The University of Maine
DigitalCommons@UMaine

Electronic Theses and Dissertations

Fogler Library

5-2001

The Foraging and Habitat Ecology of Black Terns in Maine

Andrew Gilbert

Follow this and additional works at: http://digitalcommons.library.umaine.edu/etd

Part of the Natural Resources and Conservation Commons, and the Poultry or Avian Science Commons

Recommended Citation

THE FORAGING AND HABITAT ECOLOGY OF

BLACK TERNS IN MAINE

By

Andrew T. Gilbert

B.A. Bowdoin College, 1995

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Wildlife Ecology)

The Graduate School

The University of Maine

May, 2001

Advisory Committee:
  Frederick A. Servello, Associate Professor of Wildlife Ecology, Advisor
  Judith Rhymer, Assistant Professor of Wildlife Ecology
  Aram J. K. Calhoun, Assistant Professor of Wetland Ecology of Plant, Soil, and
      Environmental Sciences
  Mark A. McCollough, Threatened and Endangered Species Group Leader, Maine
      Department of Inland Fisheries and Wildlife

THE FORAGING AND HABITAT ECOLOGY OF

BLACK TERNS IN MAINE

By Andrew T. Gilbert

Thesis Advisor: Dr. Frederick A. Servello

An Abstract of the Thesis Presented
in Partial Fulfillment of the Requirements for the
Degree of Master of Science
(in Wildlife Ecology)
May, 2001

The population of Black Terns in Maine is small and factors related to the ecology of this species' foraging and habitat ecology might limit population growth and recovery. The objectives were to (1) determine if diet and provisioning rates are limiting chick growth, (2) identify and rank suitable habitat in Maine, and (3) determine if precipitation patterns and water level dynamics are limiting in Maine.

I compared growth rates of chicks in 1998-2000 in Maine to rates from other studies, determined the influence of colony, year, and diet on growth rates and food deliveries and used an energetics model to determine the sensitivity of growth rates to feeding parameters. To identify potential wetland habitat, I used a Geographic Information System analysis of National Wetlands Inventory data from Maine based on the following criteria: wetland complexes were >5 ha total area with >1 ha open water and contained semipermanently flooded emergent wetland. To assess effects of flooding, I determined the probability of occurrence for 3 levels (low, moderate, and catastrophic)

of nest losses associated with flooding, based on nest loss data and stream gauge and precipitation data for 1960-1999.

Growth rates of Black Tern chicks in Maine ($\xi = 4.46$ g/d) were similar to other studies (range 4.18-5.18 g/d) and varied with hatch order and brood, but not year or colony. Third-hatched chicks (of 3) grew most slowly ($\xi = 4.15$ g/d) but at greater rates than one reported estimate (3.32 g/d) for starved chicks. Patterns of food deliveries were complex. The ratio of fish to insects in the diet ranged from 3.4-13.3, and total delivery rates varied widely (9.1-23.7 items/brood-hr), but there was no evidence that growth rates differed among diets. Weight change in chicks was best predicted by delivery rates of large fish, large and small insects, and temperature; however, modeling indicated that growth rates were most sensitive to rates of large insect delivery. My results indicate that diet type did not influence growth rates of chicks at the observed rates of delivery, and overall there was no evidence that food resources limited fledging rates in Black Terns in Maine.

I identified 730 potential colony sites for Black Terns in Maine. Potential sites ranged in size from 5-30,864 ha ($\xi = 425$ ha) and had 0.04-228 ha of semipermanently flooded emergent wetland. However, only 51 sites were classified as high potential sites (>20 ha of semipermanently flooded emergent wetland) The availability of potential sites does not appear to be limiting the population of Black Terns in Maine, but these sites should be ground surveyed because wetland classification data may be out-dated or too coarse-grained.

Moderate flooding events have the potential to cause the greatest long-term effect on nesting success in Maine because of a high frequency of occurrence (38% of years)

and >50% nest loss in the largest colony and 36% in other colonies. Small flooding events occurred often (70% of years), but resulted in few nest losses and catastrophic flooding events caused extensive nest losses (>94% in the largest colony and 36% in other colonies) but occurred in only 13% of years.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Black Terns (*Chlidonias niger*) are a small freshwater species, which breeds on wetlands in North America and Europe. Black Terns nest semi-colonially in large emergent wetlands primarily in northern North America. The range of this species extends from the west coast east through the prairie-pothole region of central United States and Canada to western New York. East of New York, populations of Black Terns are small and disjunct and are found in several states and provinces including Vermont, Maine and New Brunswick. During the 1960's through 1990's the population of Black Terns declined in North America (Peterjohn and Sauer 1997) renewing interesting in the ecology and conservation of this species. In Maine, this species was first documented nesting in 1946 (Grover 1946) and populations have been low (<100 pairs) since then, though survey data are limited (Gibbs and Melvin 1990; D. McDougal, Unpubl. data).

Black Terns were formally listed as endangered in the state of Maine in 1997, but with little information on the ecology of this species in Maine and the factors that limited population productivity, further study was necessary to determine the status of the population and develop management strategies. In 1997 a long-term (>6 year) study was begun in Maine to assess the population of Black Terns, monitor breeding productivity, and determine factors limiting productivity. As part of this study and using data collected in 1997-1998 on the foraging patterns and growth of Black Tern chicks and nesting success in colonies in Maine, I conducted work in 1999-2000 to determine if food resources were limiting to growth of tern chicks, determine the availability of potential habitat in Maine, and determine the long-term effects of flooding on nesting success.

