ASPECTS OF THE NESTING ECOLOGY OF THE EASTERN BLUEBIRD (*Sialia sialis*) IN SOUTHWESTERN QUEBEC

by

© BIRGIT C. SCHULTZ

A thesis submitted to the Faculty of Graduate Studies and
Research of McGill University in partial fulfilment of
the requirements for the degree of Master of Science

Department of Renewable Resources
Macdonald College of McGill University
Montreal, Quebec

August 1987

ISBN 0-315-44407-X

ABSTRACT

Aspects of the nesting ecology of the Eastern Bluebird (Sialia sialis) were studied during 1984 and 1985. An analysis of egg measurements revealed that clutch size is significantly correlated with egg length ($p < 0.001$), width ($p < 0.01$) and weight ($p < 0.001$). Egg size decreased as clutch size decreased. Hatching success and egg width were significantly correlated in 1984, with wider eggs being more likely to hatch. This relationship did not exist in 1985. Eggs in 1984 were significantly ($p < 0.001$) wider than eggs in 1985, but egg lengths were the same in both years Egg sizes for the study area were similar to those recorded in the literature.

Linear measurements and weights of nestlings were compared for those surviving to fledging and those dying during the nesting period. There were no significant differences in tarsal, antebrachial, bill or longest primary lengths and nestling weights at the ages of 0 and 4 days, but by 11 days of age survivors had significantly higher measurements than non-survivors. Growth rates for all birds were calculated using Ricklefs' (1967) method. Survivors had significantly higher growth rates than non-survivors Mean growth rate for 1984 did not differ significantly from 1985. There was no significant difference in growth rates for different brood sizes. Growth rates for the Eastern Bluebird in the study area were similar to those recorded in the literature.

RESUME

L'écologie de la nidification du Merle Bleu (Sialia sialis) a été étudié au cours des étés 1984 et 1985. Des analyses de variance ont montré une association significative entre la taille de la couvée et la longueur de l'oeuf ($p < 0.001$), la largeur de l'oeuf ($p < 0.01$) et le poids de l'oeuf ($p < 0.001$). La taille des oeufs a diminué avec une diminution de la taille de la couvée. En 1984, une relation significative a toutefois été établie entre la largeur de l'oeuf et le succès d'éclosion. Les oeufs les plus larges ont eu un plus haut succès d'éclosion. Cette relation n'a pas été trouvée en 1985. Les oeufs étaient significativement ($p < 0.001$) plus larges en 1984 qu'en 1985, mais il n'y avait aucune différence entre les longueurs. Les dimensions des oeufs recueillis au site étudié sont semblables aux valeurs présentées dans la littérature.

Les mesures linéaires et les poids ont éte comparés entre les oisillons qui ont survécu jusqu'à leur premier envol et ceux qui sont morts au nid. Aucune différence significative n'a été trouvée entre ces deux groupes lorsque les oisillons sont agés de 0 ou de 4 jours. Toutefois, lorsque ceux-ci atteignent 11 jours, les oisillons qui ont survécu étaient significativement plus grands. Les courbes de croissance ont été calculées à partir de la formule de Ricklefs (1967). Les oisillons qui ont survécu avaient un taux de croissance significativement plus élevé que les autres. Par contre, les taux de croissance n'étaient pas différents entre 1984 et 1985 et ne variaient pas en fonction de

la taille de la couvée. Au site étudié, les taux de croissance du Merle Bleu sont similaires à ceux suggérés dans la littérature.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

This study would not have been possible without the generous support and cooperation of the Province of Quebec Society for the Protection of Birds, Inc. Ethel Fogarty and Barbara MacDuff provided information about the location of the boxes and the former supplied valuable information about the Bluebird Trail in past years.

My advisor, Dr. Rodger D. Titman, deserves thanks for accepting a "non-duck" student and for always being available to help and advise. It was he who suggested I develop a project around the Eastern Bluebird.

I often bothered David T. Brown and Dave Shutler for help with computers and statistics. A special thanks goes to Dave S. for listening to all my complaints about the confusing world of numbers. Rémi Gauthier and André Lavigne also provided statistical insights. Mrs. Jane Smith gave me a great deal of help with the computer My field assistant, Wendy Benjamin, made the second summer of my field work easier. Greg Weil and Steve Tinker supplied me with the necessary equipment to carry out the study. Yves Garant kindly volunteered to translate the abstract. I am grateful to all these people.

Literature Review

General Life History

The Eastern Bluebird (Sialia sialis) of the thrush family Turdidae is native to North America, breeding in every state and province east of the Rocky Mountains except Newfoundland (Zeleny 1976). Its range, including breeding and wintering areas, extends from southern Canada south to the West Indies and Nicaragua. Bluebirds are migratory. During the spring migration they follow the warmer temperatures north, arriving in their breeding areas in February or March. The fall migration route is difficult to define. Some Eastern Bluebirds spend the winter as far north as Point Pelee and Toronto, Ontario, but most winter from the north-central United States southward (Godfrey 1976). The wave-like southward migration begins as the insect supply decreases, with the birds breeding in Canada moving perhaps to North Carolina, the North Carolina birds moving to Florida and the Florida birds moving to the Caribbean (Bent 1949, Zeleny 1976).

Eastern Bluebirds begin to breed as early as February in southern areas such as Tennessee (Laskey 1939) and as late as April in more northern areas such as Michigan (Pinkowski 1977). Males generally arrive on the breeding sites a few days earlier than the females (Bent 1949). Once a pair bond has been formed the male leads the female to potential nest sites and she chooses the most suitable one after many inspection trips to the site. Courtship feeding of the female by the male takes place prior to nest construction and may continue throughout the nesting period (Hartshorne 1962).

Eastern Bluebirds are cavity nesters and have been found in many different types of holes including tin cans, rural mailboxes, drain pipes and jars as well as the more orthodox hollow fence posts, holes in trees and man-made nest boxes (Bent 1949). The actual nest is cup-shaped and consists of fine dry grasses. The interior of the cup is either lined with finer grasses or is left unlined. The female builds the nest in three to five days Although males have been observed bringing nesting material to the cavity (Hamilton 1943, Bent 1949), they generally drop it before entering or exit from the cavity carrying the same piece of material

Eastern Bluebirds are usually monogamous, but polygyny is occasionally observed (Gowaty 1983). Gowaty attributes the monogamous breeding system to breeding synchrony among bluebirds and to the dispersion of the nest sites. Gowaty (1983) conducted an experiment in which males were removed from breeding females. No differences were found in the number of eggs laid, number of young fledged and subsequent reproductive success between paired and single females.

Bluebirds often begin to lay their eggs on the day following nest completion, although several days to a week may elapse before the first egg is laid. One egg is laid each day, generally in the morning The eggs are usually light blue in colour, but clutches of white eggs also exist (Laskey 1939). The average size of 50 eggs measured in the United States National Museum in Washington D.C. was 20.7 mm X 16.3 mm. The longest, widest, shortest and narrowest eggs measured 22.9, 17.8, 17.8 and 15.2 mm respectively. Clutches usually consist of three to six eggs, with five being the most common (Bent 1949). In areas where two clutches are laid the second clutch often has one egg less than the first Incubation begins with the laying of the last egg and lasts for 12 to 13 days (Bent 1949, Hartshorne 1962, Zeleny 1976). Although some authors have reported that males participate in incubation (Smith 1937 in Laskey 1939, Bent 1949), Hartshorne (1962), found that a male may sometimes sit on the eggs for a few minutes when the female has left the nest, but he is incapable of providing enough warmth to incubate. This statement is based on an overnight observation of a male sitting on the eggs. All the eggs were cold in the morning.

The eggs almost always hatch synchronously, but occasionally one egg will hatch a day later. Both parents feed the young although the female makes more trips to the nest (Pinkowski 1978). According to Pinkowski (1978), recently hatched young are fed soft prey items such as spiders and Lepidoptera larvae As they grow, Orthoptera and earthworms also begin to form part of their diet. Fruits are fed only very rarely (Pinkowski 1978). The feeding rate increases as the nestlings mature, then declines shortly before fledging (Pinkowski 1975).

Eastern Bluebird nestlings remain in the nest for 15 to 20 days (Zeleny 1976). When they emerge from the nest cavity they fly to the nearest tree where they may remain for several days. Bluebird fledglings are not independent upon leaving the nest. They are taught to forage mainly by the male, although the female participates to a limited extent. The male feeds the fledglings until they become independent while the female builds a nest for the next brood. Independence is achieved a week to ten days after fledging (Zeleny 1976).

The Eastern Bluebird has been found to raise at least two broods per year throughout most of its range (Peakall 1970, Pinkowski 1975). In some southern areas such as Tennessee it may even be triple-brooded (Laskey 1943) Bluebirds in the northern part of their range may raise only one brood per season Peakall (1970) found that bluebirds are single-brooded in Canada, triple-brooded in the central part of their range and double-brooded in the extreme south The length of the breeding period appears to coincide with the highest breeding density, which is in the central part of their range

Feeding techniques and diet of bluebirds have been described by Bent (1949) and Pinkowski (1978). Insects form the main part of the bluebird's diet. Bluebirds search for their prey by scanning the ground from a feeding perch. When a likely item has been spotted the bluebird drops to the ground. The prey is either consumed on the spot or carried back to the perch. If vegetation in the area is too high, bluebirds alter their feeding technique toward gleaning or aerial captures. As insects become scarcer towards fall and winter, fruit becomes more important in the diet. Bent (1949) stated that Eastern Bluebird food consists of 68% animal and 32% vegetable matter, Orthoptera being the most important prey items. Lepidoptera, Coleoptera, Hymenoptera, Hemiptera and spiders are also consumed. Pinkowski (1978) found the same items in his analysis in Michigan, but Orthoptera were second to Lepidoptera larvae as the most important food items. Less frequent taxa included Coleoptera, Annelida, Hymenoptera, Diplopoda ~~and Hem~~iptera

Eastern Bluebird populations declined steadily throughout North America during the past 30 to 40 years (Peakall 1970, Zeleny 1976) This occurrence can be traced to mans' activities. Favourite bluebird habitat consists of open fields surrounded by fence posts, shrubs, trees or stumps. Apple orchards are also preferred sites (Bent 1949, Zeleny 1976). Many of these areas have been modified so they are no longer suitable for bluebirds. Favourite nesting sites once included holes in rotting trees and old wooden fence posts. Modern agricultural practices have dictated the clearing of rotting trees (Bent 1949) and the replacement of the old wooden fence posts by the less expensive and more durable metal ones. The reduction in the number of available nest sites has led to fierce competition among the cavity nesters. Bluebirds have been displaced by Tree Swallows (*Tachycineta bicolor*), House Wrens (*Troglodytes aedon*) and the introduced European Starlings (*Sturnus vulgaris*) and House Sparrows (*Passer domesticus*) (Bent 1949, Zeleny 1976).

