages, and lakes and ponds of all sizes. Wetlands ranged in size from 1 ha (small beaver ponds) to 900 ha (large oligotrophic lake) and averaged 23.8 ha.

Wetland Acidity and Sensitivity

We sampled 79 wetlands for pH and alkalinity. Wetlands were divided into 4 general acidity classes 1) circumneutral or slightly acidic - pH $\geq$ 6.0; 2) moderately acidic - pH $\geq$ 5.5 $\leq$ 5.9; 3) very acidic -pH $\geq$ 5.0 $\leq$ 5.4 and 4) highly acidic pH $\leq$ 4.9 (Table 1). Mean alkalinity measurements (in Ueq/l) for those four water acidity classes were 40.1, 17.8, 8.6 and -12.6, respectively. Only those wetlands with pH values above 6.0 can be considered slightly buffered (average alkalinity $\geq$ 40 Ueq/l). The highest alkalinity measured was 92 Ueq/l. Most wetlands with high pH values were large oligotrophic lakes. Most wetlands with low pH and low alkalinity values were small ponds, suggesting that much acidity was of organic origin. This was supported by water colour values. We rated the Lepreau study area as moderately to highly sensitive to acidification.

Numbers of Breeding Pairs

Seven species of waterfowl were observed on the Lepreau study area during aerial breeding pair surveys in 1986 and 1987 (Table 2). The count of Black Ducks in 1987 was significantly greater than in 1986 and of Ring-necked Ducks significantly less (Chi-square). However, the estimated breeding pairs for both species did not differ significantly between years. The total number and estimated pairs of Hooded Merganser (Lophodytes cucullatus) were significantly greater in 1987. In general, total numbers of waterfowl counted were very similar between years although estimated pairs were higher in 1987 (main species being the Black Duck, Ring-necked Duck, Common (Mergus merganser) and Hooded Mergansers and Green-winged Teal (Anas crecca). Fifty-eight and 48 Common Loons (Gavia immer) were counted in 1986 and 1987, respectively.

Numbers of broods

The numbers of waterfowl broods observed on the Lepreau study in 1986 and 1987 were remarkably consistent between years (Table 3). We compared the distribution of broods among species (observed) relative to the distribution of breeding pairs (expected) recorded on aerial surveys for 1986 and 1987. These analyses show that, although in 1986 the species distribution of broods was similar to that for breeding pairs, in 1987 the distribution was significantly different, a greater proportion of Black Ducks and a lower proportion of Ring-necked Ducks being the greatest contributors to the X^2 value of 11.04 (df = 3; $P < 0.02$).

We also compared the observed number of broods for each species to the expected, where expected = the number of breeding pairs. A significant difference between pairs and broods was found only for the Ring-necked Duck in 1987 ($X^2 = 8.8$; df = 1; $P < 0.005$). The Ring-necked Duck is a late breeder and, as ground searches were completed by mid-July, it is likely that total Ring-necked broods would have been higher both years if searches had continued later. The densities of waterfowl broods on the Lepreau study area were 19.2 and 18.7/100 km^2 in 1986 and 1987, respectively (Table 4). The most common species of breeding waterfowl in both years was the Black Duck followed by the Ring-necked Duck, Common Merganser, Hooded Merganser and Green-winged

Teal. Seventeen Common Loon nests or broods were observed in the study area in both years. Twelve of the 17 (70%) breeding sites in 1987 were on lakes where loons had bred in 1986. Potential breeding pairs of loons counted during helicopter surveys in May of 1986 and 1987 did not provide accurate estimates of subsequent observed nests and/or broods. Assuming singles and pairs of loons on individual wetlands in May each represented a breeding pair, estimates for subsequent breeding pairs were 36 and 27 in 1986 and 1987, respectively. Those numbers represent over-estimates of actual breeding pairs of 111% and 58% in 1986 and 1987, respectively.

Waterfowl Distributions and Wetland Acidity

We separated observed waterfowl broods into piscivores (Common Loon, Common Merganser) and insectivores/omnivores (Black Duck, Ring-necked Duck, Green-winged Teal, Wood Duck (*Aix sponsa*), Hooded Merganser). We examined the subsample of 79 wetlands sampled for water acidity and positioned broods for both trophic classes into one of the four wetland acidity classes (Table 5). We did not use the distribution of breeding pairs in spring due to probable movements among wetlands within specific breeding territories.

The insectivores/omnivores were more common than piscivores on wetlands in all four acidity classes. This was especially evident on wetlands of pH $\leq$5.5, an acidity level below which many fish populations begin to decline (Henricksen 1980; Kelso and Minns 1982; Schofield 1982). Brood density of both trophic classes was lowest on wetlands with pH 5.0-5.4 and piscivores were rare on all wetlands with pH <5.5.

We used proportions of wetlands in each acidity class to determine the expected representation of broods in those classes for both trophic groups. The distribution of piscivores among wetlands was highly significantly weighted towards wetlands with pH $\geq$5.5 (X^2 = 31.30; df = 3; P < 0.001) whereas the insectivores/omnivores showed no significant selection for wetlands of specific acidity (X^2 = 5.31; df = 3; P > 0.05).

Waterfowl Brood Distribution and Wetland Size

We examined the relationship between wetland size and frequency of waterfowl broods (Table 6). Black Duck and Hooded Merganser broods showed no selection to size of wetlands. Ring-necked Ducks selected for wetlands of intermediate and larger size whereas the Common Merganser was highly selective for wetlands > 10 ha. Most of the smaller-sized wetlands used by Common Merganser broods were on river systems.

We re-examined the distributions of Black Duck broods relative to brood age (smaller sample sizes did not allow similar treatment of data for the other species). We used only 2 age-classes (Class I : $\leq$ 18 d; Class II : > 19 d < 43 d; Gollop and Marshall 1954) in order to maintain suitable sample sizes (Class I: n = 80; Class II: n = 37). The observed distributions of broods of both age-classes among wetland size-classes did not differ significantly from the expected (Class I: $X^2 = 2.96$; Class II: $X^2 = 1.47$).

We also examined the use of wetlands by breeding loons (Table 7). Loons generally selected wetlands $\geq$ 20 ha in size for breeding. The two wetlands < 20 ha used for breeding in 1986 were not used again in 1987. The mean size of lakes used by loons breeding on the Lepreau study area (1986 and 1987 data combined) was 139.2 ha. However, the frequency of use showed 78% nested on lakes which averaged 52.5 ha (range = 20-100 ha).

Duckling survival

We measured comparative duckling survival for the four most common species of waterfowl on the Lepreau study area by calculating mean brood sizes for estimated age classes (Table 8). There were no measureable differences in brood size for most duckling age classes of Black Duck (a significant difference between Class 1a and 2a is attributed to sampling bias). There was a significant decline in the number of Ring-necked ducklings between brood age classes 1a and 1b but not between age classes 1b and 1c. The large variance for mean sizes of Common Merganser broods explains the lack of significant decline between classes 1a ($\bar{X} = 9.33$) and 1c ($\bar{X} = 6.83$). There were no significant differences in the number of Hooded Merganser ducklings among classes 1a to 1c. Age classes beyond 1c for both species of merganser were not tested due to small sample sizes. Among the 4 species of waterfowl, age-specific brood size differed only in the 1a class. Common Merganser 1a broods were larger than 1a classes for the other 3 species (this excluded a Common Merganser 1a brood of 23 which was obviously a merger of 2 broods). Ring-necked Duck 1a broods were larger than Hooded Merganser 1a broods but not Black Duck 1a broods.