Chapter 1

FOOD DELIVERY PATTERNS AND GROWTH OF BLACK TERN CHICKS

Introduction

Black Terns (*Chlidonias niger surinamensis*) have recently been the focus of numerous studies in North America as a result of a range-wide population decline and the need to fill significant gaps in our knowledge of the ecology and management of this species (Dunn and Agro 1995, Peterjohn and Sauer 1997). The cause of the decline is unknown, but breeding productivity for Black Terns is generally low (Dunn and Agro 1995, Servello 2000), and a better understanding of factors limiting breeding success is needed.

Food resources frequently limit productivity in tern species (LeCroy and Collins 1972, Schaffner 1986, Monaghan et al. 1989, Massias and Becker 1990), and evidence of food limitation, i.e. loss of third-hatched chicks in a brood, has been documented in Black Terns as well (Chapman Mosher 1986, Beintema 1997). Also, because tern chicks hatch asynchronously suggests that Black Terns have evolved in food-limited environments. Black Terns typically hatch 3 eggs in 12-24 hour intervals, and feeding of chicks occurs soon after hatch of the first egg (Cuthbert 1954) resulting in the third chick lagging behind in growth (Chapman Mosher 1986). Preferential feeding of older, larger chicks by adults may lead to starvation at the expense of third or second-hatched chicks during periods of low food availability (Chapman Mosher 1986, Beintema 1997). Even when

chicks do not starve, poorly fed chicks grow more slowly, which may be detrimental to future survival as juveniles (Cooch et al. 1991, Emms and Verbeek 1991).

The quality and types of food delivered to chicks by adults, particularly the proportions of fish and insects, also may influence chick growth and survival. The proportion of fish varies from 0-34% in literature reports (Cuthbert 1954, Dunn 1979, Chapman Mosher 1986, Beintema 1997, Bernard 1999), but the effects of dietary variation on growth are not known. Diets comprised of poor quality foods may reduce growth of Black Tern chicks because of poor digestibility (Krebs and Avery 1984, Massias and Becker 1990), low energy density (Golet et al. 2000, Massias and Becker 1990, Johnston 1993), or vitamin deficiency (Beintema et al. 1996, Beintema 1997). Although often abundant, insects are more difficult to digest (Castro et al. 1989) and generally lower in energy per unit item than fish (Welham and Ydenberg 1993). Relationships between diet and chick growth need to be determined in order to understand how diet influences chick growth and population productivity of Black Terns.

Feeding patterns may differ among colony sites and therefore chick growth rates may vary as well. In poor agricultural habitat in the Netherlands, food resources limited growth of Black Tern chicks during periods of bad weather; however, in natural habitat alternative prey allowed chicks to grow normally (Beintema 1997). Additionally, Chapman Mosher (1986) reported higher growth rates where nests were close to open water and proportions of fish in the diet were higher (35-50%).

Several investigators have reported some diet data for Black Terns (Cuthbert 1954, Dunn 1979, Chapman Mosher 1986, Beintema 1997, Bernard 1999), but for the exception of Beintema (1997) who collected extensive feeding observations in Europe,

collection of food habits data were limited to a few observation sessions at few nests and did not attempt to describe the relationship between diet and growth of chicks in this species. Preliminary data on foraging by Black Terns in Maine during 1997-1998 suggested that food delivery to chicks differed among colonies, providing an excellent opportunity for studying the effects of diet and food delivery rates on growth of Black Tern chicks. My specific objectives were to (1) compare chick growth rates in Maine to rates in other regions, (2) determine factors that affect growth rates and relationships of fish and insect delivery to growth rate, (3) determine temporal and colony variation in food delivery patterns, and (4) determine the sensitivity of growth rates to variation in feeding parameters.

Study Area

I conducted research in 7 Black Tern colonies in Maine during 1999-2000. Douglas Pond, Palmyra was the largest colony with approximately 30 breeding pairs followed by the next largest colony Carlton Bog, Troy with approximately 24 pairs. The number of breeding pairs ranged from 4-20 at the remainder of the study sites: Messalonskee Lake, Belgrade; Great Moose Lake, Harmony; Huntley Brook Flowage, Princeton; Madawaska Pond, Palmyra; and Plymouth Pond, Plymouth.

All colony sites are dammed, which influences water level dynamics. At Messalonskee Lake, a hydroelectric dam strictly controls water levels. Douglas pond is an impoundment of the Sebasticook River. Water levels are controlled in this colony by the dam upstream at Great Moose Lake, a dam impounding the river downstream and a

dam on Indian River, a tributary. Madawaska Pond, Plymouth Pond, and Carlton Bog have smaller dams, which are regulated little except in the spring or fall. Madawaska Pond is in a Wildlife Management Area and is managed by the Maine Department of Inland Fisheries and Wildlife. Carlton Bog is part of the Wildlife Refuge System and is managed by the U.S. Fish and Wildlife Service (USFWS). Huntley Brook Flowage is part of a larger lake system that is influenced by at least 2 hydroelectric dams.