The establishment of "Bluebird trails" has somewhat alleviated the problem of nest-site competition Nest boxes, readily accepted by cavity nesters, have been set up all over eastern North America At first, competition remained a problem for bluebirds as the preferred sites were often occupied by more aggressive Tree Swallows. However, setting up the boxes in pairs with about 3 m between them eliminates this difficulty Tree Swallows will not nest next to each other, but will accept bluebirds as neighbours. The same is true of bluebirds Half of the boxes are thus potentially available for the bluebirds Starlings can easily be excluded from the boxes by making the entrance holes too small for them House Sparrows remain a problem. They will build a nest on top of a bluebird nest containing eggs or kill bluebird nestlings and often their parents too (Zeleny 1976). Nest site defence by the male bluebird is generally timid Some males dive towards perceived intruders to their nests while snapping their bills, but others simply remain in nearby trees and give warning calls (Laskey 1939)

Eastern Bluebird populations have been increasing gradually since the establishment of the Bluebird trails and more detailed studies of their biology may provide information facilitating their restoration to former levels of abundance. Zeleny (1976) stated that migratory flocks of Eastern Bluebirds once consisted of several hundred individuals, but now there are usually fewer than 20 in a flock.

Measurements of Growth.

Growth data usually consist of measurements of length or mass of different body parts (Ricklefs 1983). Lack (1968) proposed that growth rates result as a balance between the fast growth necessary to reduce risk of predation and slower growth that allows parents of altricial young to raise larger numbers. Ricklefs' (1984) agreed that variation in altricial growth rates may be explained by the above hypothesis, but retained his former stand (Ricklefs 1968) that altricial and precocial young grow as fast as possible within the physiological constraints on tissue growth. Precocial species grow more slowly because their tissues are more mature than altricial tissues and the rate of cell division declines as tissues mature Avian nutritional requirements and the length of the pre-fledging period depend on the growth pattern (Sedinger 1986).

The easiest and perhaps the most comprehensive way in which to look at growth is to look at the relationship between nestling weight and age. Growth for most birds is sigmoidal (O'Connor 1984). Rates of weight gain are small at first, then they increase and finally level off at a weight close to that of the adult In some species the leveling off may occur long before the adult weight has been reached (O'Connor 1984).

A basic assumption underlying interspecific comparisons of growth is that each species has a characteristic and inherent growth pattern (Ricklefs 1967) Ricklefs (1967) developed a graphical method for calculating growth parameters by creating growth curves using body weights. Intraspecific comparisons of growth patterns may help to show up differences in the inherent growth pattern and this may give clues to the nutritional state of the growing organism

The basic technique behind Ricklefs' (1967) graphical method is that the raw body weight data are replaced by conversion factors, transforming the sigmoid growth curve to a straight line. The slope of this line is proportional to the overall growth rate. Rather than fitting a curve exactly to complex growth data, Ricklefs (1967) presents three generalised equations While these equations give a more generalised fit, they are better for comparative purposes because fewer independent variables are involved than in precise equations Each equation has only one rate constant. The equations may not have any biological significance or be realistic models of the growth process; but they can be used for reliable intra- and interspecific comparisons (Ricklefs 1967)

The three curves mentioned above are the logistic, the Gompertz and the von Bertalanffy. The differences between the three curves are as follows. The inflection points of the logistic, the Gompertz and the von Bertalanffy curves occur when 50%, 37% and 30% respectively of the asymptotes have been reached. The growth rate is slowed and prolonged in relatively later stages of growth in the Gompertz and von Bertalanffy curves as opposed to the logistic curve (Ricklefs 1967).

Ricklefs (1968) found that the growth data of most passerines fit the logistic curve. He presents the logistic equations as follows

Cumulative growth (W)	$\frac{a}{1+be^{-Kt}}$
Absolute growth rate (dW/dt)	$KW(1-W)$
Relative growth rate ($1/W \cdot dW/dt$)	$K(1-W)$
Inflection point (W_1)	1/2

where.

W weight of growing organism
a - final weight (asymptote) achieved
K - constant proportional to overall growth rate
e - base of natural logarithms
b - constant which translates time axis such that time t is equal to zero at the inflection point $b = 1$ for logistic equation

Species whose growth curves are fitted by the same equation can be compared using the value K, since K is independent of body size.

These equations describe the body weight as a function of time. Conversion factors are substituted for weight to transform the curve to a straight line. Derivations of the equations used to obtain the conversion factors are found in Ricklefs (1967).

Ricklefs (1967) described the technique for using the growth equations in six fairly simple steps. The first one is to estimate the asymptote, or final weight, of the growth curve. The values for growth are then calculated as percentages of the estimated asymptote. The conversion factors corresponding to these percentages can be read from a table presented by Ricklefs (1967). These factors can be plotted as a function of time. If a straight line is obtained, at least through the lower half of the graph, the equation chosen is appropriate. If the relationship is straight through the lower half of the graph, but rises or falls off sharply in the upper half, the estimate of the asymptote may have to be refined. Once a straight line has been obtained the slope is measured. The slope is directly proportional to the rate constant, K, of the growth equation

Ricklefs (1967) also presented a formula which can be used for interspecific comparisons of species with different growth equations. The amount of time needed to complete a certain amount of growth is calculated. The standard time interval used is the time needed to complete growth from 10% to 90% of the asymptote It is calculated by the formula $t_{10-90} = \frac{C_{90} - C_{10}}{dW/dt}$

C represents the conversion factor for the appropriate equation This is a reciprocal of the growth rate and varies directly with the temporal features related to growth such as length of incubation and nesting periods.

The logistic, Gompertz and von Bertalanffy models are quite specialised because they have fixed inflection points. Richards (1959) developed a model encompassing the three mentioned above. The Richards model has a variable inflection point specified by the shape parameter, n. The logistic model is represented by an n of 1. An n value of or close to 0 represents the Gompertz model and an n value of -0.3 represents the von Bertalanffy model. The Richards model is often considered superior to the other three because of its flexibility and because the subjectiveness involved in choosing one of the other three is eliminated (Zach et al. 1984). Conversely, a drawback to the Richards model is that it is more complicated to use.

Zach et al. (1984) compared the Richards model to the logistic, Gompertz and von Bertalanffy models. Daily body masses and primary feather lengths of Tree Swallows were used as test data. No significant difference between the Richards and the logistic models was found for body mass. Because the Richards model has rarely been used in the analysis of growth curves, Zach et al (1984) were not able to properly evaluate the usefulness of this model. Tree Swallow data do not indicate clear superiority for any of the three models.

Several useful indices through which further analyses can be carried out are obtained from growth models. The two main indices are the growth rate constant and the asymptote. Other indices include the time needed to reach 99% of the asymptote and the time required for growth between 10% and 90% of the asymptote (Zach et al. 1984). These values permit intra- and interspecific comparisons which may lead to a more thorough understanding of avian ecology.

Introduction

Studies concerning intraspecific variation in laying dates, clutch sizes and egg sizes (e.g. Kendeigh et al. 1956, Coulson et al. 1969, Howe 1976, Murphy 1978, Batt and Prince 1979) have been conducted on many species. Intraspecific variation in laying dates of the Mallard (Anas platyrhynchos) may result from adaptation to local ecological conditions (Batt and Prince 1979). Individual consistency may be due to a differential ability to find food (Perrins 1970). No clear relationships between clutch and egg sizes have been found. In a study by Kendeigh et al. 1956) larger clutches of House Wren eggs were found to have larger eggs within each clutch sequence. No significant differences in the average length, width, shape or calculated volumes were found between eggs in different size clutches, but larger clutches contained heavier eggs. The authors were unable to explain the biological meaning of this. Howe (1976) found that mean egg weight per clutch of the Common Grackle (Quiscalus quiscula) did not vary significantly with clutch size, but he hypothesised that a larger sample might have shown a reduction of mean egg weight in larger clutches. The conclusion reached by all authors above is that genetic control is an important factor in laying dates, clutch size and egg size Detailed studies of these three factors in the Eastern Bluebird have not been conducted.

Much can be learned about the adaptive significance of growth patterns by looking at intraspecific variation (Ricklefs

1969). Growth may be affected by various conditions. Time of year may have a different effect on different species. Ricklefs (1968) calculated growth rates for European Robins (Erithacus rubecula) measured by Lack and Silva (1949) in Oxford. Late broods grew faster than early broods. Early and late broods of the Great Tit (Parus major) in Oxford (Gibb 1950 in Ricklefs 1968) and the European Starling in Czechoslovakia (Hudek and Folk 1961 in Ricklefs 1968) grew at the same rates. However, the asymptotes for late broods of all three species mentioned above were lower. The same results were found for exceptionally early broods of the Woodpigeon (Columba palumbus) (Murton et al. 1974).

Geographic location may also have an effect on growth rates (Ricklefs 1968). European Starlings in Scotland grew 4% more slowly than those in Czechoslovakia (Dunnet 1955 and Hudek and Folk 1961 in Ricklefs 1968). Chipping Sparrows (Spizella passerina) in New York and Michigan grew at the same rate (Weaver 1937, Walkinshaw 1944 and Dawson and Evans 1957 in Ricklefs 1968). Yellow-Headed Blackbirds (Xanthocephalus xanthocephalus) grew 26% more slowly in Utah than in Washington (Fautin 1941 and Willson 1966 in Ricklefs 1968).

Growth may be affected by brood size. Broods of five European Robins grew faster than any other brood sizes (Lack and Silva 1949) Single Woodpigeon young grew 14% more slowly and attained 10% higher asymptotes than Woodpigeons in broods of two (Murton et al. 1974). Young in large broods of the Pied Flycatcher (Muscicapa hypoleuca) were lighter than those in smaller broods. Crossner (1977) found that growth rates for smaller broods of the European Starling were higher than the rates for artificially increased broods as long as the amount of food available was the same for all brood sizes. However, large broods provided with extra food increased their growth rates to the levels of the smaller broods

Despite all the factors that may affect growth rates, they still remain surprisingly constant for each species. Lack and Lack (1951) showed that young of the Common Swift (Apus apus) suffer under conditions of fluctuating food availability not only through weight loss, but also in linear dimensions such as wing length. However, the rate of growth, which is proportional to the slope of the transformed growth curve, apparently remains constant. It is only the magnitude that changes. Unless severe starvation takes place growth rates remain the same.

Growth of a wild population of Eastern Bluebirds has not been studied in great detail. Pinkowski (1975) measured and observed the young of bluebirds from a Michigan population kept in captivity. He calculated the growth rate using the method described by Ricklefs (1967) Hamilton (1943) measured three broods in New York and Gowaty (1983) examined a few broods in South Carolina. Ricklefs (1968), using data from two of the broods measured by Hamilton (1943) calculated the growth rate for the Eastern Bluebird. His value of K = 0.484 is quite close to that of Pinkowski (1975) who calculated a rate of K = 0.488 for his captive broods.

The purpose of this study was to gather information about aspects of the breeding ecology of the Eastern Bluebird in southwestern Quebec and to make comparisons with the studies mentioned above. Comparing aspects of the life history of the Eastern Bluebird in the Hudson-Rigaud region of Quebec to those of Eastern Bluebirds in other geographical areas may show whether there are significant differences between areas. The most suitable regions in which to concentrate efforts to re-establish Eastern Bluebirds may be found and it may also be determined whether their decline is perhaps a natural one. Their preferred habitat is man-made and it is possible that populations increased to unnatural levels as land was cleared by settlers. With the increase of urban areas and a subsequent reduction in favourite bluebird habitat the population levels may be returning to what they once were.