We examined daily survival of ducklings for 16 and 15 broods of Black Ducks with multiple observations in 1986 and 1987, respectively (Table 9). Multiple observations of broods of other species were not sufficient for meaningful analyses. Between-year data sets were very comparable and the 2-year daily survival rate of 0.9835 is only slightly higher than the 4-year duckling survival rate of 0.9811 for Black Ducks in Maine (Ringelman and Longcore 1982). This overall daily rate of survival does not consider age-specific disparate rates of survival. The 2-year daily survival rate of 0.98 (composite age) can provide a general probability for individual duckling survival through time (0.98 x itself n times where n = number of days). Survival rates for 10, 20, 30 and 55 days were 0.83, 0.70, 0.59 and 0.39, respectively. This is, however based on an assumed stable mortality rate which is not likely to occur.

We combined the 2-year Black Duck data set and compared early duckling survival for broods from Ia to IIb (approximately 3-30 days old) with survival for broods from ages IIa through III (approximately 22-55 days old). The overlap of ages was necessary due to a scarcity of broods with multiple observations within brood age classes. Many broods were first seen and aged as Class Ia and next seen as Class IIc or Class III broods. These broods could not be used in age-specific survival rate calculations. The younger ducklings had a daily survival rate of 0.97 $\pm$ .01 (95% CI) with the probability of a duckling surviving the 27-day interval of 0.46. The older ducklings had a daily survival rate of 0.98 $\pm$ .01 (95% CI) with the probability of a duckling surviving the 28-day interval of 0.72.

The overall survival from Class I to III can be estimated as the product of the above two age-specific mortality rates. The overall estimate of 0.33 was less than the 55-day rate of 0.39 using a stable mortality rate for all ages and also less than the rate of 0.42 estimated for young Black Ducks in Maine. Both estimates from Lepreau, however, were similar to the relatively low survival rate of 0.34 estimated by Reed (1975) for juvenile Black Ducks in estuarine habitat in Quebec.

The mean Class III brood size at Lepreau of 4.06 in 1986 was appreciably less than the mean size of 5.00 in 1987. Both are less than the mean of 5.26 in Maine but similar to the figure of 5.00 often used in other Black Duck production estimates. However, the Class III brood size of 5.26 in Maine was a 4-year mean, individual annual values being 6.0, 5.5, 4.3 and 3.8 illustrating the potential variability of annual age-specific Black Duck brood sizes.

Water Acidity and Aquatic Invertebrates

Thirty-four wetlands (pH 4.5 - 6.5) were also sampled for aquatic invertebrates. We compared numbers and mean dried weights of aquatic invertebrates for wetlands within the 4 acidity classes (Table 10). There was a significant positive correlation between increasing total invertebrate mass (dried wt.) and increasing wetland acidity (Spearman's $r_s = 1.00$). However, there was considerable variation in changes of numbers and mass among invertebrate taxa. The taxa Amphipoda, Ephemoptera and Pelecypoda declined significantly in numbers and mass with increasing acidity, especially in wetlands with pH $\leq$ 5.0. Taxa such as Hemiptera and Trichoptera showed moderate declines while others, notably Odonata, increased in abundance with increased water acidity.

Invertebrates of the taxa Odonata and Hemiptera comprised approximately 80% of the invertebrate mass (dried wt in mg) on wetlands of all acidity classes. On more acidic wetlands, odonates became more important to total invertebrate numbers and mass (Figures 1 and 2), and that taxon alone represented over 70% of the available biomass on wetlands of pH <5.0. Such taxa as Amphipoda, Ephemoptera and Diptera contributed little to biomass on acidified wetlands and the pelecypods became absent. On acidified wetlands odonates were the single most abundant taxon and contributed most to the available biomass.

We examined invertebrate abundance and biomass for significant correlations. A Kruskal-Wallis H Test was applied to invertebrate abundance data to see if numbers and weights by taxa were influenced by water acidity. We again used the 4 wetland acidity classes and ranked abundance and weights of each invertebrate taxon collected from wetlands within each class (Table 11). Only Amphipoda showed significant dependence upon wetland acidity for numbers and weight (decrease with acidity).

Waterfowl Broods - Invertebrate Availability

We used linear regression to examine data from 17 ponds and small lakes (1.5-13.6 ha; $\bar{x}$ = 4.7 ha) for correlation between brood production of insectivores/omnivores and aquatic invertebrate biomass (dried wt. in mg). The correlation was not strong (r = 0.60) but suggested a positive relationship (Figure 3). Wetlands supporting the greatest abundance of invertebrates and most broods contained no fish (fish not captured during bait trapping or sweep-netting for invertebrates).

Fish Community Structure

Fish were absent from 11 of the 35 (31.4%) wetlands sampled. The most widely distributed species were the Golden Shiner (Notemigonus crysoleucas), Northern Redbelly Dace (Chrosomus eos), Brown Bullhead (Ictalurus nebulosus), and White Sucker (Catostomus commersoni) (Table 12). The least common species detected were the Yellow Perch (Perca flavescens) and Common Shiner (Notropis cornutus).

We examined distribution of fish among wetlands relative to wetland size (Table 13). Fishless lakes were significantly smaller than lakes with fish and all were under 10 ha in size. This corroborates similar studies in Ontario (Minns 1981; McNicol et al 1987) where most fishless lakes represented head-water wetlands susceptible to acidification. These data also confirmed that water pH generally declined with decreasing wetland size, suggesting that many of the acidified wetlands involved organic acidification. Smaller ponds may also be susceptible to oxygen limitations or freezing in winter which can influence fish distribution and abundance. There appeared to be little influence of water acidity on fish species distribution and abundance where pH levels $\geq$ 5.5 (Table 14). No fish were in the small sample of wetlands with pH < 5.0.

Influence of Fish on Aquatic Invertebrates

We compared total biomass of aquatic inverterbates between wetlands with and without fish (Table 15). The mean weights for wetlands without fish were greater for all acidity classes (significantly so for several). The overall mean weight of aquatic invertebrates from fishless lakes was significantly greater than the mean weight from wetlands with fish. Fish depress aquatic invertebrate biomass on wetlands with pH values $\geq$ 5.0, below which fish normally become absent. These data support the theory that fish represent serious competitors of insectivorous and omnivorous waterfowl for the aquatic invertebrate food base in northern freshwater wetlands.

Waterfowl Production and Aquatic Invertebrate Biomass

We have shown that invertebrate biomass was greater on wetlands without fish. We examined waterfowl brood data for 1986 and 1987 (2 years data summed) for the same data set (excluding piscivores), summed total ducklings for first observations only (many broods were resighted during subsequent ground surveys) and excluded the 3 lakes > 100 ha to minimize influence of wetland size. The percentage occurrence of ducklings on wetlands with fish was 0.58 compared to 0.88 for wetlands without fish. The mean number of ducklings on wetlands with fish was 5.6 compared to 15.4 for wetlands without fish. The difference between number of ducklings on wetlands with and without fish was significant ($t = 2.43$; df = 21; $P < 0.02$).

To avoid the variable influences of fish populations upon invertebrate populations, we examined the direct relationship of invertebrate availability (biomass) and duckling production for fishless lakes only (Figure 4). This limited data set suggests that a significant positive relationship exists between duckling production and available invertebrate food base.