Terns nest locally within patches of semipermanently flooded emergent wetland (hereafter referred to as semipermanent emergent wetland). Douglas Pond (227 ha) has 44 ha of semipermanent emergent wetland bordering 85 ha of open water in 3 large patches. Great Moose Lake (1800 ha) has 43 ha of semipermanent emergent wetland mostly in a large area along the northern periphery of the lake, but the lake is largely unvegetated open water (1552 ha). Madawaska Pond (106 ha) contains 14 ha of semipermanent emergent wetland in a thin strip along the edge of 21 ha of open water. Carlton Bog (431 ha) has 75 ha of semipermanent emergent wetland bordering 113 ha of open water that has dense mats of vegetation. Plymouth Pond (253 ha) has 32 ha of semipermanent emergent wetland bordering 100 ha of heavily vegetated open water in the one cove where terns nest. Messalonskee Lake (1786 ha) has 55 ha of semipermanent emergent wetland in a large bog at the southern end of the lake and the remainder (1469 ha) is primarily open water. Huntley Brook Flowage (8271 ha) has 47 ha of semipermanent emergent wetland predominantly in a single patch adjacent to 6955 ha of open water.

At Great Moose Lake and Douglas Pond, Black Terns nest in semipermanent emergent areas dominated by river bulrush (*Scirpus* spp.) and sedge (*Carex* spp.) with

smaller patches of cattail (*Typha* spp.). At Carlton Bog, Madawaska Pond, Messalonksee Lake, Plymouth Pond, and Huntley Brook Flowage terns nest in areas dominated by *Carex* spp. and *Sphagnum* spp. and feed in open water areas predominantly vegetated by pickerelweed (*Pontederia cordata*), yellow pond-lily (*Nuphar variegatum*) and fragrant water-lily (*Nymphaea odorata*).

Methods

Chick Growth

Twenty-eight nests were enclosed in 1998-2000 in 2 wetlands (Douglas Pond and Carlton Bog). During 1999-2000 enclosures were 1-m diameter x ½-m high and constructed of 20-gauge wire mesh (6.4-mm square) and were camouflaged around the lower 12 cm with painted cloth. Two camouflaged horizontal sections (0.30 x 0.60 m) of 25-mm square wire mesh were added for shelter 15-10 cm below the top of enclosures. Vegetation similar to the nesting area was added liberally within and outside of enclosures for additional camouflage and shelter. In 1998 nests were enclosed similarly to 1999-2000, but were camouflaged only with vegetation. Enclosures were erected midway through incubation to allow adults time to adjust to enclosures before hatch. A replica of a video tripod was erected 1-2 m from each enclosure to habituate adults for future videotaping of the nest site.

I measured weight of chicks daily for a period of at least 1 week from the hatch of the first chick or until brood loss. Weight was measured using 30 g (±0.1 g) or 60 g (±0.2 g) Pesola scales (Pesola AG, Baar, Switzerland). Chicks were marked on top of the head

with enamel paint (The Tester Corp., Rockford, IL) to identify individuals. Chicks were later banded with aluminum USFWS bands on their right leg and a colony-specific color band on their left leg.

Food Delivery Observations

Five observers in 1999 and 8 observers in 2000 conducted 1 to 3-hour observations sessions of food deliveries at regular intervals throughout the nestling period from observation blinds 3-4 m above the wetland surface. I placed blinds 30-40 m from clusters of enclosed nests and 50-60 m from clusters of natural nests (no enclosures). One to 3 nests were observed during 1-2 observation sessions per colony per day. Terns at enclosures were observed during 4 time periods: 0700-1000 h (early morning), 1000-1300 h (late morning), 1300-1600 h (early afternoon), and 1600-1900 h (late afternoon). Observation sessions in the early morning and early afternoon were done on the same day and similarly late morning and late afternoon sessions were done on the same day. I alternated observation periods every other day to comprehensively record observations during 0700-1900. Terns were observed for 1-2 hours each day at clusters of natural (unenclosed) nests using a similar schedule.

I recorded food type (fish, insect, or unknown) and size relative to the adult bill (small ≤½ length of bill and large >½ length of bill). I recorded adult trips to the nest as food deliveries unless contrary evidence was observed (e.g., sustained brooding, adults ate the items themselves).

I recorded food delivery data using a remote video camera at a subset of enclosed nests concurrent with observations from blinds. A Sony CCD-TRV16 8mm video camera

was used in 1999 and a Sony CCD-TR700 HI-8mm video camera was used in 2000

(Sony Corp., Tokyo, Japan). Video recording was begun before each observation session

in blinds and recorded continuously through each observation session. Video cameras

were moved after each session to another nest in the group to cover all nests equally. I

recorded food habits and delivery data from videotapes using the same method as

described for enclosed nests and recorded information about all other visits to document

cases of misclassified observations.

Insect Sampling

I sampled aerial insect abundance at Douglas Pond in 1999 using 4 sticky traps

placed 20 m apart in the approximate center of the pond. The traps were located away

from nesting terns but in an area of heavy feeding. Traps were constructed of two 216

mm x 279 mm acetate sheets covered on both sides with Tanglefoot spray-on adhesive

(The Tanglefoot Company, Grand Rapids, MI) and affixed to two 2.4 m x 5 cm stakes.

One sheet was placed just above the water level and a second 0.9 m above the water

level. Traps were changed every other day during 1100-1600 hr. Acetate sheets were

wrapped in plastic-wrap and stored in the freezer. Insects were counted and identified to

order on each sampling sheet.