The first part of this study dealt with examining egg measurements. The purpose of this was to see whether egg measurements are affected by varying external conditions. Several research questions were developed, including whether:

1). egg size will remain constant regardless of clutch size

2) egg size will be the same in 1984 and 1985

3) the size of eggs that hatch will be the same as that of eggs that do not hatch

4) egg size for southwestern Quebec will be the same as egg size recorded in the literature for more

southern latitudes

The second part of this study dealt with the growth of the Eastern Bluebird. The aim was to determine factors that might affect growth rates of this species. The hypothesis to be tested was that growth rates of the Eastern Bluebird will vary under changing external conditions. Predictions arising from this hypothesis were:

1) Growth rates will be lower for individuals in larger broods.

2) Growth rates will differ for 1984 and 1985 young.

External conditions such as temperature and food availability are unlikely to be identical in two breeding seasons. and growth rates may reflect these differences.

3) Growth rates for Hudson-Rigaud Eastern Bluebirds will differ from those recorded in the literature for New York and Michigan.

The last aspect of growth rates looked at was a comparison between the growth rates of young surviving to fledging and the growth rates of young dying while still in the nest. It would be expected that non-survivors would have lower growth rates because they are dying of factors such as starvation or disease. The research question was whether growth rates of young surviving to fledging will be higher than those of young dying while still in the nest.

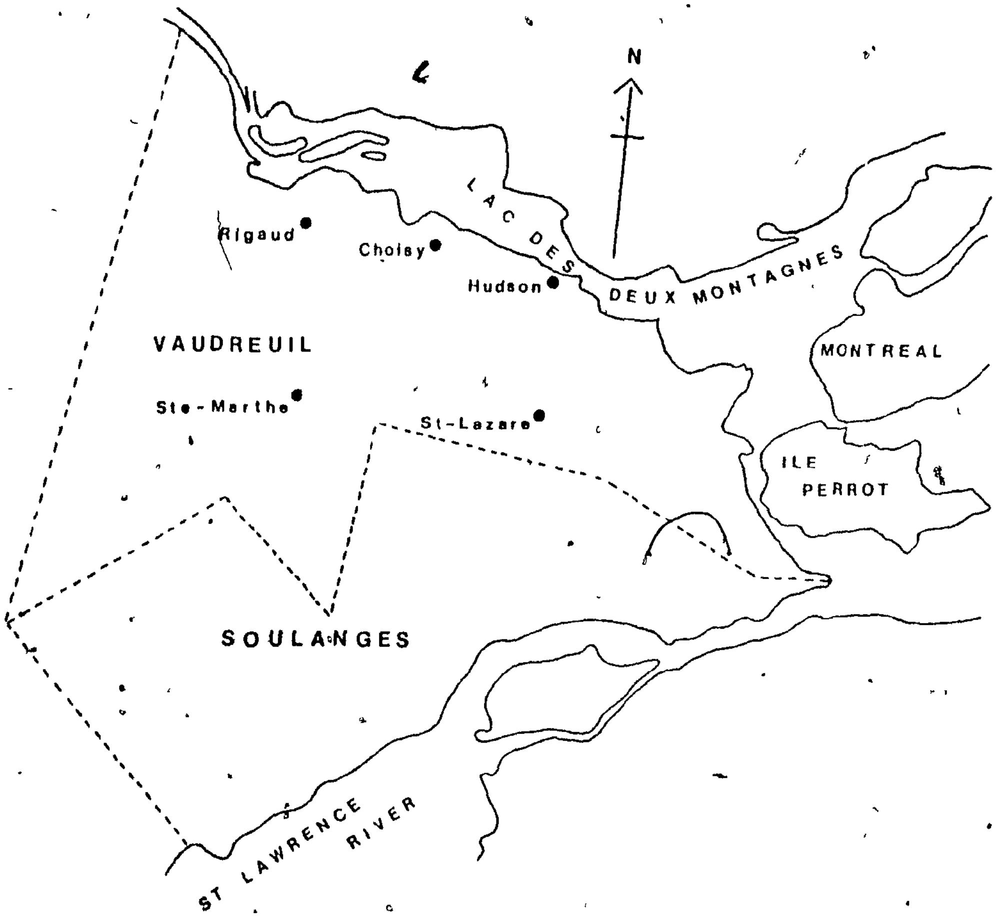
Study Area

The study was conducted in the Hudson-Rigaud area of southwestern Quebec (45°25'N;74°17'W) (Fig. 1). Covering approximately 50 km^2, Vaudreuil county consists mainly of flat or gently rolling land lying at an elevation of 42 m - 60 m above sea level. The highest spot in the area is 200 m high Mont Rigaud, located at the western edge of the county. To the east of the mountain lies the sandy plain of St. Lazare with an elevation of 60 m - 120 m above sea level. Rivière Raquette, one of three main rivers in the county, drains into the Ottawa River at the northern border of Vaudreuil county (Lajoie and Stobbe 1951).

The soils of Vaudreuil reflect their glacial origin and their subsequent submersion by the Champlain Sea. The till deposited by the glaciers consists of particles of all sizes, from the tiny clay and lime to the much larger sand and gravel. Much of the acidic soil belonging to the Podsol and Brown Podsolic groups was formed from rocks not containing any limestone (magnesium carbonate and calcium carbonate). Features of the vegetation and climate have further contributed to the acidity of the soil through the promotion of leaching of soluble elements (Lajoie and Stobbe 1951).

The climate of the Vaudreuil area can be classified as temperate and quite moist. The vegetation consists mainly of deciduous trees such as Red Maple (<u>Acer rubrum</u>) and ash (<u>Fraxinus</u> spp.) mixed with Red Oak (<u>Quercus borealis</u>), White Birch (<u>Betula papyrifera</u>), some pine (<u>Pinus</u> spp.) and Fir (<u>Abies balsamea</u>).

Figure 1. A map of the study area, including towns around which bluebird boxes were set up.


N
LAC DES DEUX MONTAGNES
Rigaud
Choisy
Hudson
VAUDREUIL
Ste-Marthe
St-Lazare
MONTREAL
ILE PERROT
SOULANGES
ST LAWRENCE RIVER

The whole region is primarily agricultural (Lajoie and Stobbe 1951), which constitutes ideal breeding habitat for bluebirds (Zeleny 1976). The Province of Quebec Society for the Protection of Birds (PQSPB) has set up 66 nest boxes on fence posts surrounding various fields such that there is at least one tree within 25 m The dimensions of the boxes are 13 X 13 x 25 cm. Starlings cannot fit through the 3.8 cm entrance hole as recommended by Zeleny (1976) The boxes have been set up in pairs approximately 3 m apart to reduce competition for them from the more aggressive Tree Swallows

The study area comprised various agricultural fields, either cultivated or used for livestock. Bluebirds used six different fields. The field with the densest population of bluebirds was a cattle pasture with a fairly steep slope leading down to a field in which hay was cut twice each summer. The dominant vegetation consisted of various grass species (Poacea) interspersed with Birdsfoot Trefoil (Lotus corniculatus). Small deciduous trees and shrubs like Staghorn Sumac (Rhus typhina) and hawthorns (Crataegus sp.) grew around the perimeter of the field. Soil in this area has been classified as Rigaud stony gravelly loam which is developed on till and derived mainly from quartzite and gneiss. It belongs to the Great Soil Group of Brown Podsolic soils. Thirteen nest boxes were set up around this field.

The second and third fields were level and fairly stone-free and surrounded by a mixture of coniferous and deciduous trees. The soil was Ste. Rosalie clay in the second field, belonging to the Great Soil Group of Hydromorphic soils. St. Amable loamy sand from the Groundwater Podsol soils, found in the third field, originates from sandy alluvial deposits over clay. Hay was cut in the second field once each summer. There were ten boxes set up around the perimeter. The third field, surrounded by eight boxes, was used several times a week by a polo club and hence had short grass at all times.

The very large fourth field was divided into several sections and was used to grow alfalfa (Medicago sativa) and hay, as well as being a pasture for dairy cows (Bos taurus). The soil was well-drained Ste. Sophie fine loamy sand, a light textured soil developed on water-deposited and sorted minerals and belonging to the Great Soil Group of Podsols. Fifteen boxes were located in this field which was surrounded mainly by mature conifers (Abies balsamea, Tsuga canadensis, Pinus sp.).

The soil in the fifth field was also Ste. Sophie fine loamy sand mixed with stones. One side of the field was lined with shrubs and several large oak trees (Quercus sp.). Hay was harvested twice each summer. Five boxes were mounted on the surrounding fence posts. The sixth field was similar, but its uncut grass was used by horses (Equus caballus). It contained five boxes.

METHODS AND MATERIALS

The study took place from mid-May to the end of July in 1984 and from late April to mid- August in 1985. Boxes were monitored from the beginning of April in both years. The first step was to locate all the nest boxes of the PQSPB "Bluebird Trail". Measurement of the eggs was the next task. Prior to incubation the width at the widest point and the length of all eggs were recorded using calipers. In 1985 the eggs were weighed using a triple-beam balance. An attempt to weigh the eggs in 1984 was abandoned because a Pesola spring scale proved to be too sensitive to air currents. Boxes were checked every second or third day to minimise disturbance.

An attempt was made to colour-band the adult females while they sat on their eggs in 1985 It is easily possible to catch the females while they are sitting on their nests Laskey (1939) found that brief handling of the birds did not cause desertion. However, three of the four females banded during early incubation in the Hudson-Rigaud study did not return to their nests, so the banding operation was stopped

Using calipers accurate to 0.05 mm, the following measurements were taken on the young bill length, antebrachial length, tarsal length, length of longest primary, skull length and weight (Olendorff 1972, Pinkowski 1975). Olendorff (1972) defined the measurements as follows.

BILL LENGTH - the distance from where the culmen emerges from the cere to the tip of the upper mandible as measured by the arc from the cere to the tip

ANTEBRACHIAL LENGTH - the distance from the elbow to the wrist. The elbow was located by finding the notch between the distal end of the humerus and the proximal end of the ulna

TARSAL LENGTH - the distance from the heel to the joint between the distal end of the tarso-metatarsus and the third toe

LENGTH OF LONGEST PRIMARY - the distance from where the shaft exits the skin dorsally to the tip of the feather

The young usually defecate upon being handled, so weights recorded are without faecal sacs. Weights in 1984 were taken using a 50 g Pesola spring scale, but they tended to vary with wind strength. Hence, the Pesola scale was abandoned in favour of a triple-beam balance accurate to 0.1 g and placed in a cardboard box to shield it from the wind

Originally it was planned that measurements would start either on the day of hatch or the day after and then to conduct measurements every second day. Inclement weather did not always allow this, so measurements were taken as close to the schedule as possible. They were taken at approximately the same time each day (between 8:00 am and noon) in order to keep intervals between measurements constant. Data were recorded until the nestlings were between 13 and 17 days old.