DISCUSSION

The wet sulphate deposition level for New Brunswick has been estimated at > 30 mmol $SO_4 \cdot m^{-2}$ (Kelso et al. 1986). This level is equalled in eastern Canada only by that measured in parts of southern Quebec. Although calcite saturation indices (a measure of wetland vulnerability to acidification) suggest that lakes in New Brunswick are generally less susceptible to acidification than lakes in other Atlantic Provinces, a mean pH of 5.6 for lakes sampled in New Brunswick was the second lowest of provincial samples in eastern Canada (Kelso et al. 1986). Most lakes of pH $\leq$ 5.5 in the composite sample from New Brunswick were located in the southwestern portion of the province. Forty-three percent of the wetlands that we sampled in the Lepreau study area had pH values < 5.5 and 77% < 6.0.

The 2-year mean densities for breeding pairs (21.6/100 km^2) and broods (20.0/100 km^2) of waterfowl were considerably lower than densities in selected areas of central and northern Ontario (Dennis and North 1984; Ross 1987). However, whereas Ross (1987) reported up to 11 species of waterfowl breeding on his study blocks (100 x 100 km) in Ontario, we found only 6 species at Lepreau, 2 of which (Black Duck and Ring-necked Duck) together comprised 73% and 63% of estimated breeding pairs in 1986 and 1987, respectively. In Ontario those 2 species comprised from 35-59% of total breeding pairs (Ross 1987) and averaged 45%. At Lepreau the number of breeding species was low; we did not record broods of species such as the Mallard (A. platyrhynchos), Blue-winged Teal (A. discors) or Common Goldeneye (Bucephala clangula) - all fairly common breeding species on plots surveyed in Ontario.

At Lepreau the 2-year average densities for breeding pairs of Black Duck and Ring-necked Duck were 9.83/100 km^2 and 4.75/100 km^2, respectively. Respective average densities on survey blocks in Ontario were 16.4 and 19.9 (Ross 1987). However, at Lepreau the density of wetlands was considerably lower than on most survey blocks in Ontario. The 2-yr mean indicated pairs of waterfowl per wetland at Lepreau was 0.80. On 5 survey blocks in Ontario the mean number of indicated pairs/wetland was 1.03 (range: 0.69-1.40). The apparent low densities of breeding waterfowl at Lepreau compared to central Ontario was the product of low species diversity and relative paucity of potential breeding habitat (i.e. available wetlands).

On a 151 km^2 study area in central Maine, the density of breeding pairs of Black Duck has varied from 12.5/100 km^2 (1977) to 25.0/100 km^2 (1987) (Diefenbach 1987), again suggesting that breeding densities of Black Ducks at Lepreau should be considered moderate to low. As much of New Brunswick supports lower densities of wetlands than at Lepreau, densities of breeding waterfowl recorded during this study should be considered higher than the provincial average, on an area basis.

Our study represents the first in eastern Canada where spring helicopter surveys to count breeding pairs of waterfowl on wetlands in forested habitat were subsequently followed by intensive ground surveys to count waterfowl broods. We found good agreement between counts of pairs and broods in both years, especially for early nesting species such as the Black Duck. Although we suggest that spring helicopter surveys can provide accurate estimates of "potential" waterfowl production for a given unit of wetland habitat, we caution that aerial surveys must be flown under rigidly followed conditions.

Spring breeding pair surveys must be conducted within a fairly narrow framework of time which, for the Black Duck in most of New Brunswick, falls within the last week of April and the first 10 days of May. This "survey window" of 2-3 weeks represents that period of Black Duck breeding chronology when maximum counts of breeding pairs will be obtained, i.e. after passage of migrants but prior to departure from territories by most males (males begin to leave established territories approximately 7-10 days after the female initiates incubation (Seymour 1984)). The "survey window" was calculated by backdating from estimated ages of Black Duck broods seen during ground surveys in 1986 and 1987.

The affinity of piscivores for wetlands of pH $\geq$ 5.5 was not unexpected. The requirement of piscivores for fish and the documented declines in fish populations on wetlands of pH < 5.5 represent obvious reasons for that correlation. However, the attraction of both species of piscivores (i.e. Common Loon and Common Merganser) to larger water bodies for breeding habitat and the tendency for the larger ponds and lakes at Lepreau to have higher pH values also influences measured wetland selection, i.e. the correlation may not be solely dependent upon water acidity, at least not at the present time (i.e. increased wetland acidity, and consequent impact upon fish populations, would ultimately tighten the correlation between acidity and use of wetlands by piscivores).

Duckling survival, and mean brood sizes of Black Ducks at Lepreau, were comparable to other studies of that species in Maine (Ringelman and Longcore 1982) and Quebec (Reed 1975). We do not think that wetland acidity is presently affecting breeding success (broods/breeding pairs) or duckling and brood survival. The requirement of breeding female dabblers and young ducklings for a diet rich in protein has been well documented (Street 1977; Collias and Collias 1963; Moyle 1961; Sugden 1973; Swanson et al. 1979; and others). Experimental studies with imprinted and/or impounded Black Duck ducklings on acidified wetlands (DesGranges and Rodrigue 1986; Haramis and Chu 1987) have correlated suppressed body growth and development and increased mortality with increases in water acidity. Those studies also measured increased duckling activity with increased water acidity and concluded that that was a result of reduced aquatic invertebrate availability. DesGranges and Rodrigue (1986) however, found that increased water acidity and moderate to high fish populations were required before ducklings showed demonstrable reductions in growth and survival.

A study in Maine (Hunter et al. 1986), again using imprinted Black Duck ducklings on selected paired wetlands of varying acidity, demonstrated that the presence of fish, not necessarily water acidity, influenced invertebrate abundance and subsequent duckling growth and survival. Again in Maine, Rattner et al. (1987), using the same 0.2 ha ponds constructed by Haramis and Chu (1987), confirmed the conclusions of those researchers that, under controlled experimentation on fishless enclosures, acidification can adversely affect growth and physiological condition of Black Duck ducklings. Rattner et al. (1987) noted that growth of ducklings in their experiments was poorer than that reported for free-ranging Black Ducks in Maine (Reinecke 1979), but concluded that acidification may be adversely affecting the productivity of free-ranging duck populations, particularly those occupying fish-free palustrine habitats. We suggest as demonstrated by McNicol et al. (1987), Eriksson

(1979), Eriksson et al. (1980) and others that, due to the interspecific competition for the same aquatic invertebrate food base by fish and dabbling ducks, suppression of duckling growth and survival is more pronounced on wetlands with fish than on wetlands without fish, especially on wetlands of marginal productivity and moderate levels of acidity. Although the results of Hunter et al. (1986) appeared to conflict with those of DesGranges and Rodrigue (1986), both agreed those differences probably resulted from disparate rates of regional wetlands productivity i.e. the threshold of invertebrate abundance at which fish competition becomes important was probably reached on the circumneutral lakes in Maine but not in Quebec (DesGranges and Rodrigue (1986)).

Our study at Lepreau showed that, although species diversity of aquatic invertebrates may be adversely affected by water acidity, total biomass appeared unaffected, at least in wetlands of pH $\geq$ 5.0 (i.e. acid tolerant species increase in the absence of acid-intolerant species and in the absence of fish). Large aquatic invertebrate predators (eg. Belostomatidae, Dytiscidae) increase in the absence of fish. We did not study the relative availability (accessibility) of acid-tolerant vs. intolerant invertebrates, a factor of potential significance when evaluating these very complicated relationships.

At Lepreau, we suggest that the abundance and availability of aquatic invertebrates were the most important factors influencing use of wetlands by Black Duck broods. As invertebrate abundance is a function of wetland productivity (nutrient release and inflow) and diversity and abundance of predatory fish, we suggest that attempts to evaluate the capability of wetlands to support insectivorous waterfowl from morphometric measurements alone are misdirected.