Statistical Analyses

Growth rates.- I used regression to calculate linear growth rates (Emms and

Verbeek 1991, Nisbet et al. 1995, Golet et al. 2000) for individual chicks aged 2-10 days

when growth of Black Terns chicks is approximately linear (Beintema 1997). I excluded

3 growth rates from future analyses because regressions were not significant at $\alpha = 0.10$. I calculated linear growth rates because (1) Ricklefs' logistic method (1967) required estimation of asymptotic weight, (2) non-linear growth rates are sensitive to changes in asymptotic weight (A. Gilbert, Unpubl. data), and (3) the logistic method can give misleading results for chicks with different asymptotic weights (Emms and Verbeek 1991). For comparison with growth rates, I calculated linear growth rates for other studies when logistic growth rates were reported (Dunn 1979) or no growth rates were provided (Bailey 1977, Chapman Mosher 1986). I used a t-test to compare rates among colonies in Maine and analysis of variance (ANOVA) for differences among years. I used a one-sample t-test to determine if mean growth rates from Maine differed from rates from other studies of Black Terns. I also tested for a seasonal trend in growth rate with hatch date by linear regression analysis, and I used a nested ANOVA design with brood as the nested factor to test for differences in growth rates due to hatch order (Zar 1984). Tukey's test was used to test for individual differences among factor levels. An alpha level of 0.05 was used for all tests.

Feeding observations.- I tested the assumptions that daily food delivery rates were accurate and data were temporally unbiased estimates. I paired food delivery data recorded from video with data simultaneously collected by observers in blinds and calculated the accuracy of food deliveries from observation blinds as a percentage of known deliveries determined by video. I determined the percentage of omission errors, defined as deliveries recorded from video but not recorded by observers at blinds, and commission errors, defined as deliveries recorded by observers at blinds but not recorded from video. I calculated mean accuracy and commission and omission error rates only for

observation periods with ≥25 video food deliveries to minimize effects of small sample sizes. I calculated accuracies for each taping session to estimate daily accuracies as well as observer bias (2 observers recorded >90% of observations with concurrent video data) and used a t-test to compare error rates between observers. Finally, I determined the accuracy of food habits data by type (insect or fish) and size (small or large) in cases when they were recorded by both an observer and by video.

I tested for temporal bias in daily delivery rates by tallying food deliveries over 15-minute blocks and calculating delivery rates (items/hr) for each time block. Delivery rate data were non-normal; therefore, I tested for temporal bias using ANOVA of ranked delivery rates (Zar 1984). Pair-wise comparisons were made with Tukey's test. I also grouped delivery rate data into early morning/early afternoon and late morning/late afternoon sessions and tested for differences in mean rates of food delivery between sampling periods using ANOVA on ranks.

For all analyses, I calculated delivery rates to each brood because it was impossible to observe deliveries to individual chicks. Observations of unknown type or size constitute a large proportion of observations and can affect total delivery rates by type; therefore I assigned unknown observations to food types in the same proportions that those types occurred in the diet of each brood each day. I assumed that ratios of small fish to small insects and large fish to large insects were unbiased estimates of the true ratios in the broods' diets. I used mean proportions of fish or insects from all other days for each brood when not computable. I evaluated the assumption that ratios of small and large food items described above were unbiased representatives of the true ratios in the diet. I first calculated the proportion of small food items in the diet that were small

insects and the proportion of large food items in the diet that were large insects for observations from blinds which were recorded as unknown, but for which their type and size was determined by video. Secondly, I calculated the same proportions of small and large insects in the diets of small and large food items from known deliveries from blind observations for enclosed nests and compared proportions determined from video to those calculated from blind observations.

Colony-specific diets.- I calculated mean rates of food delivery to Black Terns chicks for all colonies with greater than 5 nest-observation days. Only broods between 2 and 10 days old were included because growth is approximately linear during that period. I calculated separate estimates for enclosed and natural nests. I tested differences in rates of food delivery between enclosed and natural nests at Douglas Pond and Carlton Bog colonies using Mann-Whitney tests, but pooled all data for colony and year effects. Additionally, I calculated mean rates of food delivery to chicks of all ages in all colonies. I tested for effects of year, colony, and age of brood (categorized as young [2-5 d] or old [6-10 d]) and all 2-way interaction terms on food delivery rates at Carlton Bog and Douglas Pond during 1999-2000 by forage type using nested ANOVA at $\alpha = 0.05$. Brood was the nested factor within each of the main effects (Zar 1984). I limited food delivery data for this analysis to broods aged 2-10 days with at least 3 days of data.

Relationship between chick growth and food deliveries.- I analyzed the relationship between food delivery rates and mean daily temperature (predictive variables) to weight change per day per brood (dependent variable) using backwards-stepwise multiple linear regression analysis. A criterion of $\alpha = 0.10$ was used to include variables in the analysis. I evaluated assumptions of normality using Liliefors test (Neter

et al. 1996) and independence of predictive variables by Pearson's correlation. This analysis was limited to enclosed broods for which we had both growth and simultaneous food habits data

Insect sampling.- Linear regression analyses were used to analyze seasonal trends in total aerial insect abundance and abundances of the 5 most abundant orders.

Modeling Growth of Black Terns

To predict the sensitivity of growth of Black Tern chicks to different forage types and delivery rates, I developed a model of Black Tern chick growth (Figure 1.1) similar to that used by Winkler and Adler (1996), but using energetic equations derived for terns by Klaassen (1994). I calculated growth in discrete age increments (days) based on mean daily rates of food intake from field measurements (Table A.1). I calculated daily metabolizeable energy (DME, kJ/d) by first converting hourly food intake to metabolizeable energy intake (MEI), summing over 15 hour days, then dividing by the average clutch size for Black Terns (2.8; Servello 2000) and by assuming a 100% hatch rate of nests that survive to hatch.