All linear measurements were analysed for three different groups. (1) all young, (2) those surviving to fledging and (3) the non-survivors. Nearly fledged young known to have died as a result of predation were included with the survivors on the assumption that they were growing normally. The average daily increase of each body part was calculated for the three groups of birds. In order to compare the growth of survivors and non-survivors, a t-test was used to compare the mean lengths on the day of hatch, age four days and age 11 days, which was the highest age reached by non-survivors. Before the t-tests were performed, homogeneity of variance for the groups at each age was tested using an F-statistic (Sokal and Rohlf 1969)

Weights were analysed in a manner identical to lengths and were also used to calculate growth rates following Ricklefs (1967) technique. Growth rates were determined and analysed for each individual, for each brood size, for each year, and for survivors and non-survivors.

The homogeneity of variance of survivors versus non-survivors was checked. Variances for years were homogeneous, but variances for survivors versus non-survivors were not. The means of the survivors versus non-survivors were tested for equality of means of two samples whose variances are assumed to be unequal (Sokal and Rohlf 1969). The homogeneity of variance of the different boxes was calculated using Bartlett's test for homogeneity of variance (Steel and Torrie 1980)

RESULTS

Initiation of Laying, Clutch Size and Egg Size

The nesting season started almost one month later in 1984 than in 1985. The earliest laying date in 1984 was 13 May. The peak laying period in 1984 took place during the first half of June (Fig 2). A smaller peak occurred towards the middle of May. Six of 12 clutches in 1984 consisted of five eggs, and six nests contained four eggs each. The average clutch size for 1984 was 4.50 ± 0.522 (n=12 nests).

The first egg of the 1985 season was laid 20 April. The end of April, the middle of May and the middle of June were the main periods of egg laying in 1985. The season was considerably longer than in 1984 (Fig 2). Thirteen of the 22 nests completed in 1985 contained five eggs, six contained four eggs each and one clutch each of six, three and two eggs were laid. The average clutch size for 1985 was 4.55 ± 0 858 (n=22) The mean clutch size for 1984 and 1985 combined was 4 53 ± 0 748 (n=34).

Egg width ranged from 15.00 mm to 17.21 mm with a mean of 16.28 ± 0.543 (n=149). Lengths ranged from 19.09 mm to 22.84 mm with a mean of 21.01 ± 0.917 (n=149). In 1985, the lightest egg weighed 2.45 g while the heaviest egg weighed 3.60 g. Mean egg weight was 3.05 ± 0 258 (n=72).

Egg sizes for the different clutch sizes are presented in Table 1. There does not appear to be a relationship between the morphological measurements of the eggs in either breeding season. The lightest egg is not th shortest nor the most narrow. The

Figure 2. Number of eggs laid per five-day period in 1984 and 1985 for the Eastern Bluebird (<u>Sialia</u> <u>sialis</u>) in southwestern Quebec.

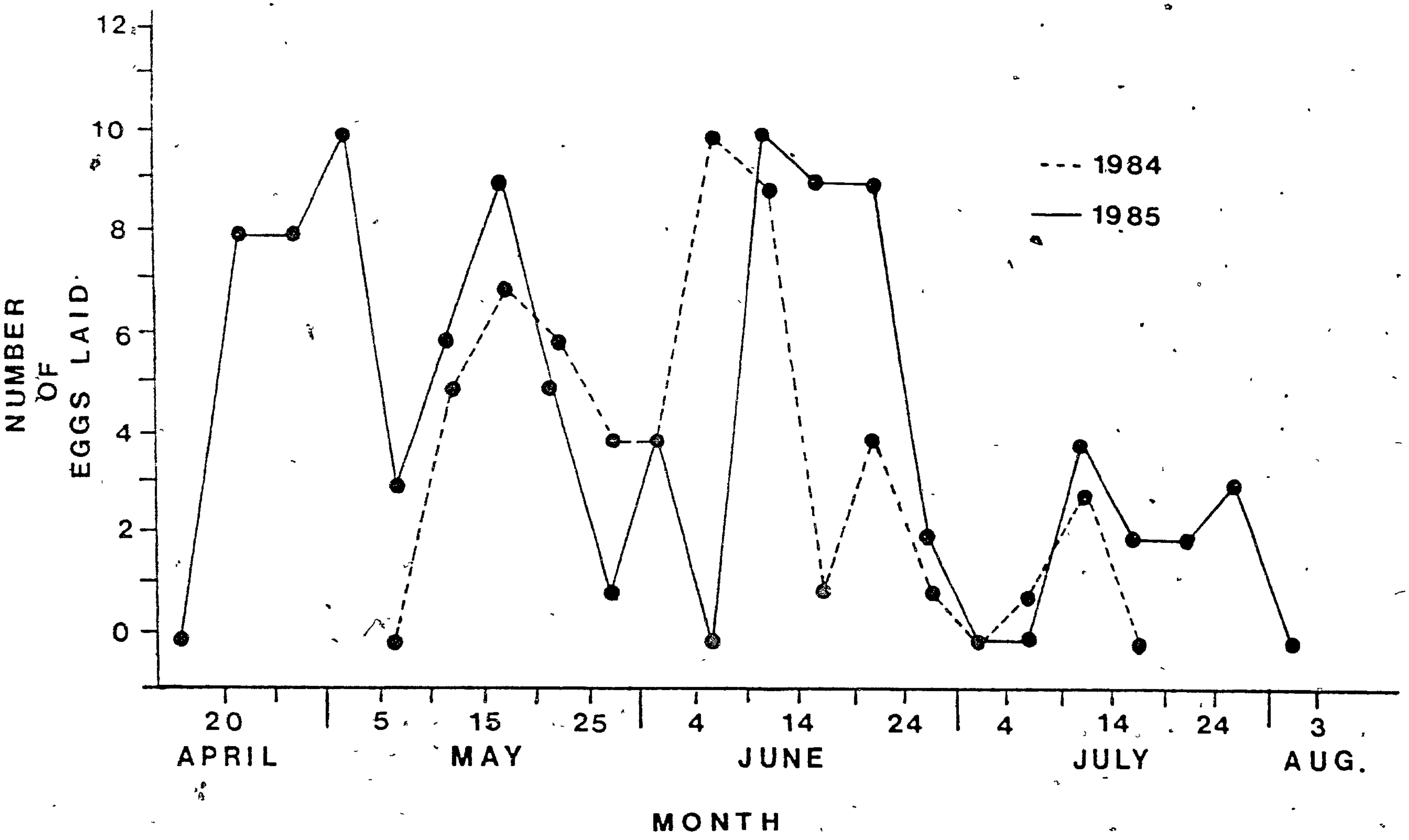

12
10
8
6
4
2
0
NUMBER OF EGGS LAID
- - - 1984
—— 1985
20
APRIL
5
15
25
MAY
4
14
24
JUNE
4
14
24
JULY
3
AUG.
MONTH

Table 1. Average egg sizes for each clutch size for the 1984, 1985 and 1984 + 1985 breeding seasons for the Eastern Bluebird (<u>Sialia sialis</u>) in southwestern Quebec

CLUTCH SIZE	LENGTH (mm) 1984	LENGTH (mm) 1985	WIDTH (mm) 1984	WIDTH (mm) 1985
1				
2		23.45±0.54 (2)		15.05±0.34 (2)
3		22.09±0.07 (3)		15.38±0.21 (3)
4	20.86±0.77 (23)*	20.69±0.75 (23)	16.40±0.38 (23)	16.19±0.75 (23)
5	20.82±1.09 (30)	21.13±0.91 (64)	16.58±0.28 (30)	16.15±0.61 (64)
6		21.77±0.21 (6)		16.53±0.27 (6)

* average, standard deviation, (sample size)

heaviest egg is neither the longest nor the widest. In 1985 the lightest egg and the widest egg of the season were laid in the same box, but not in the same clutch. The heaviest egg and the narrowest egg were laid in the same two-egg clutch. This was the second clutch of a female which had successfully reared a brood of five. In 1984 the longest egg and the widest egg were laid in the same clutch and both hatched. The eggs in all successful clutches (clutches in which at least one egg hatched) hatched after an incubation period of 12 to 13 days.

In 1984, neither egg length nor width were correlated with clutch size ($p > 0.05$). A significant relationship was found between hatching success and egg width in 1984 ($p < 0.05$), with wider eggs being more likely to hatch The mean width for unhatched eggs was 16.39 mm, while those that hatched had a mean width of 16.58 mm. There was no significant relationship between hatching success and either egg length ($p > 0.10$) or clutch size ($p > 0.05$).

In 1985, clutch size was related to egg width ($p < 0.01$). Hatching success was not influenced by egg length ($p > 0.05$), egg width ($p > 0.05$), or clutch size ($p > 0.05$). A highly significant positive relationship ($p < 0.001$) was found between egg weight and clutch size. Both egg length and egg width were positively correlated with clutch size ($p < 0.05$). Hatching success was not related to egg weight ($p > 0.05$).

A combined analysis for 1984 and 1985 together suggests that clutch size was significantly correlated with egg length

($p < 0.001$) and width ($p < 0.01$), but not with hatching success ($p > 0.05$). Eggs in 1984 were significantly ($p < 0.001$) wider ($\bar{x}$ = 16.50 mm) than in 1985 ($\bar{x}$ = 16.14 mm). There was no difference between 1984 and 1985 lengths.

Measurements of Young

Measurements of young and the adult females caught and banded are summarised in Table 2.

Tarsus Length

The tarsus length of young Eastern Bluebirds increased approximately 3 5-fold from the day of hatching until the last measurement before fledging. The young appear to achieve their full tarsal length before leaving the nest (Table 2).

The period of greatest average daily increase in length occurs between the third and the tenth day of life (Table 3). The pattern of overall increase in tarsus length for 1984 and 1985 can be seen in Fig.3. Growth appears to level off between day 9 and day 11. The largest increase in one day was 2.82 mm between 5 and 6 days of age in 1985.

There was no difference in the tarsal lengths of young surviving to fledging age and those dying while still in the nest on the day of hatching. The same was true for the lengths at 4 days, but by 11 days, the highest age for which there were non-survivors, there was a significant difference ($t=6.551$, $df=27$ $p < 0.001$). The tarsi of survivors were significantly longer than those of non-survivors.