Recent beaver flowages have long been recognized as prime Black Duck brood-rearing habitat. Periodic flooding and drainage of a wetland (which is what beaver activity represents) stimulates immediate nutrient release and increases in aquatic invertebrates, often preceding increases in numbers of fish. Those early years of a beaver flowage provide maximum benefits to breeding waterfowl, i.e. stable water levels, readily available cover and an abundant food supply of protein-rich aquatic invertebrates.

Aside from beaver flowages, Black Duck broods at Lepreau were recorded on wetlands of almost any description, from large oligotrophic lakes to small acidic sphagnum ponds. Our limited sampling suggested, especially on wetlands with minimal water exchange, that the presence and absence of fish, and their effect on populations of aquatic invertebrates, represented the single most important factor influencing the presence or absence of Black Duck broods (also other insectivorous species such as the Hooded Merganser and Ring-necked Duck). On river systems where food sources are regularly replenished, and on larger lakes where brood mobility is largely unrestricted, the correlation between brood and invertebrate biomass may be less clear. Black Ducks often nest in areas far removed from invertebrate-rich-brood rearing sites. Travel down small feeder streams by young broods to a wetland abundant in invertbrates often results in several broods using a common wetland of 1-2 ha in size.

Although it has been demonstrated that increased water acidity can ultimately adversely affect production of insectivorous waterfowl, we do not believe that that situation presently exists at Lepreau. Most larger oligotrophic lakes had acidity levels of pH $\geq$ 6.0, and the lower pH values on smaller wetlands were most likely of organic origin (in contrast to anthropogenic origin). Densities of breeding waterfowl at Lepreau were believed depressed due to generally low densities of wetlands, a nutrient-poor substrate and low densities of active beaver flowages. We recognize the potential for increased wetland acidification at Lepreau but, in the near to intermediate term, do not see that as a threat to reduce further the production of insectivorous waterfowl.

ACKNOWLEDGEMENTS

We thank P. Trimper, J. Maxwell and S. Makepeace for assistance during ground waterfowl surveys. Maritime Helicopters, Fredericton, provided flawless service during aerial breeding pair and brood surveys.

LITERATURE CITED

Atmospheric Environment Service. 1980. Cansap data summary (1977 to 1980 inclusive). Environment Canada. Downsview, Ontario.

Clair, T. A., J. P. Witteman and S. H. Whillow. 1982. Acid precipitation sensitivity of Canada's Atlantic Provinces. Technical Bulletin No. 124. Inland Waters Directorate. Environment Canada. Working Paper No. 10.

Clayton, J. S., W. A. Ehrich, D. B. Cann, J. H. Day and I. B. Marshall. 1977. Soils of Canada. I. Canada Dept. of Agriculture, Ottawa.

Collias, N. E. and E. C. Collias. 1963. Selective feeding by wild ducklings of different species. Wilson Bull. 75: 6-14.

Coulter, M. W. 1955. Spring food habits of surface-feeding ducks in Maine. J. Wildl. Manage. 19: 263-267.

Cowell, D. W., A. E. Lucas and C. D. A. Rubec. 1981. The development of an ecological sensitivity rating for acid precipitation impact assessments. Lands Directorate, Environment Canada. Working Paper No. 10.

Dennis, D. G. and N. R. North. 1984. Waterfowl densities in northwestern Ontario during the 1979 breeding season. pp. 6-9 in Waterfowl studies in Ontario, 1973-81. S. G. Curtis, D. G. Dennis and H. Boyd, eds. CWS Occasional Paper No. 54. 71 pp.

DesGranges, J.-L. and M. Darveau. 1985. Effect of lake acidity and morphometry on the distribution of aquatic birds in southern Quebec. Holarctic Ecology 8: 181-190.

DesGranges, J.-L. and J. Rodrigue. 1986. Influence of acidity and competition with fish on the development of ducklings in Quebec. Water Air Soil Pollut. 30: 743-750.

Diefenbach, D. R. 1987. Changes in the population of breeding black ducks and wetland habitats in south-central Maine. Maine Cooperative Fish and Wildlife Research Unit - Report to Cooperators. U. of Me. Orono, pp. 40-43.

Environment New Brunswick. 1982. New Brunswick precipitation monitoring network data summary for 1980-82. Environmental Services Branch, Fredericton.

Eriksson, M. O. G. 1979. Competition between freshwater fish and Goldeneyes (Bucephala clangula) for common prey. Oecologia 41: 99-107.

Eriksson, M. O. G., L. Hendrikson, B. L. Nilsson, G. Nyman, H. G. Oscarson, A. E. Stenson, and K. Larsson. 1980. Predator-prey relations important for the biotic changes in acidified lakes. Ambio 9:248-249.

Gollop, J. B. and W. H. Marshall. 1954. A guide for aging duck broods in the field. Miss. Flyway Tech. Sect. Leafl. 14 pp.

Haramis, G. M. and D. S. Chu. 1987. Acid rain effects on waterfowl: use of Black Duck broods to assess food resources of experimentally acidified wetlands. ICBP Technical Publication No. 6. 173-181.

Hawkins, G. R. and A. J. Spavold - Tims. 1984. The sensitivity of New Brunswick ecosystems to acidification. Environment New Brunswick, Environmental Services Branch, Fredericton. Technical Report No. T-8401. 41 pp.

Henriksen, A. 1980. Acidification of freshwater - a large scale titration pp 68-74 in Proc. Int. Conf. Ecological Impact of Acid Precipitation. D. Drablos and A. Tollan, eds. Acid-Rain-Forest and Fish Project, Aas, Norway.

Hughson, W. B. 1971. Habitat preferences of breeding Black Ducks (Anas rubripes) in Nova Scotia. M.Sc. Thesis. Acadia U., Wolfville. 114 pp.

Hunter, M. L., J. J. Jones, K. E. Gibbs and J. R. Morning. 1986. Duckling responses to lake acidification: do black ducks and fish compete? Oikos 47: 26-32.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96: 651-661.

Kelso, J. R. M. and C. K. Minns. 1982. Current status of lake acidification and its effect on the fishery resources of Canada. Pg. 69-81 in Proc. Int. Symp. on Acidic Precipitation and Fishery Impact in Northeastern North America. Aug. 2-5, 1981. R.E. Johnson, ed. Cornell U., Ithaca, N.Y.

Kelso, J. R. M., G. K. Minns, J. E. Gray and M. L. Jones. 1986. Acidification of surface waters in Eastern Canada and its relationship to aquatic biota. Can. Spec. Publ. Fish Aquat. Sci. 87: 42 pp.

Kerekes, J., S. Beauchamp, R. Tordon and T. Pollock. 1986. Sources of sulphate and acidity in wetlands and lakes in Nova Scotia. Water Air Soil Pollut. 31: 207-214.

Krapu, G. L. and G. A. Swanson. 1975. Some nutritional aspects of reproduction in prairie nesting pintails. J. Wild. Manage. 39: 156-162.

Mayfield, H. 1975. Suggestions for calculating nesting success. Wilson Bull. 73: 255-261.

Mendall, H. L. 1949. Food habits in relation to black duck management in Maine. J. Wildl. Manage. 13: 64-101.

McNicol, D. K., B. E. Bendell and R. K. Ross. 1987. Studies of the effects of acidification on aquatic wildlife in Canada: waterfowl and trophic relationship in small lakes in northern Ontario. CWS Occas. Paper No. 62. 46 pp.