In the model, daily metabolizeable energy intake (DME, kJ/d) is allocated to daily energy expenditure (DEE, kJ/d) first, then to tissue production (E_{tissue}) (Eqn. 1), which is estimated as the difference between DME and DEE. I used direct estimates of DEE because it avoided calculating energetic costs of basal metabolism (BMR), thermoregulation (E_{tr}), activity (E_{act}), and tissue synthesis (E_{syn}). The latter parameters would require additional assumptions and estimations that are difficult to support because of the lack of energetics data on Black Terns.
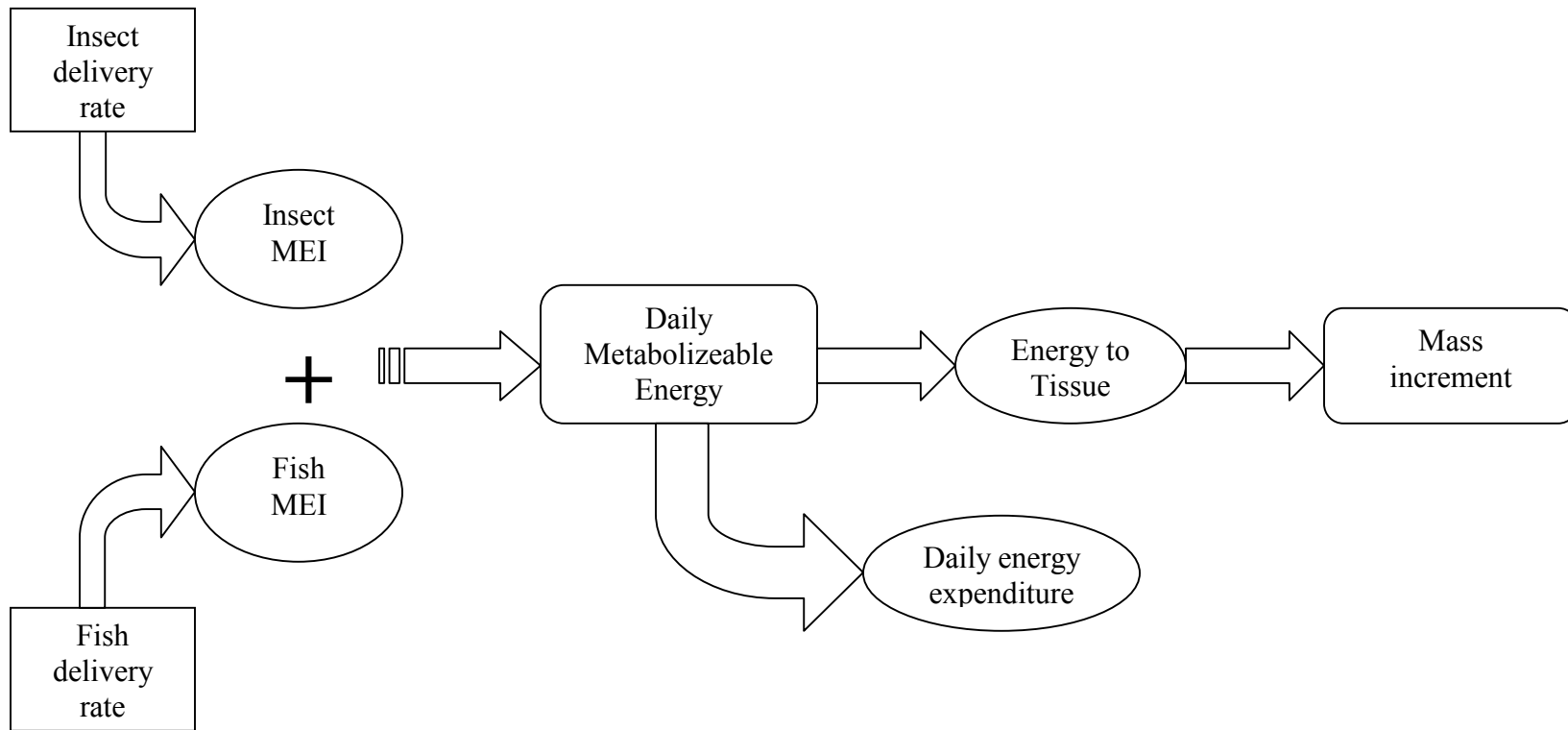
Figure 1.1. Flow model of growth of Black Tern chicks based on the energy distribution model of Klaassen (1994) and the state variable model of Winkler and Adler (1996). Food intake rates were converted to metabolizeable energy intake in kJ/hr (MEI) using conversion coefficients (mass of items, assimilation efficiency, and energy conversion). Daily metabolizeable energy was the summation of the hourly rates of insect and fish MEI over 15 hour days and converted to energy per chick per day. Energy was first allocated to daily energy expenditure (DEE), then secondarily to tissue energy production. Tissue energy was converted to daily mass increment that yielded growth in chicks when food delivery rates exceeded requirements of DEE.

$$DME = DEE + E_{tissue} \qquad\qquad (1)$$

I calculated mass increment from the relationship between E_{tissue} and tissue energy density (Winkler and Adler 1996) derived for Arctic (*Sterna paradisaea*), Common (*S. hirundo*), and Sandwich Terns (*S. sandvicensis*) (Klaassen 1994). Mass increment was accumulated from mass at hatch defined as 8 g (Dunn 1979). I estimated linear growth rates from model growth curves using the same method described above for field data.