Table 2 Measurements of Eastern Bluebird (*Sialia sialis*) adult females and young at hatching and just prior to fledging (day 18) in southwestern Quebec

PARAMETER	AT HATCHING				PRIOR TO FLEDGING				ADULT FEMALES			
	RANGE	MEAN	SE	n	RANGE	MEAN	SE	n	RANGE	MEAN	SE	n
Tarsus (mm)	5.31-8 12	7 06	0 73	22	18.75-22.94	20.97	1.17	15	21 27-25 16	23 07	1 40	6
Antebrachium (mm)	5.31-7.86	6 89	0 63	22	29 46-30 85	29.29	1.28	8	27 22-31 13	29.18	1 39	5
Bill (mm)	2.94-6 19	3.83	0.63	22	6.48-9.50	8 07	0.75	15	11 24-16.60	12.57	2 04	6
Longest primary (mm)	5.24-10.21*	7 39	1.47	11	45 88-60.31	53.60	4.25	8	72 72-94.45	86.43	8 22	5
Skull (mm	11.12-12.30	11 92	0.55	4	25.41-26.55	25 05	1.65	4	27.10	-----	----	1
Weight (g)	1.80-3 80	2.78	0 54	22	25.9-30.00	27.9	1.37	6	32 50-32.80	32.65	0 21	2

* first day on which primary can be measured (day 5)

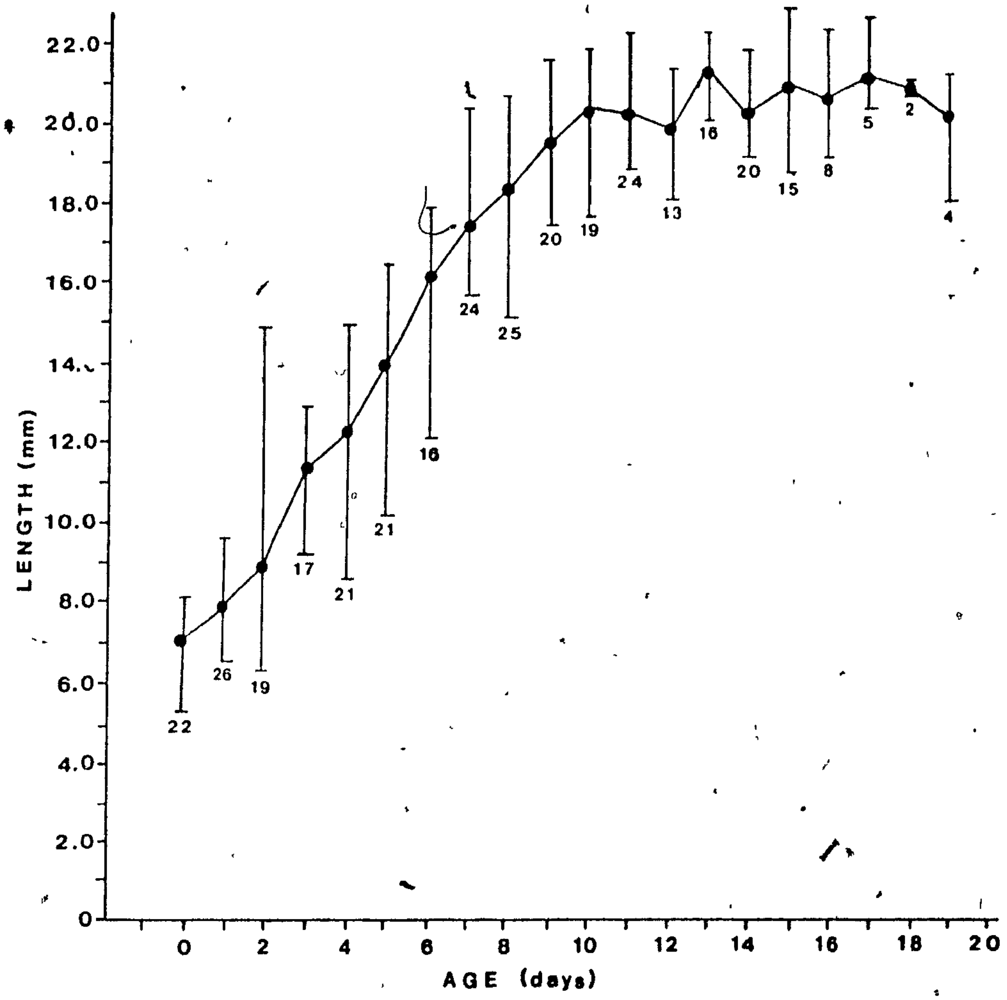
Table 3. Average daily increase in tarsus, antebrachium, bill and longest primary feather lengths for 1984 and 1985 combined for the Eastern Bluebird (*Sialia sialis*) in southwestern Quebec.

AGE (days)	n	TARSAL LENGTH INCREASE (mm)	ANTEBRACHIAL LENGTH INCREASE (mm)	BILL LENGTH INCREASE (mm)	n	PRIMARY LENGTH INCREASE (mm)
0	22					
1	26	0.79	0.27	0.29		
2	19	1.04	1.30	0.53		
3	17	2.53	2.85	0.52		
4	21	0.90	0.06	0.29		
5	21	1.69	2.95	0.50	11	
6	16	2.18	2.36	0.33	7	3.09
7	24	1.34	2.50	0.69	15	4.01
8	25	0.84	1.96	0.08	13	3.81
9	20	1.24	2.58	0.17	9	4.66
10	19	0.81	2.76	0.35	15	5.22
11	24	-0.08	-0.46	0.04	17	0.96
12	13	-0.41	0.79	-0.61	11	4.95
13	16	1.46	1.85	1.15	12	10.27
14	20	-1.08	-0.49	-0.37	19	-3.01
15	15	0.66	1.18	0.30	11	9.38
16	8	0.32	-0.06	0.00	8	2.87
17	5	0.53	0.62	0.39	5	3.54
18	2	-0.18	-0.31	-0.44		
19	4	-0.80	-1.79	-0.31		

Figure 3. Pattern of increase in tarsus length for 1984 and 1985 for the Eastern Bluebird (_Sialia sialis_) in southwestern Quebec.

The bars represent the range of values for each age.

The numbers represent the sample size for each age.


LENGTH (mm)
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
AGE (days)
0
2
4
6
8
10
12
14
16
18
20
22
26
19
17
21
21
16
24
25
20
19
24
13
16
20
15
8
5
2
4

Antebrachial Length

The growth of the antebrachium closely parallels that of the tarsus for the first eight days of life. Values for each day are very close for the two body parts (Figs 3 and 4). However, after the 8th day the antebrachium becomes longer than the tarsus. The leveling off of growth for the antebrachium is less obvious than that of the tarsus. The most rapid growth occurs between days 2 and 13 (Table 3) The largest average increase over a one day period was 3.94 mm from the 4th to the 5th day in 1984 Antebrachial growth appears to be complete at the time of nest departure (Table 2).

A two-way analysis of variance comparing survivors and non survivors showed that there is no difference in antebrachial length at 0 and 4 days of age, but there is a significant difference at 11 days ($t=4.70$, $df=27$, $p < 0.001$), with survivors having longer antebrachi than non-survivors

Bill Length

The bill length does not increase as rapidly as antebrachial and tarsal length (Table 3). It begins to level off at about 11 days of age (Fig.5).

A two-way analysis of variance performed on survivors and non survivors showed that there is no difference in bill length at the ages of 0, 4 and 11 days The largest average increase in length in one day was 1.32 mm from 3 to 4 days of age in 1984.

Figure 4 Pattern of increase in antebrachial length for 1984 and 1985 for the Eastern Bluebird (*Sialia sialis*) in southwestern Quebec

The bars represent the range of values for each age.

The numbers represent the sample size for each age.

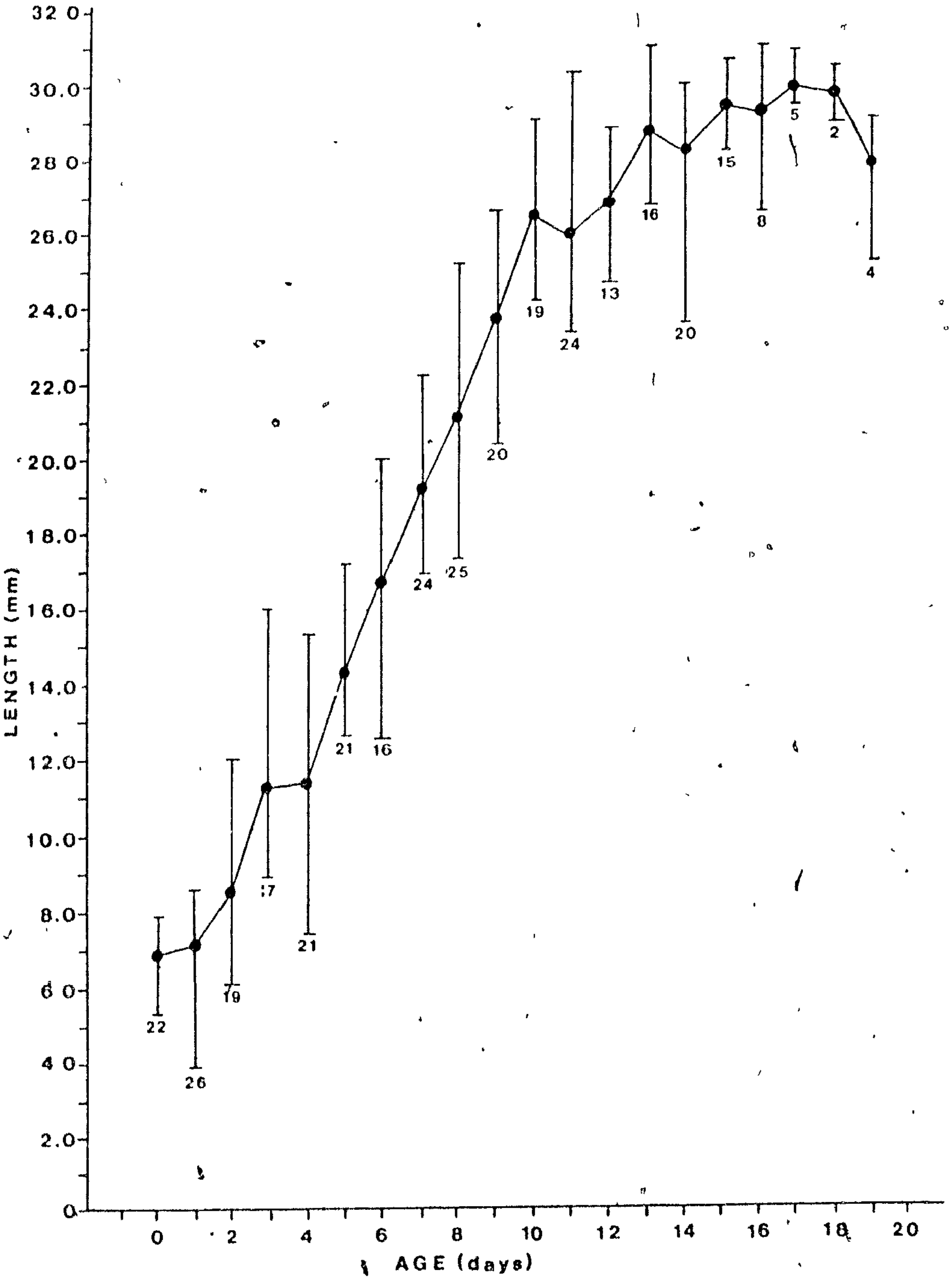
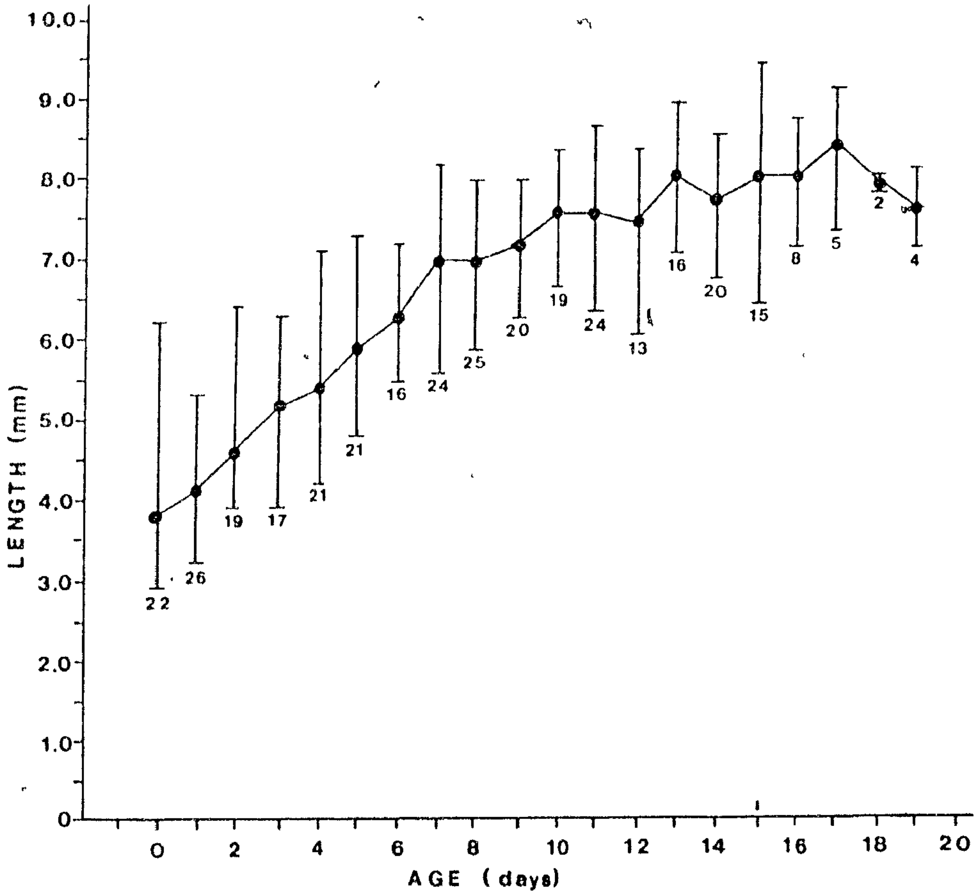