Minns, C. K. 1981. Acid rain: a preliminary estimate of the risk to Ontario's inland fisheries. Can. Ms. Rep. Fish. Aquat. Sci. No. 1622.

Moyle, J. B. 1961. Aquatic invertebrates as related to larger plants and waterfowl. Minnesota Dept. Conser. Invest. Rept. No. 233.

Putnam, D. F. 1940. The climate of the Maritime Provinces. Can. Geog. J. 21: 134-147.

Rattner, B. A., G. M. Haramis, D. S. Chu and C. M. Bunck. 1987. Growth and physiological condition of black ducks reared on acidified wetlands. Can. J. Zool. 65: 2953-2958.

Reed, A. 1975. Reproductive output of black ducks in the St. Lawrence estuary. J. Wildl. Manage. 39: 243-255.

Reinecke, K. J. 1979. Feeding ecology and development of juvenile Black Ducks in Maine. Auk 96: 737-745.

Reinecke, K. J. and R. B. Owen, Jr. 1980. Food uses and nutrition of black ducks nesting in Maine. J. Wildl. Manage. 44: 549-558.

Renouf, R. N. 1972. Waterfowl utilization of beaver ponds in New Brunswick. J. Wildl. Manage. 36: 740-744.

Ringelman, J. K. and J. R. Longcore. 1982. Survival of juvenile black ducks during brood rearing. J. Wildl. Manage. 46: 622-628.

Ross, R. K. 1987. Interim report on waterfowl breeding pair surveys in northern Ontario. 1980-83. CWS Progress Note No. 168. 9 pp.

Rowe, J. S. 1972. Forest regions of Canada. Canadian Forestry Service. Dept. Environment, Publ. No. 1300. 172 pp.

Shiltz, W. W. 1981. Sensitivity of bedrock to acid precipitation: modification by glacial processes. Paper 81-14. Geological Survey of Canada. Ottawa.

Schofield, C. L. 1982. Historical fisheries changes in the United States related to decreases in surface water pH. pp 57-67 in Proc. Int. Symp. on Acidic Precipitation and Fishery Impact in Northeastern North America. Aug. 2-5, 1981. R.E. Johnson, ed. Cornell University, Ithaca, N.Y.

Sergeant, D. B., V. Zitko and L. E. Burridge. 1981. Sampling analysis, and data evaluation of precipitation at St. Andrews, New Brunswick, Canada, 1978-80. Can Tech. Rep. Fish Aquat. Sci. 1023. 26 pp.

Seymour, N. R. 1984. Activity of Black Ducks nesting along streams in northeastern Nova Scotia. Wildfowl 35: 143-150.

Street, M. 1977. The food of Mallard ducklings in a wet gravel quarry, and its relation to duckling survival. Wildfowl 28: 113-125.

Sugden, L. G. 1969. Foods, food selection, and energy requirements of wild ducklings in southern Alberta. Ph.D. Thesis. Utah State Univ. 171 pp.

__________. 1973. Feeding ecology of pintail, gadwall, American widgeon and lesser scaup ducklings in southern Alberta. C.W.S. Rep. Ser. 24. 45 pp.

Swanson, G. A., and M. I. Meyer. 1973. The role of invertebrates in the ecology of Anatidae during the breeding season. pp. 143-184 in The Waterfowl Habitat Management Symposium, Moncton, N.B.

Swanson, G. A., G. L. Krapu, and J. R. Serie. 1979. Foods of laying dabbling ducks on breeding grounds. pp. 47-54 in: Waterfowl and wetlands - an integrated review. T. A. Bookhout (ed.). Proc. Symp. North Central Section of the Wildlife Society. LaCrosse Printing Co., La Crosse, Wisconsin.

Table 1. Mean size, alkalinity and water color of 79 wetlands within 4 acidity classes on Lepreau study area.

Water acidity class (pH)	No of wetlands	$\bar{X}$ alkalinity (Ueq/l)	$\bar{x}$ water colour (Rel. units)	$\bar{X}$ Size (ha)
$\geq$ 6.0	18	40.1 $\pm$ 19.2	15.5 $\pm$ 14.2	100.2 $\pm$ 216.4
5.5 - 5.9	27	17.8 $\pm$ 7.6	14.0 $\pm$ 21.8	45.5 $\pm$ 51.3
5.0 - 5.4	23	8.6 $\pm$ 5.8	31.9 $\pm$ 28.7	7.5 $\pm$ 5.9
$\leq$ 4.9	11	-12.6 $\pm$ 16.5	66.0 $\pm$ 33.4	3.4 $\pm$ 2.6

Table 2. The numbers and densities of waterfowl recorded on the Lepreau study area during helicopter surveys on May 6, 1986, and May 9, 1987 (1987 data in parentheses).

	Waterfowl Species							
	Black Duck	Ring-necked Duck	Common Merganser	Hooded Merganser	Green-winged Teal	Wood Duck	Common Goldeneye	Totals
Numbers:								
Total	119 (153)[3]	171 (117)[3]	58 (60)	15 (39)[3]	14 (7)	2 (0)	4 (1)	383 (377)
Density[1]	18.8(24.3)	27.1(18.6)	9.2(9.5)	2.3(6.2)	2.2(1.1)	0.3(0)	0.6(0.1)	60.8(59.8)
Estimated pairs[2]:								
Total	52 (66)	27 (30)	18 (30)	9 (21)[3]	1 (5)	1 (0)	0 (1)	108 (152)[3]
Density	8.2(10.5)	4.2(4.8)	2.8(4.8)	1.4(3.3)	0.1(0.8)	0.1(0)	0.0(0.1)	17.1(24.3)

[1] density = number/100 km^2

[2] estimated pair = groups of 1 and 2 only

[3] between-year difference significant ($\underline{X}^2 > 3.84$; $\underline{P} < 0.05$)

Table 3. The number of broods of waterfowl observed on the Lepreau study area in 1986 and 1987 and potential broods from May aerial surveys. Total broods include new broods recorded during mid-July aerial brood survey. Also shown are Chi-square values (excludes Green-winged Teal and Wood Ducks as expected cells < 5) comparing breeding pairs counted during early May aerial survey (expected percentages) with observed brood production (percentages in parentheses).

		Waterfowl Species							
		Black Duck	Ring-necked Duck	Common Merganser	Hooded Merganser	Green-winged Teal	Wood Duck	Totals	
Pairs seen in May	1986	52(48.2)	27(25.0)	18(16.7)	9(8.3)	1(0.9)	1(0.9)	108	
(expected broods)	1987	66(43.4)	30(19.7)	30(19.7)	21(13.9)	5(3.3)	- -	152	
Broods seen in May-July	1986	64(53.2)	24(18.9)	21(18.0)	8(6.3)	4(2.7)	2(0.9)	123	
(observed broods)	1987	65(55.1)	11(9.3)	19(16.1)	14(11.9)	4(3.4)	5(4.2)	118	
X^2 values	1986	1.14	1.68	0.05	0.40	expected cells	< 5	3.27	$P > 0.05$
	1987	3.84	6.26	0.69	0.25			11.04	$P < 0.02$

Table 4. Estimated densities (numbers/100 km^2) of breeding pairs and broods of the 6 major species of waterfowl breeding in the Lepreau study area in 1986 and 1987 (1987 in parenthesis).