Estimates of daily energy expenditure.- To estimate DEE for Black Terns, I used the least squares power function derived by Klaassen (1994) from field estimates of DEE for Antarctic (*S. vittata*), Common, and Arctic Terns (Table 1.1). I assume that this relationship is similar for Black Terns, but recognize that differences in environmental conditions, growth rates, and activity of Black Terns could lead to differences in DEE.

Estimates of metabolizeable energy intake.- I calculated metabolizeable energy intake (MEI) from the product of food intake rates, energy conversion relationships, assimilation efficiencies, and forage mass (Table 1.1). I used field estimates of age-specific food delivery rates for each of the 4 forage types from this study (Table A.1). Food delivery data, relative to age, were averaged over all colonies in Maine with age specific data in 1999 and 2000. Energy conversion relationships and assimilation efficiencies were derived from the literature (Table 1.1). Assimilation efficiencies vary more by food types than avian species (Castro et al. 1989); therefore, I used the average assimilation efficiency for Common, Arctic and Sandwich Terns feeding on fish (0.813; Drent et al. 1992) and the average assimilation efficiency for birds feeding on insects (0.739; Castro et al. 1989).

Table 1.1. Parameter values or equations used in the energetics model of Black Tern chick growth.

Model parameters	Value or equation	Units	Source
Intake rate[a]			
Small insect (SII)	Mean values in Maine	items/hr	This study
Large insect (LII)	Mean values in Maine	items/hr	This study
Small fish (SFI)	Mean values in Maine	Items/hr	This study
Large fish (LFI)	Mean values in Maine	items/hr	This study
Assimilation efficiency			
Insect (IAE)	0.739		Castro et al. (1989)
Fish (FAE)	0.813		Drent et al. (1992)
Energy conversion			
Insect (IEC)	24.2 (dry weight)	kJ/g	Bell (1990)
Fish (FEC)[b]	4.079 (wet weight)	kJ/g	Welham and Ydenberg (1993)
Mass			
Small fish (MSF)	0.034 (wet weight)[c]	g	Kolander et al. (1993)
Large fish (MLF)	0.31 (wet weight)	g	Kolander et al. (1993), Welham and Ydenberg (1993)
Small insects (MSI)	0.0037 (dry weight)[d]	g	Sample et al. (1993)
Large insects (MLI)	0.0633 (dry weight)[e]	g	Krebs and Avery (1984), Sample et al. (1993)
Gross intake			
Fish (GIF)	(LFI * MLF) + (SFI * MSF)	g/hr	
Insects (GII)	(LII * MLI) + (SII * MSI)	g/hr	
Metabolizeable energy			
Intake of fish (MEIF)	GIF * FAE * FEC	kJ/hr	
Intake of Insects (MEII)	GII * IAE * IEC	kJ/hr	
Daily (DME)[f]	(MEIF + MEII) * 15 hr / 2.8 chicks per brood	kJ/d	
DEE[g]	$0.67 * \text{chick mass}^{1.259}$	kJ/d	Klaassen (1994)
E_{tissue}	DME - DEE	kJ/d	Klaassen (1994)
Tissue energy density	4.094 + 4.713 * chick mass / 62.5	kJ/g	Klaassen (1994)
Mass increment	E_{tissue} / tissue energy density	g	Winkler and Adler (1996)

[a] Intake rates are per brood, not individual chicks.

[b] The average estimate of for yellow perch (3.870 kJ/g) and smallmouth bass (4.351 kJ/g).

[c] The mass for a smallmouth bass 16 mm in length.

[d] The weighted average mass of insects 7 mm in length, for 4 of the most abundant insect orders measured in 1999 at Douglas Pond by aerial sticky traps: Hemiptera (6.7%, 3.32 mg), Diptera (58.7%, 3.07 mg), Coleoptera (29.3%, 4.96 mg), and Trichoptera (5.4%, 3.71 mg).

[e] Average of the literature values for dragonflies from Krebs and Avery (1984) and estimates of masses of 21 mm moths based on Sample et al. (1993).

[f] Daily metabolizeable energy was calculated by converting hourly food intake to metabolizeable energy intake (MEI), summing over 15 hour days, then dividing by the average clutch size for Black Terns (2.8; Servello 2000), assuming a 100% hatch rate of nests that survive to hatch.

[g] Direct estimates of daily energy expenditure were calculated because it avoided calculating energetic costs of basal metabolism (BMR), thermoregulation (E_{tr}), activity (E_{act}), and tissue synthesis (E_{syn}).

Estimated masses of food items were based on published length-weight relationships and literature masses for each forage type. Small insects were defined as ≤14 mm, one-half the adult bill length (Dunn and Agro 1995) and large insects were defined as >14 mm. I estimated mass of insects 7 mm in length, the midpoint of the small insect length, based on relationships in Sage (1982) and Sample et al. (1993). A weighted average mass was calculated for the 4 most abundant insect orders measured in 1999 at Douglas Pond by aerial sticky traps: Hemiptera (6.7%, 3.32 mg), Diptera (58.7%, 3.07 mg), Coleoptera (29.3%, 4.96 mg), and Trichoptera (5.4%, 3.71 mg). I used average literature values for dragonflies from Krebs and Avery (1984) and estimates of masses of small moths (21 mm in length, ¾ the length of the adult bill) based on Sample et al. (1993). The mass of small fish was estimated from relationships between length and mass for smallmouth bass (Kolander et al. 1993) and assuming a length of 16 mm, half of the mean length of fish provided to nestling Black Terns (Welham and Ydenberg 1993).