32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
LENGTH (mm)
0
2
4
6
8
10
12
14
16
18
20
AGE (days)
22
26
19
17
21
21
16
24
25
20
19
24
13
16
20
15
8
5
2
4

Figure 5 Pattern of increase in bill length for 1984 and 1985 for the Eastern Bluebird (*Sialia sialis*) in southwestern Quebec

The bars represent the range of values for each age. The numbers represent the sample size for each age.


LENGTH (mm)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
AGE (days)
0
2
4
6
8
10
12
14
16
18
20
22
26
19
17
21
21
16
24
25
20
19
24
13
16
20
15
8
5
2
4

Length of Longest Primary

At the age of six days, i.e. the day after which the feathers first appear, there is no difference between the longest primary of survivors and non-survivors. However, by the age of 7 days a difference has become apparent ($t=2.561$, $df=19$, $p < 0.05$). At 9 days there is a significant difference, with the feathers of the survivors being significantly longer than those of the non survivors ($t=5.499$, $df=17$, $p < 0.001$), and at 11 days the significant difference is still obvious ($t=3.042$, $df=20$, $p < 0.01$). The period of greatest growth seems to continue until the age of 15 days (Table 3). The largest increase occurred from 14 to 15 days of age in 1985 with these primaries increasing in length by 11.72 mm.

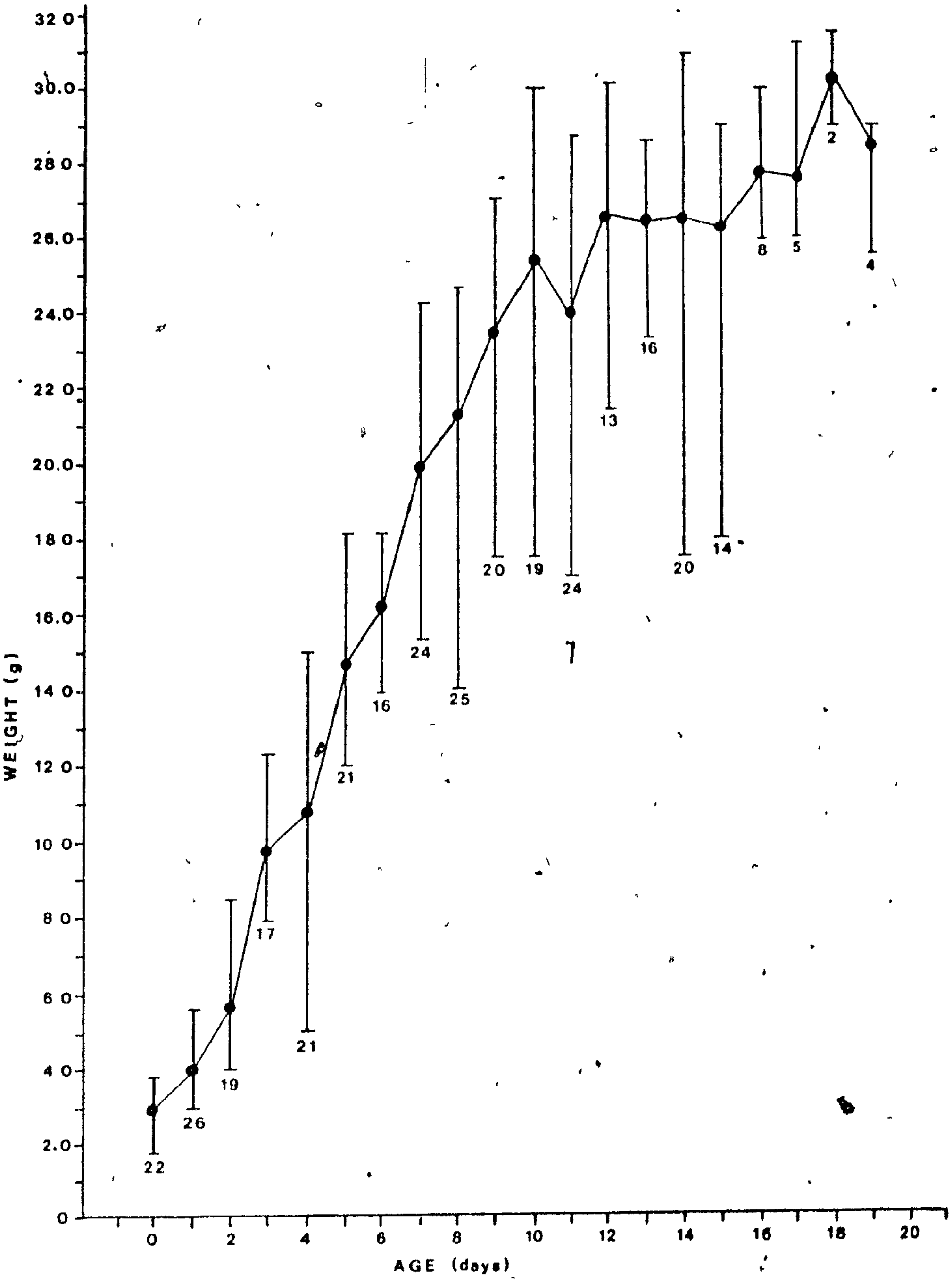
Weight

The young birds reach close to adult weight while still in the nest (Table 2). Weight increased very rapidly to an age of 9 days and then increased at a lower rate (Fig. 6). The two way analysis of variance for differences in weight between survivors and non-survivors follows the same pattern as for the linear measurements. There is no difference at hatch and at 4 days of age, but by 9 days there is a significant difference ($t=6.196$, $df=26$, $p < 0.001$). The largest weight increase over a one day period occurred from age 11 days to age 12 days in 1984.

Figure 6. Pattern of weight increase for 1984 and 1985 for the Eastern Bluebird (*Sialia sialis*) in southwestern Quebec.

The bars represent the range of values for each age.

The numbers represent the sample size for each age.


32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
WEIGHT (g)
0
2
4
6
8
10
12
14
16
18
20
AGE (days)
22
26
19
17
21
21
16
24
25
20
19
24
13
16
20
14
8
5
2
4

Growth Rate

The growth rates of all nestlings were calculated for both field seasons. Calculating the rate with an asymptote of 27.35 g gave the best line for the data. Ricklefs (1967) method involves fitting the best line by eye through the converted body weight data. The value of 27.35 was chosen by obtaining the average of the highest weight attained by all surviving individuals. Values surrounding this average of 27.44 g were tried until the one giving the longest straight line was determined. Survivors had a significantly ($p < 0.001$) higher mean growth rate ($K = 0.439$) than non-survivors ($K = 0.300$). No significant difference ($p > 0.05$) was found between the mean growth rates of 1984 and 1985.

To compare the growth rates of different brood sizes, only broods in which all nestlings reached fledging age were included. There was one brood each of clutch sizes one, two and three, seven broods of four and three broods of five. There was no significant difference ($p > 0.10$) between the growth rates of the different brood sizes when the mean value for each brood size was used. The average growth rates of each brood size were as follows: 1: $K = 0.513$, 2: $K = 0.469$, 3: $K = 0.436$, 4: $K = 0.414$ and 5: $K = 0.444$. A Spearman Rank Correlation test performed on these five values revealed no significant differences ($r = 0.7$, $p > 0.10$).

Age at Nest Departure

Although precise ages at nest departure were not obtained, it can be said with certainty that no young left the nest before the age of 16 days. Most broods (n=7) left after a minimum of 17 days of age and at least two broods left after a minimum of 18 days.

Although almost twice as many nests were built in 1985 as in 1984, only five more young were fledged (Table 4).

Predators, Parasites and Weather

Two nests were destroyed by predators shortly before the young were due to fledge Two young were found in the nest box with broken necks at an age of 19 days The other two members of the clutch had disappeared, but whether they were also preyed upon or whether they fledged is not known. In the second nest three members of a clutch of five were dismembered in the nest box. The other two young disappeared. The most likely predator of these boxes was a Raccoon (<u>Procyon lotor</u>) The young in two other boxes apparently died of starvation after the parents disappeared, possibly as a result of predation by an American Kestrel (<u>Falco sparverius</u>). The bird was seen close to the nest boxes on several occasions. The young in one box disappeared one by one at one-day intervals. It could not be determined whether this was a result of predation or whether they died of disease and were removed by the parents. Starvation was not a cause of their death Both parents were observed feeding the young.

Table 4 Hatching, fledging, nestling and nest success for the Eastern Bluebird (<u>Sialia</u> <u>sialis</u>) in the Hudson - Rigaud region of southwestern Quebec.