Density (no/100 km^2)	Waterfowl species						
	Black Duck	Ring-necked Duck	Common Merganser	Hooded Merganser	Green-winged Teal	Wood Duck	Total Waterfowl
Breeding pairs[1.]	8.2 (10.4)	4.2 (4.7)	2.8 (4.7)	1.4 (3.3)	0.1 (0.8)	0.1 (-)	17.1 (24.1)
Broods[2.]	10.1 (10.3)	3.4 (1.7)	3.3 (3.0)	1.2 (2.2)	0.6 (0.6)	0.3 (0.8)	19.2 (18.7)

[1.] from May helicopter survey

[2.] from May-July ground surveys + July helicopter brood surveys

Table 5. Distribution of waterfowl broods among wetlands of varying acidity (1986, 1987 observations combined).

Wetland acidity (pH)	No. of Wetlands (n)	Piscivores			Insectivores/Omnivores		
		Frequency of occurrence	No. of Broods[1]	Broods/ Wetland	Frequency of occurrence	No. of Broods[2]	Broods/ Wetland
≥6.0	17	0.41	17	1.00	0.47	31	1.82
5.5–5.9	28	0.50	34	1.21	0.57	39	1.39
5.0–5.4	23	0.04	2	0.08	0.43	21	0.91
4.5–4.9	11	0.09	1	0.09	0.63	17	1.54
Totals	79	0.29	54	0.68	0.51	108	1.36

1. $\chi^2 = 31.30$; $p < 0.001$

2. $\chi^2 = 5.31$; $p > 0.05$

Table 6. Observed and expected frequencies of waterfowl broods by wetlands size classes on Lepreau study area in 1986 and 1987.

Waterfowl Species		Wetland size classes (ha) ≤2	>2 ≤5	>5≤10	>10	Total Broods	X^2
Black Duck	o	14	35	25	43	117	0.67
	e	16.9	35.4	24.2	40.5		
RN Duck	o	0	5	11	17	33	12.55**
	e	4.8	10.0	6.8	11.4		
H. Merganser	o	3	8	5	6	22	0.59
	e	3.2	6.7	4.6	7.5		
C. Merganser	o	3	3	5	25	36	20.20**
	e	5.2	10.9	7.5	12.4		

** p <0.01

Table 7. Use of wetland size classes by breeding loons (1986 and 1987 combined)

		Wetland size class (ha)					
		>10 <20	20–50	51–100	≥101	*n*	X^2
Available wetlands	no.	19	19	8	4	50	
	%	38.0	38.0	16.0	8.0		
Breeding loons	o	2	15	11	5	33	
	e	12.54	12.54	5.28	2.64		17.62*

*$p<0.005$

Table 8. Distribution of brood sizes among age classes for the 4 most common species of waterfowl breeding in the Lepreau study area in 1986 and 1987.

		Age Class						
		1a	1b	1c	2a	2b	2c	III
Black Duck	n	24	33	21	19	11	9	6
	$\bar{x}$	5.91[a,1]	5.63	5.28	3.31[a]	5.54	5.11	4.50
	s	2.60	2.10	3.03	1.85	2.29	1.90	2.07
Ring-necked Duck	n	18	12	3				
	$\bar{x}$	7.22[a,2,3]	4.91[a]	5.33				
	s	2.53	1.67	1.52				
Common Merganser	n	12	14	6	2	2	2	
	$\bar{x}$	9.33[1,2,4]	7.28	6.83	9.00	3.50	4.00	
	s	2.87	4.06	3.43	2.82	0.70	2.82	
Hooded Merganser	n	7	4	6	3	1	1	
	$\bar{x}$	5.00[3,4]	5.50	4.50	5.66	5.00	7.00	
	s	1.06	2.38	2.42	1.52			

[a] intraspecific means with similar letters significantly different (*t* - test; $P<0.05$).

[1] interspecific means with similar numerals significantly different (*t* - test; $P<0.05$).

Table 9a. Individual broods, exposure time, losses and estimated survival rates for juvenile Black Ducks in the Lepreau study area, May-July, 1986 (The Mayfield method (1975) for estimating nest success as applied to juvenile Black Duck survival in Maine by Ringelman and Longcore 1982).

Brood	No. of sightings	Average time between sightings (days)	Total exposure (duckling days)	Total losses	Daily survival rates(s) ± 95% C.I.[1]
1	4	15.6	216.0	6	.9722 ± .0223
2	5	12.0	311.0	3	.9903 ± .0110
3	2	44.0	308.0	6	.9805 ± .0156
4	3	15.0	88.0	4	.9545 ± .0442
5	2	43.0	78.0	0	1.0000
6	2	32.0	144.0	1	.9930 ± .0138
7	2	30.0	135.0	1	.9926 ± .0146
8	2	23.0	129.0	5	.9612 ± .0339
9	2	32.0	144.0	3	.9791 ± .0237
10	3	10.0	85.0	6	.9294 ± .0555
11	2	20.0	100.0	0	1.0000
12	2	17.0	95.0	3	.9684 ± .0358
13	2	13.0	71.5	1	.9860 ± .0277
14	2	15.0	67.5	3	.9555 ± .0501
15	2	14.0	70.0	2	.9714 ± .0397
16	2	12.0	48.0	0	1.0000
Totals	39	19.1	2090	44	.9789 ± .0062

1. after Johnson 1979

Table 9b. Individual broods, exposure time, losses and estimated survival rates for juvenile Black Ducks in the Lepreau study area, May-July, 1987 (The Mayfield method (1975) for estimating nest success as applied to juvenile Black Duck survival in Maine by Ringelman and Longcore 1982).

Brood	No. of sightings	Average time between sightings (days)	Total exposure (duckling days)	Total losses	Daily survival rates(s) ± 95% C.I.[1]
1	2	42	231	3	.9870 ± .0148
2	2	45	407	4	.9901 ± .0097
3	3	22	174	6	.9655 ± .0276
4	2	19	57	0	1.0000
5	2	34	238	0	1.0000
6	3	16	138	5	.9637 ± .0318
7	4	14	99	2	.9797 ± .0282
8	3	15	245	2	.9918 ± .0114
9	2	30	150	2	.9866 ± .0187
10	3	15	253	1	.9960 ± .0078
11	2	27	189	3	.9841 ± .0181
12	2	19	133	0	1.0000
13	2	15	75	0	1.0000
14	2	13	104	2	.9807 ± .0269
15	2	12	48	2	.9583 ± .0576
Totals	36	22.5	2541	32	.9874 ± .0022

1. after Johnson 1979

Table 10. Mean numbers and dried weights of common aquatic invertebrates for wetlands sampled within 4 acidity classes (numbers (wt. in mg.)).

Wetland acidity class	(n)	Amphipoda	Ephemeroptera	Odonata	Hemiptera	Coleoptera	Trichoptera	Diptera	Acarina	Pelecypoda	Totals
		Common invertebrate taxa									
≥6.0	7	50.7	43.4	71.2	135.8	13.5	25.1	44.0	15.8	7.4	406.9
		(12.4)	(46.7)	(639.3)	(281.7)	(27.1)	(76.4)	(22.7)	(11.3)	(19.1)	(1136.7)
5.5-5.9	12	74.1	23.9	56.2	41.5	6.6	31.5	41.2	23.9	2.9	301.8
		(21.9)	(54.4)	(627.8)	(103.4)	(68.5)	(84.4)	(14.4)	(14.6)	(23.6)	(1013.0)
5.0-5.4	11	47.7	8.7	76.3	48.3	22.4	33.1	41.0	30.4	2.3	310.2
		(15.8)	(18.2)	(1125.4)	(157.1)	(205.1)	(68.5)	(20.7)	(15.0)	(9.9)	(1635.7)
4.5-4.9	4	1.7	3.5	120.5	65.5	24.0	23.0	54.7	24.7	-	317.6
		(0.4)	(9.4)	(1484.0)	(341.2)	(172.0)	(59.5)	(12.9)	(11.3)		(2090.7)

Table 11. Kruskal-Wallis H values for numbers and biomass (mg) for common invertebrate taxa within wetland acidity classes.