Sensitivity analysis.- I examined the sensitivity of growth rates of Black Tern chicks to ±20% deviations of foraging and energetic variables using Stella 5.1.1 (High Performance Systems, Inc., Hanover, NH) (Figure A.1). I calculated linear growth rates for each deviation in input variables and determined the percent change relative to the reference case. I initially used multiple sensitivity levels, but limited sensitivity results to one level of deviation (±20%) because other analyses produced similar conclusions.

Results

Chick Growth Rate

Linear growth rates ranged from 2.65 to 6.11 g/d for 19 chicks from Carlton Bog in 1998 and 2000 and 36 chicks from Douglas Pond in 1998-2000 (Table B.1). High r^2 values ($\xi = 0.983$) indicated that growth was highly linear. Mean growth rate of Black Terns (4.46 g/day, $SE = 0.09$, n = 55) at Douglas and Carlton colonies during 1998-2000 was less ($t = -2.180$, $P = 0.034$) than the literature mean of 4.65 g/d ($SE = 0.11$) but within the range of growth rates of Black Terns in other regions (Table 1.2, Figure 1.2).

Table 1.2. Linear growth rates of Black Tern chicks in Maine and other colonies in North America and Europe.

Colony/Year	Growth Rate (g/d)[a]	n[b]	*SE*	Source
	Literature reports			
Creston Valley, BC 1981-84	4.18-4.87	4		Chapman Mosher (1986)
Long Pt., Ontario 1975-76	5.18	1		Dunn (1979)
Rush Lake, WI 1976-77	4.90	1		Bailey (1977)
Netherlands	4.56	1		Beintema (1997)
Poland	4.24	1		Beintema (1997)
Mean	4.65	8	0.11	
	Present study			
Carlton Bog 1998,2000	4.49	19	0.12	
Douglas Pond 1998-2000	4.44	36	0.12	
Pooled mean 1998-2000	4.46[c]	55	0.09	

[a] Creston Valley, Long Pt., and Rush Lake growth rates were calculated by me from data extracted from growth curves of Black Terns in these studies.
[b] The number of years of years of study for literature growth rates and the number of chicks in this study used in mean values reported.
[c] The mean value of all chicks pooled over 3 years of study.
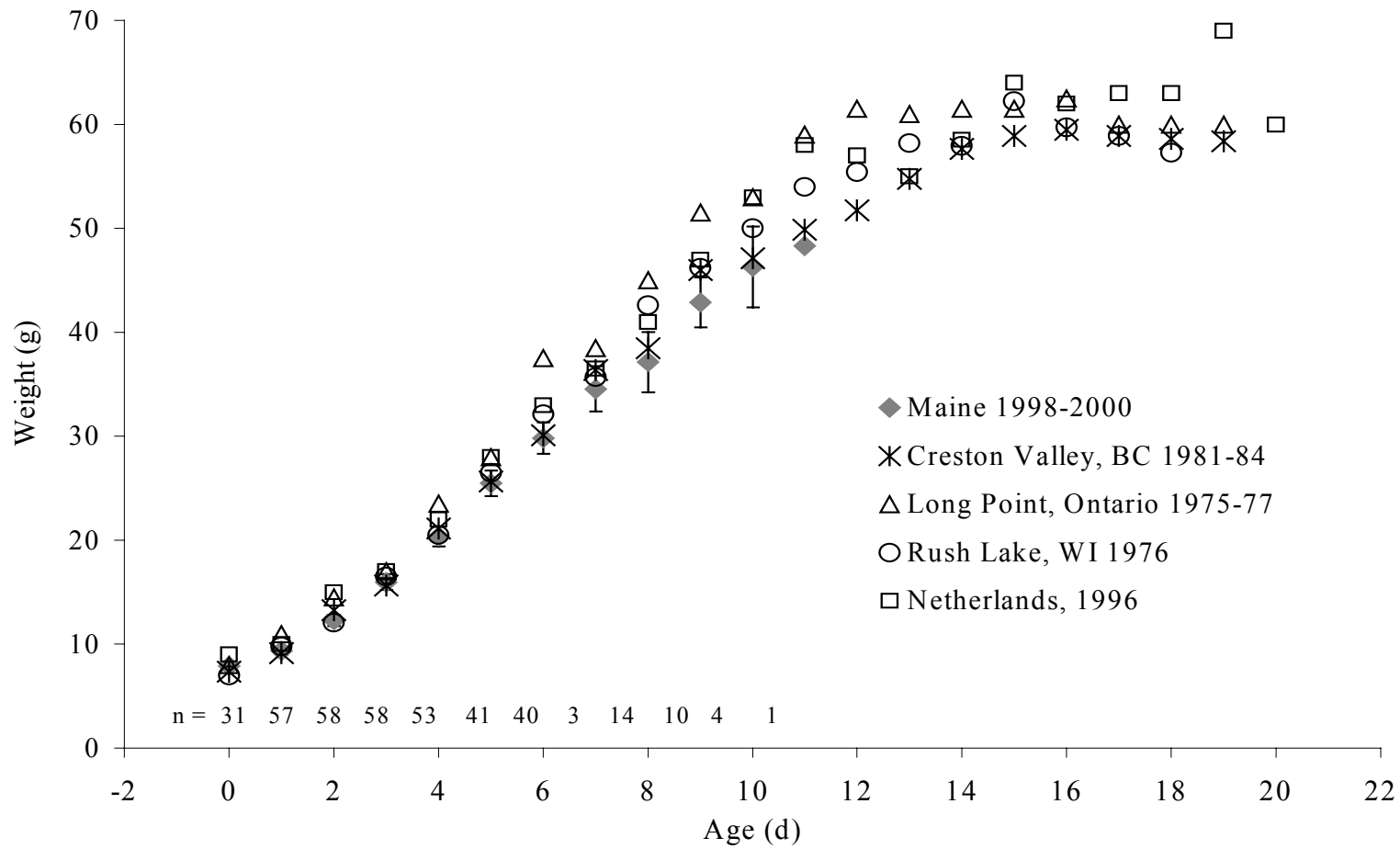
Figure 1.2. Growth of 61 Black Tern chicks at Douglas Pond and Carlton Bog colonies in Maine during 1998-2000 (0-11 days) compared with chicks from other studies in North America and Europe (0-20 days). Comparative data were from study areas in Creston Valley, British Columbia by Chapman Mosher (1986); Long Point, Ontario by Dunn (1979), Rush Lake, Wisconsin by Bailey (1977) and the Netherlands by Beintema (1997). Standard error bars represent ±2 *SE* for Maine data.