YEAR	1984	1985	1984+1985
NO. OF NESTS	12	22	34
NO. OF EGGS LAID	54	100	154
NO. OF EGGS HATCHED	30	53	83
NO. OF YOUNG FLEDGED	25	30	55
HATCHING SUCCESS (%)*	55.6	53.0	53.9
FLEDGING SUCCESS (%)+	46.3	30.0	35.7
NESTLING SUCCESS (%)^	83.3	56.6	66.3
NEST SUCCESS (%)#	66.7	36.4	47.1

*Hatching success percent of eggs that hatch

+Fledging success percent of eggs producing fledged young

^Nestling success percent young which hatch to fledging $\frac{\text{FLEDGING}}{\text{HATCH}} \text{ X } 100$

#Nest success percent nests which fledge at least one young

Many bluebird broods were infested with blowfly (Calliphora) larvae. These maggots were usually attached to the tarsi, but in heavily infested nests they were also on the abdomen, wings and head of the birds. However, this heavy infestation occurred in only 2% of the nests and the maggots were removed when the birds were two days old. They did not recur.

One entire brood of five died after a day of heavy rain and cool temperatures (13° C). The nesting material was wet and the young appear to have died as a result of this. The male parent was seen at the box the following day, but the female was not seen again.

Two predators responsible for the destruction of eggs were House Wrens and House Sparrows One box exhibited classic signs of House Wren predation, with five pierced eggs (Zeleny 1976) and a House Wren was found in a box 25 m away. House Sparrows destroyed two bluebird nests by building their own nests on top of the bluebird eggs. A third suspected predator was a Red Squirrel (<u>Tamiasciurus hudsonicus</u>). Five broken eggs were found below a nest box and a squirrel was frequently in the area.

There was an interesting occurrence at one of the nests during the 1985 breeding season. A clutch of two eggs containing both the heaviest and narrowest eggs of the season, was found in a box in which a brood of five had been reared. The five young and the parents were often seen around the box and it was assumed that the female had laid these eggs as her second clutch. The female seemed to disappear during the last days of incubation and the only birds seen around the box after this time were two juveniles from the first brood. These two birds were often seen directly at the box, but were never seen carrying any food items. Only the heaviest egg hatched, but the hatchling died in an emaciated condition four days after hatch. Its weight at hatching was similar to the hatching weight of other young. It appeared as though the two juveniles were attempting to raise the hatchling, but that they did not yet have the experience to do so.

DISCUSSION

The one month discrepancy in laying dates between 1984 and 1985 is difficult to explain. The weather in the month of April was similar in both years (personal records). The dates for the 1985 breeding season in the study area coincide closely with those given by Peakall (1970). Peak periods of egg laying in April, May and June 1985 are the same as those reported by Peakall (1970) for Quebec and Ontario. The 1984 period of peak laying in the study area was identical to the peak laying period in Peakall's study. The small peak in mid-May was also reported by Peakall.

Clutch sizes for the Hudson-Rigaud region during the 1984 and 1985 breeding seasons were very close to the Canadian average. The normal clutch size for the Eastern Bluebird is four to six eggs, with five being the most common (Laskey 1939, Hamilton 1943, Zeleny 1976, Pinkowski 1977). Peakall (1970) found the average clutch size for southern Canada at the peak of the breeding season to be 4.35, with an overall average of 4.18 ± 0.79 (n=51 nests).

The range of egg weights in this study was slightly wider than the range reported by Hamilton (1943) for bluebirds nesting in New York. Hamilton found eggs to weigh between 2.55 g and 3.22 g, while the eggs weighed in this study ranged from 2.45 g to 3.60 g. However, the range in this study covers a much larger sample size (72 versus 24). The mean egg weight for 72 eggs in this study was higher at 3.05 g than Hamilton's mean egg weight of 2.91 g for 24 eggs.

Twelve to 13 days were found to be the normal incubation period in this study Burns (1915 in Hamilton 1943) has said that the incubation period for bluebirds is 12 days. Hamilton (1943) found 13 to 14 days to be more accurate for the birds he studied.

The relationships between egg measurements and clutch size and hatching success were not very clear. There was a highly significant positive relationship between egg weight and clutch size, but not for egg weight and hatching success for the bluebirds in southern Quebec. Quinney (ms.) found that egg weight did not vary with clutch size in his study of Tree Swallows in Ontario. Kendeigh *et al* (1956) found that larger clutches of the House Wren contained heavier eggs, but they were unable to explain this phenomenon Howe (1976) did not find this relationship for Common Grackle eggs, but thought that egg weight would probably decrease in clutches larger than five Coulson *et al.* (1969) found large intra- and interclutch variations in egg size for the Shag (*Phalacrocorax aristotelis*). The lack of a correlation between egg weight and hatching success for this bluebird study agrees with the findings of Schifferli (1973), whose study on the Great Tit revealed the same result.

Decreasing egg weight with decreasing clutch size was a finding opposite to what was expected. It would seem likely that females would either put their energy reserves (protein and fat) into a large clutch of smaller eggs or a small clutch of larger eggs Slagsvold *et al.* (1984) stated that variation in the size of birds' eggs may reflect the condition of the egg-laying female The results from this study may indicate that the females laying smaller clutches have fewer reserves available Laying a smaller clutch than the normal one of five may mean that the female is in less than prime condition and is capable of laying only smaller eggs However, according to Lundberg and Vaisanen (1979), it is more advantageous to produce one egg less in unfavourable conditions than to decrease egg size because smaller eggs lead to decreased survivorship of young.

Eastern Bluebird nestlings appear to attain almost complete growth in tarsal and antebrachial length by the time they fledge The bill and the longest primary feather of fledglings are shorter than those of the adults. The weight at fledging is also close to that of the adults, but that some of this weight is lost is likely as young bluebirds begin to expend energy foraging on their own. O'Connor (1976) found that nestling Blue Tits (Parus caeruleus) and Great Tits vary greatly in weight. The heavier young probably have extra subcutaneous fat which acts as a food reserve while the young are learning to forage on their own He stated that the heavier young are more likely to survive than the lighter ones. Welty (1982) says that young that leave the nest at close to adult weight often have extra fat reserves that help them to survive periods of food shortage as they reach independence.

The tarsal growth of the young bluebirds in this study is similar to the tarsal growth of the captive young in Pinkowski's (1975) study Average tarsal length at hatching for the Hudson-Rigaud bluebirds was 7.38 mm with the most rapid period of growth beginning on the third day. Tarsal lengths at day 11 were approximately 20 mm The average tarsal length at hatching for the Michigan young was 6 3 mm By day 4 the tarsi were growing at their most rapid rate. At day 14 they had reached 21-22 mm in both studies.

The antebrachial lengths for the Hudson-Rigaud bluebirds were compared to the tarsal lengths and it was found that the antebrachi exceeded the tarsi in length by fledging age, but both appendages were close to adult length, whereas the bill was still considerably shorter The young bluebirds are fed by their parents after fledging, but they are responsible for their own locomotion. It is likely that adult lengths for the antebrachi and tarsi are more important than adult length for the bill.

The weight range for newly hatched bluebirds in this study was similar to the weight range in Pinkowski's (1975) study in Michigan (1.7-3.1 g as opposed to 1.8-3.8 g). The rate of weight gain in this study seemed to continue until the age of 8 or 9 days. The weight continued to increase after this, but it did so at a lower rate. The asymptote was found to be 27.35 g. It occurred at 13 days of age. Pinkowski found that the rate of weight gain levels off after 5 days. The pattern of weight increase for the Eastern Bluebird can be compared to that of other species. Lack and Silva (1949), working with nestling

European Robins, found the weight increase during the first 10 days of life to be extremely rapid. During the first 2 days an average increase of 2 5 times the initial weight was found, while over the whole 10 day period the robins increased their initial weight by up to 10 times The nestling weight curve constructed by Pinkowski (1975) leveled off and approached an asymptote of 27.2 g at an age of 12 days The heaviest weight reached by a nestling in Pinkowski's study was 31.8 g for a 14-day old female, while in this study it was 31.5 g for an 18-day old bird

Large differences in weight may occur for each day in Eastern Bluebirds. A range of 6.79 g was found at age 4 days in 1984, the lightest bird weighing 8.21 g and the heaviest 15.0 g A range of 10.63 g was found at age 8 days in 1984. Several more such differences were recorded for both 1984 and 1985 All birds mentioned are individuals which survived to fledging. Large differences in weight occurred for several ages in European Robins (Lack and Silva 1949). It was found that at age of 5.5 days the lightest European Robin weighed 7.8 g while the heaviest weighed 14.1 g. On day 9 5 the lightest weighed 14.9 g and the heaviest 21.9 g.

Differences in the linear measurements and weights of young surviving to fledging age and those dying on or before the 11th day of life were are not apparent at hatching It was not possible to predict which individuals will survive by examining hatchling measurements. A difference was still not apparent even on the fourth day. Only by the 11th day was there a significant difference between the measurements of survivors and non-survivors. A difference in the length of the longest primary showed up on the 7th day. Significant differences in weight occurred by the 9th day.

The fact that non-survivors grow normally for the first few days, a period during which rapid growth is taking place, suggests that they may be normal at hatching. The parents for several of the non-survivors disappeared, perhaps abandoning them in favour of starting a new brood. However, the normal growth of these broods suggests that this might not have been the case. Many broods were infested with blow-fly (Calliphora) larvae, but the infestation of non-survivors was not heavier than that of survivors. The parasitised birds generally had only two or three maggots on their bodies at one time The main reasons for nestling deaths appeared to be inclement weather and starvation due to abandonment by the parents

The Hudson-Rigaud bluebirds in this study grew at a rate of K = 0.439, with an asymptote of 27.35 g. Pinkowski's (1975) captive Michigan bluebirds had a growth rate of K = 0.488. Ricklefs (1967) calculated a growth rate of K = 0.462 for bluebirds measured in New York. The asymptotes were measured at 27.[illegible] g and 27.5 g respectively. At first glance it may seem unusual that the most northerly birds should have the slowest growth rate. Expectedly, the rate should be higher because of the shorter breeding season. However, Pinkowski (1975) reported that bluebirds in Michigan are double-brooded. Peakall (1970) also found that bluebirds are double-brooded throughout most of their range. With only two exceptions the birds in the Hudson-Rigaud area in this study did not attempt to raise two broods. Possibly, this is the reason for the lower growth rate The parents may not feed their young as vigourously as those birds destined to raise multiple broods According to Quinney (1986) the parents may be expending less energy without reducing the total costs of producing a fledgling Although he goes on to say that it is advantageous to the young to grow as quickly as possible in order to reduce the risk of predation while still in the nest, growth rates are held in check by physiological factors and by the provisioning ability of the parents. The growth pattern may be adjusted to balance the energy budget of the family group (Ricklefs 1968). Bluebirds, being cavity nesters, can afford to have a slower growth rate. Hole-nesting species generally grow at a slower rate than open-nesting species because the predation pressure on cavity-nesters is not as great.