Invertebrate Taxa	H values	
	Numbers	Biomass
Odonata	1.89	2.48
Trichoptera	0.80	2.73
Diptera	1.74	0.19
Hemiptera	1.88	3.53
Ephemeroptera	5.27	2.63
Amphipoda	8.14*	7.87*

*$p < 0.05$

Table 12. The number and percentage of wetlands occupied by fish species for those wetlands sampled in the Lepreau study area, 1987.

Fish species		Fish occurrence (n = 35)	
Common name	Scientific name	No.	%
1. Eastern brook trout	Salvelinus fontinalis	5	14.2
2. Brown bullhead	Ictalurus nebulosus	9	25.7
3. White sucker	Catostomus commersoni	8	22.8
4. Yellow perch	Perca flavescens	1	2.8
5. Golden shiner	Notemigonus crysoleucas	12	34.2
6. Common shiner	Notropis cornutus	1	2.8
7. Northern red-belly dace	Chrosomus eos	10	28.5
8. Creek chub	Semotilus atromaculatus	4	11.4
9. Banded killifish	Fundulus diaphanus	2	5.7
10. Ninespine stickleback	Pungitius pungitius	4	11.4
11. American eel	Anguilla rostrata	2	5.7
Fish absent		11	31.4
Fish present		24	68.6

Table 13. Mean size (ha) for wetlands with and without fish within water acidity classes (sample size in parenthesis).

	Water acidity				
	pH ≥ 6.0	pH 5.5-5.9	pH 5.0-5.4	pH 4.5-4.9	Totals
Fish present	182.5 (8)	54.6 (10)	7.0 (6)	-	85.3 (24)
Fish absent	3.2 (2)	5.6 (3)	3.3 (3)	5.7 (3)	4.6 (11)
Total	146.6 (10)	43.2 (13)	5.8 (9)	5.7 (3)	59.9 (35)

Table 14. Mean numbers of fish trapped on wetlands of variable levels of acidity.

Fish species	Water acidity pH ≥ 6.0 (n = 10)	pH 5.5-5.9 (n = 13)	pH 5.0-5.4 (n = 9)	pH 4.5-4.9 (n = 3)
1. Specked trout	0.20	0.07	0.55	
2. Brown bullhead	2.50	12.38	0.33	
3. White sucker	6.40	0.69		
4. Yellow perch	2.40			
5. Golden shiner	2.90	38.61	0.33	
6. Common shiner		2.61		
7. Northern Redbelly	23.70	2.38	0.55	
8. Creek chub	3.20	0.07		
9. Banded killifish	4.90			
10. Ninespine stickleback		0.07	6.33	
11. American eel		0.15		
Totals	46.20	57.03	8.09	0.00
% occurrence fish	0.80	0.77	0.67	0.00

Table 15. Comparative mean dried weights (mg) of aquatic invertebrates from wetlands with and without fish.

	Wetland acidity					
	pH ≥ 6.0[1]	pH 5.5-5.9	pH 5.0-5.4[1]	pH 4.5-4.9	pH ?	Totals[1]
Fish present	720 ± 370 (4)	745 ± 447 (7)	1244 ± 950 (6)		1329 ± 332 (3)	977 ± 640 (20)
Fish absent	2589 ± 343 (2)	2319 ± 1295 (3)	3177 ± 1190 (3)	962[2] ± 759 (3)	3020 ± 2222 (5)	2828 ± 1514 (13)

[1] mean wt. of aquatic invertebrates significantly greater ($p \leq 0.05$) in fishless wetlands (Student's "t" test).

[2] not included in total mean wts. as acidity levels apparently affecting invertebrate abundance.

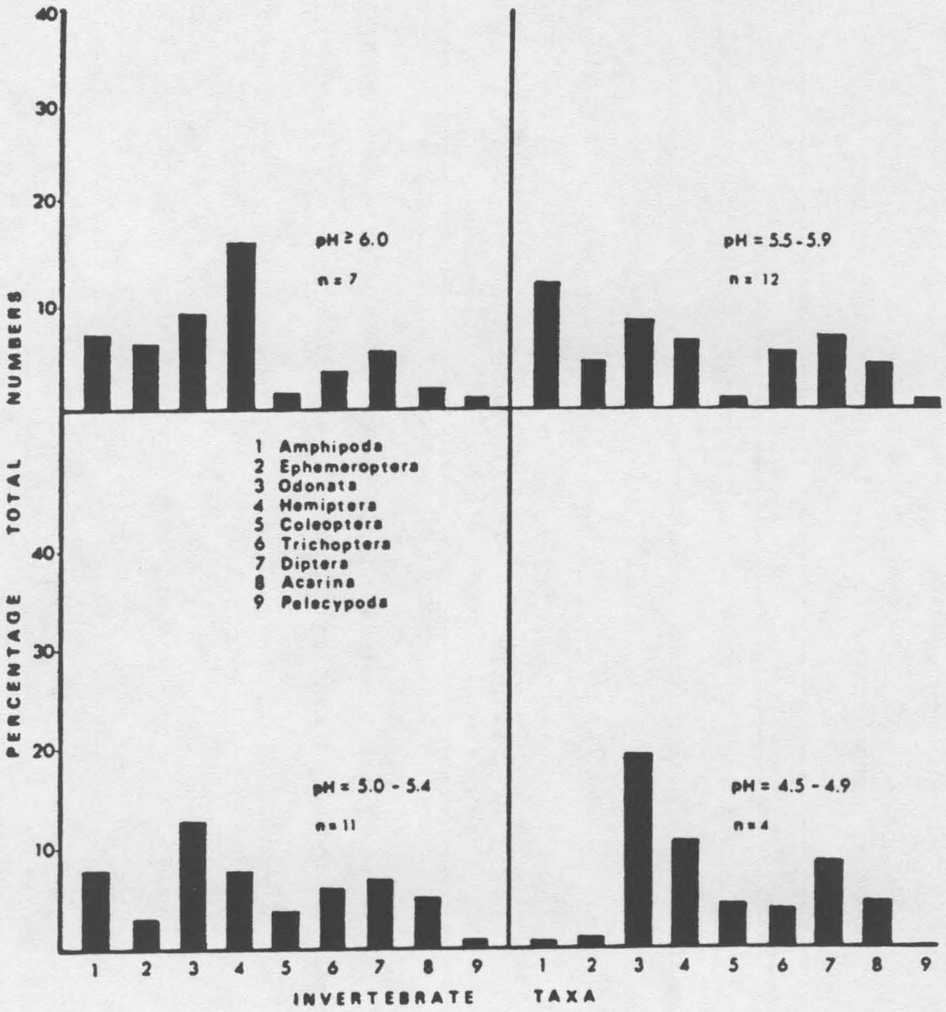

Figure 1. Proportionate changes in numbers of invertebrates for common taxa on wetlands of different water acidity.