The fact that there was no significant difference in growth rate between broods of different sizes was interesting Crossner (1970) studied different brood sizes of the European Starling and found that individuals in large broods (up to size 10) reached the same weights as individuals in smaller broods as long as a large supply of food was present. Ricklefs (1984) felt that size of nestlings is related to parental care during the growth period, but that final sizes of the body parts, attained after fledging, depend on genotypic factors. Lack and Silva

(1949), did not calculate a growth rate for their European Robins, but did find a difference in average weights of broods of size 3 and broods of size 7. Lees (1949) obtained similar results Murton et al_ 1974) found that young Woodpigeons in a brood of 1 grew 14% more slowly than young in a brood of 2. However, they attained 10% higher asymptotes. Young in large broods appear to grow more rapidly, but reach a smaller size than young in smaller broods.

When young surviving to fledging age in this study were compared to young dying while still in the nest, the survivors showed a significantly higher growth rate which was quite close to the rates given by Pinkowski (1975) and Ricklefs (1967). Growth of the non-survivors was significantly reduced.

Approximate ages at nest departure for the Hudson-Rigaud bluebirds are similar to that of 16 and 18.8 days reported by Hamilton (1943) and Pinkowski (1975) respectively The youngest birds to leave the nest in his study were 16 days old and the oldest, 22 days old. Gowaty (1983) reported the fledging age as lying between 16 and 21 days of age.

Disturbing young bluebirds after 12 days of age apparently leads to premature fledging (Hartshorne 1962, Pinkowski 1974,1975, Zeleny 1976). Most of the bluebirds in this study were handled up to an age of 13 to 16 days and the fledging ages correspond closely to those in studies where the bluebirds were not disturbed after 12 days. This finding contradicts the above.

Pinkowski (1977) found that nesting success was lowest for the earliest and the latest nests. Spring and summer nests in his study were 52.5% and 54 6% successful respectively, whereas 69.2% of nests built in the intermediate period were successful. However, because brood size was largest in the spring more young were fledged from spring clutches than from intermediate or summer clutches. The nests in this study in Hudson-Rigaud could not be divided into early and late periods, but the overall nest success for 1984 was 66.7% and for 1985 it was 36.4%, with 25 and 30 bluebirds fledging. The 1982 and 1983 breeding seasons were more successful with 42 and 44 young fledging respectively (Jackson 1982, 1983) It is possible that the lower number fledged during the two seasons of the study was due to the disturbance caused by the observer. Predators including House Wrens and raccoons were found to be the main reasons for nest failure. Cold, wet weather was also a factor. Two broods were lost after a day of heavy rain, but it could not be determined whether this was due to lack of food or to the cold temperature.

CONCLUSIONS

The beginning of this study dealt with the initiation of laying, clutch size and egg size of the Eastern Bluebird. There was no apparent reason for the earlier start to the breeding season in 1985 The periods of peak laying coincided with those reported by Peakall (1970) for Quebec and Ontario The breeding season in the study area started later and ended earlier than the breeding seasons in Michigan (Pinkowski 1975, 1977, 1978), South Carolina (Gowaty 1983) and Tennessee (Laskey 1939, 1943). Clutch size and egg size were similar to the sizes reported in the literature.

The first aspect of Eastern Bluebird nesting ecology looked at was the relationship between egg measurements and varying external conditions The answer to the first research question, whether egg size will remain constant regardless of clutch size, was negative Egg size decreased as clutch size decreased This unexpected finding is difficult to explain, but it is possible that both egg size and clutch size reflect the condition of the female

The second question, whether egg size will be the same for 1984 and 1985, could not really be evaluated. Egg width was significantly different for the two years, but egg length was the same The significant difference may simply be an artifact.

The third question must be evaluated in the same way. Eggs that hatched were significantly wider than eggs that did not hatch in 1984, but there was no difference in 1985 Egg lengths did not differ.

The last research question for egg measurements concerned egg sizes in different geographical areas. Egg sizes for the Hudson-Rigaud clutches were within the same range as that reported by Hamilton (1943) and Bent (1949).

The second aspect of Eastern Bluebird nesting ecology examined dealt with growth rates. The hypothesis to be tested was that growth rates of the Eastern Bluebird will vary under changing external conditions. The first prediction was that growth rates will be lower for individuals in larger broods. This was based on the assumption that it should be easier for parents to feed a small brood efficiently. This prediction was false. There was no significant difference between broods of one and broods of five.

The second prediction was that the growth rates for 1984 and 1985 young should differ. This prediction was false. There was no significant difference between the growth rates for the two years. The calculated growth rate appears to be normal for this area. It would be expected that a significant difference would exist if a higher or lower rate were normal.

The last prediction, that growth rates will differ from those recorded in the literature for New York and Michigan, was not tested statistically. However, the calculated rates are quite close and it is likely that there is no significant difference. The pressure on the bluebirds to grow as quickly as possible in this area because of the shorter breeding season may be balanced by the pressure on the southern birds to grow quickly because two broods are raised. This may result in the similar growth rates for the different latitudes.

The answer to the question whether growth rates of survivors would be higher than growth rates of non-survivors was positive. Survivors had significantly higher growth rates than non-survivors, indicating that non-survivors die from starvation or disease.

Eastern Bluebird populations in the Hudson-Rigaud area, while not increasing, seem to be holding their own. This study helped to show that the birds seem to be growing and developing normally, but whether or not they survive to adulthood could not be determined.

REFERENCES

Batt, B.D.J. and H.H. Prince 1979 Laying dates, clutch size and egg weight of captive Mallards Condor 81:35-41.

Bent, A.C. 1949 Life histories of North American thrushes, kinglets and their allies. U.S. Natl. Mus. Bull. 196:233-260.

Coulson, J C., G.R. Potts and J Horobin 1969. Variation in the eggs of the Shag (Phalacrocorax aristotelis). Auk 86: 232-245

Crossner, K.A. 1977. Natural selection and clutch size in the European Starling Ecology 58 885-892.

Godfrey, W.E. 1976. The Birds of Canada. Minister of Supply and Services. Ottawa.

Gowaty, P.A. 1983. Male parental care and apparent monogamy among Eastern Bluebirds (Sialia sialis) Am. Nat 121.149-157

Hamilton, W J ,Jr. 1943. Nesting of the Eastern Bluebird Auk 60.91-94.

Hartshorne, J.M. 1962. Behaviour of the Eastern Bluebird at the nest. Living Bird I:131-149.

Howe, H.F. 1976. Egg size, hatching asynchrony, sex, and brood reduction in the Common Grackle Ecology 57:1195-1207

Jackson,D. 1982. Flycatchers through Starlings. Tchebec 12.37-45.

__________. 1983 Flycatchers through Starlings Tchebec 13:41-50.

Kendeigh, S.C., T.C. Kramer and F. Hamerstrom. 1956. Variations in egg characteristics of the House Wren. Auk 73.42-65

Lack, D. 1968. Ecological Adaptations for Breeding in Birds. Chapman and Hall. London.

__________ and E. Lack 1951. The breeding biology of the Swift (Apus apus). Ibis 93.501-546

__________ and E.T. Silva. 1949. The weight of nestling Robins. Ibis 91:64-88.

Lajoie, P. and P. Stobbe. 1951. Etude des sols des comtés de Soulanges et de Vaudreuil dans la province de Québec King's Printer, Ottawa.

Laskey, A R. 1939. A study of nesting Eastern Bluebirds. Bird-Banding 10:23-32.

____________ 1943 The nesting of Bluebirds banded as nestlings Bird- Banding 14·39-43

Lees, J 1949. Weights of Robins Ibis 91·79-88.

Lombardo, M.P 1982 Sex ratios in the Eastern Bluebird. Evolution 36·615-617.

Lundberg, C A. and R.A. Väisänen 1979. Selective correlation of egg size with chick mortality in the Black-Headed Gull (*Larus ridibundus*) Condor 81·146-156

Murphy, E.C 1978 Seasonal variation in reproductive output of House Sparrows. the determination of clutch size. Ecology 59 1189-1199.

Murton, R.K , N J. Westwood and A.J. Isaacson 1974. Factors affecting egg-weight, body weight and moult of the Woodpigeon (*Columba palumbus*). Ibis 116:52-73.

Nisbet, I.C T. and W.H. Drury. 1972. Post-fledging survival in Herring Gulls in relation to brood size and date of hatching. Bird-Banding 43:161-172.

O'Connor, R.J 1976 Weight and body composition in nestling Blue Tits (*Parus caeruleus*). Ibis 118·108-112.

____________. 1984 *The Growth and Development of Birds*. John Wiley and Sons, Toronto.

Olendorff, R.R. 1972. On weighing and measuring raptors. Raptor Res. 6·53-56

Peakall, D.B. 1970. The Eastern Bluebird· its breeding season, clutch size and nesting success. Living Bird 9:239-255.

Perrins, C.M. 1970. The timing of birds' breeding seasons. Ibis 112·242-255.

Pinkowski, B.C 1975. Growth and development of Eastern Bluebirds Bird Banding 46 273-289.

____________. 1977. Breeding adaptations in the Eastern Bluebird. Condor 79:289-302.

____________. 1978. Feeding of nestling and fledgling Eastern Bluebirds. Wilson Bull 90:84-98.

Quinney, T.E. (ms.) Sources of variation in Tree Swallow egg weights.

_____________, D.J.T Hussell and C.D. Ankney. 1986. Sources of variation in growth of Tree Swallows Auk 103:389-400

Richards, F.J. 1959. A flexible growth function for empirical use J.Exp Bot 10:290-300

Ricklefs, R.E 1967. A graphical method of fitting equations to growth curves. Ecology 48:978-983

_______________. 1968. Patterns of growth in birds Ibis 110:419-451.

_______________. 1969 Preliminary models for growth rates in altricial birds. Ecology 50 1031-1039

_______________ 1983. Avian postnatal development. In Avian Biology vol. 7 Farner, D S , J.R King and K C Parkes, eds Academic Press. New York.

_______________. 1984. Components of variance in measurements of nestling European Starlings (Sturnus vulgaris) in southeastern Pennsylvania Auk 101 319-333

Schifferli, L. 1973 The effect of egg weight on the subsequent growth of nestling Great Tits (Parus major) Ibis. 115·549-558.

Sedinger, J.S. 1986. Growth and development of Canada Goose goslings. Condor 88·169-180

Slagsvold, T., J. Sandvik, G. Rofstad, O. Lorentsen and M Husby 1984 On the adaptive value of intraclutch egg-size variation in birds. Auk 101·685-697.

Sokal, R.R. and F J. Rohlf. 1969 Biometry. W H Freeman and Company, San Francisco.

Steel, R.G.D. and J.H. Torrie. 1980 Principles and Procedures of Statistics. McGraw-Hill Book Company, U.S A

Welty, J.C. 1982. The Life of Birds. Saunders College Publishing, U.S.A.

Zach, R., Y. Liner, G.L. Rigby and K R. Mayoh. 1984 Growth curve analysis of birds: the Richards model and procedural problems. Can. J. Zool. 62:2429-2435.

Zeleny, L 1976 The Bluebird Indiana University Press, Bloomington.