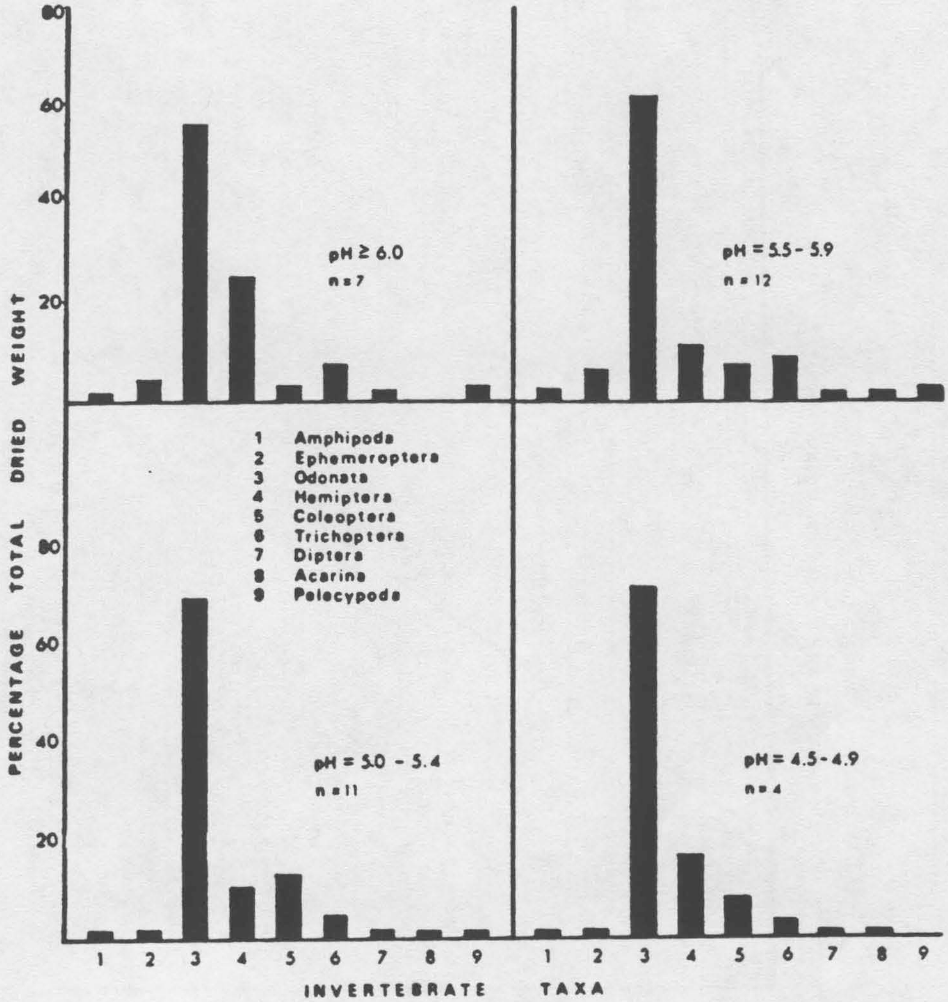

Figure 2. Proportionate changes in weights of invertebrates for common taxa on wetlands of different water acidity.

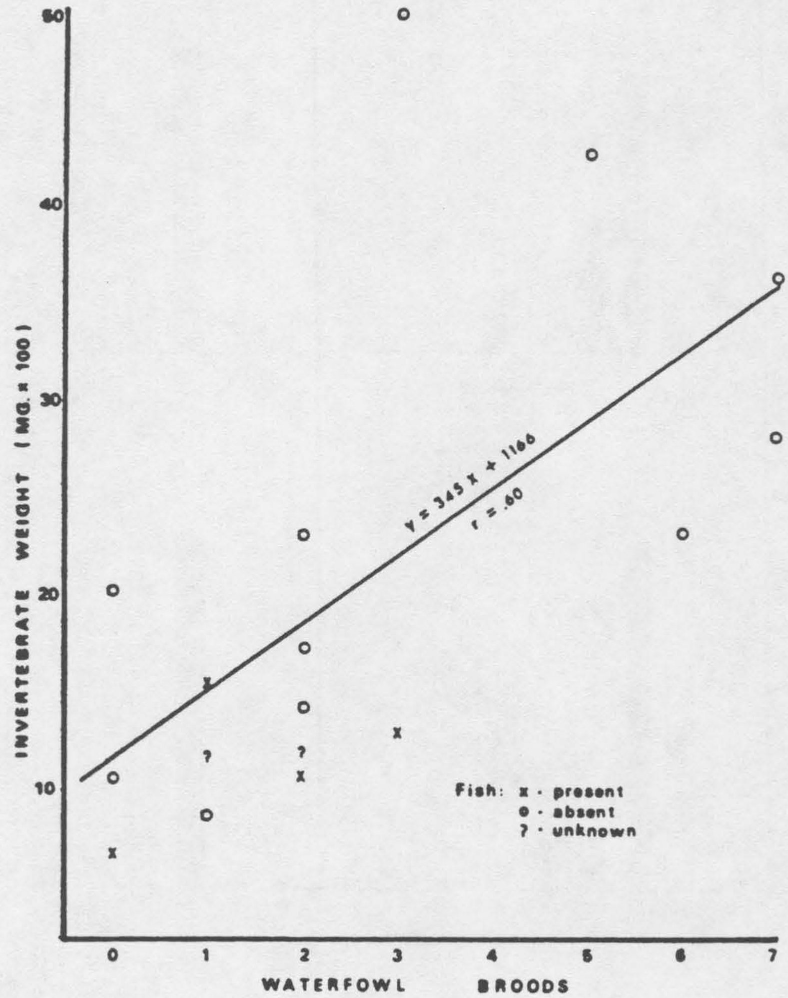

Figure 3. Relationship between brood abundance and aquatic invertebrate biomass.

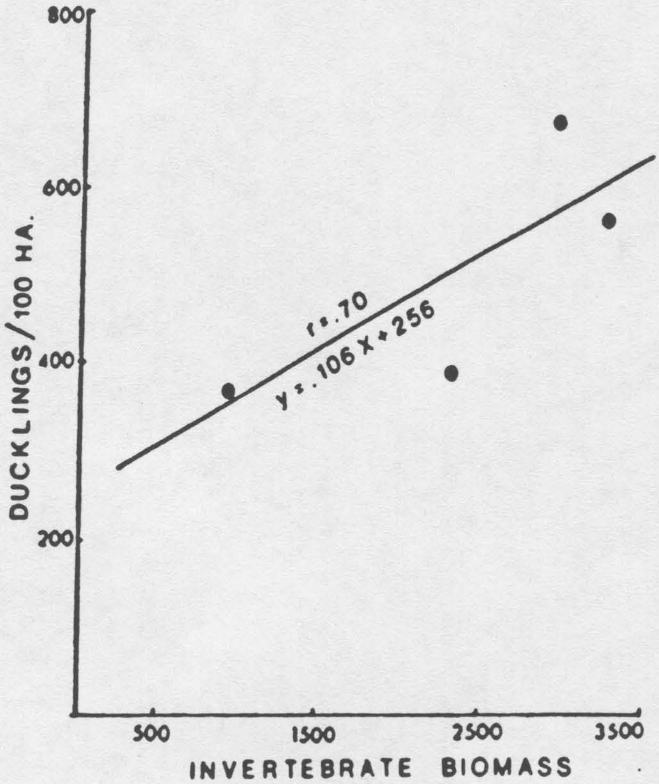

Figure 4. Relationship between waterfowl production and aquatic invertebrate biomass on fishless lakes sampled on Lepreau study area.