Growth rates did not differ among years ($P = 0.167$) or colonies ($t = 0.253$, $P = 0.801$); therefore, growth rate data were pooled over years and colonies for further analyses. Growth rates were not affected by hatch date within the breeding season ($P = 0.186$, n = 55, $r^2 = 0.033$) but varied among nests (range from 3.30 to 5.58 g/d, $\xi = 4.46$ g/d, $SE = 0.12$, n = 18). Growth rates were also affected by hatch order ($P = 0.031$, n = 55) (Table B.2): A-chicks ($\xi = 4.76$, n = 14, $SE = 0.17$) grew faster ($P = 0.020$) than C-chicks ($\xi = 4.15$, n = 14, $SE = 0.20$), whereas AB ($\xi = 4.47$, n = 14, $SE = 0.15$) and B-chicks ($\xi = 4.45$, n = 13, $SE = 0.16$) grew at intermediate rates.

Feeding Observations

From 1997 to 2000, >19,500 feeding observations were recorded at 5 Black Tern breeding colonies in Maine. In 1997, 624 hours of food observations at an unknown number of nests were collected at Carlton Bog, Douglas Pond, and Madawaska Pond. The actual number of nests was unknown in this year because observations were begun after nests hatched. In 1998, 247 hours of food observations were recorded from 3 nests at Douglas Pond. During 12 June-10 July 1999, 216 hours of food observations were conducted at 7 enclosed nests at Douglas Pond and 168 hours at 17 natural nests at Douglas Pond (n = 9) and Carlton Bog (n = 8). During 16 Jun-13 July 2000, 224 hours of food observations were conducted at 5 enclosed nests at Douglas Pond and 5 enclosed nests at Carlton Bog and 242 hours at a total of 23 natural nests at Douglas Pond (n = 3), Carlton Bog (n = 7), Messalonskee Lake (n = 8), Great Moose Lake (n = 4), and Madawaska Pond (n = 1). Also, 78 hours of observations by video were recorded at 5 nests in 1999 and 42 hours of observations by video at 7 nests in 2000. I reported chick

diet data for 1997 and 1998, but used only 1999-2000 data for regression analyses because 1997 data were collected opportunistically as part of productivity monitoring and are probably biased towards large food items and 1998 data were collected differently from methods used in 1999-2000.

Accuracy of feeding observations.- Overall, observers correctly identified 96.5% of feedings (n = 1293). Identification errors were comprised of 7.5% omission errors and 4.0% commission errors. Commission errors resulted from adults entering the nest to brood or incubate without feeding (32.7%), chicks refusing food items (32.7%), food items eaten by adult at the nest (9.6%), adult landed near the nest (1.9%), and unknown causes (23.1%). Mean delivery accuracy per session ranged from 82.1% to 106.9% and did not differ between observers ($t = -1.782$, n = 18, $P = 0.094$). Mean omission (6.2%) and commission (1.8%) error rates were also not different between observers (omission $t = 1.536$, n = 18, $P = 0.144$; commission $t = -1.732$, n = 18, $P = 0.102$). Observers accurately reported forage type (95.5%, n = 270); whereas, size was reported less accurately (87.9%, n = 479).

Unknown food deliveries comprised 40% of food deliveries (median = 35%) and were not obviously biased towards fish or insects. The proportion of small insects of the total of small items in the diet from video observations was similar (0.93) to the proportion of small insects of known small items in the diet (0.83) calculated from observations from blinds. Similarly, large insects were in the same proportion of total large food items in the diet from video observations compared with dietary data determined from blinds (0.63).

Assessment of temporal bias.- Total, small insect, large insect, small fish and large fish delivery rates differed ($P < 0.001$) among hourly period (Figure 1.3), with a consistent increase occurring at 1800 hr ($P < 0.05$) for total delivery, small insects, small fish, and large fish. The greatest rate occurred at 1300 hr for large insects ($P < 0.05$) and lower ($P < 0.05$) delivery rates occurred at 0700 and 0800 hr (Table C.1). This pattern was similar between enclosed and natural broods (Figure 1.4), although comparison is difficult because of the inclusion of broods from additional colonies as well as ages in the data for natural broods. Difference in feeding patterns between enclosed and natural broods may be due to differences among colonies and ages rather than enclosed vs. natural broods. Mean food delivery estimates were not biased by diurnal patterns of food delivery ($P = 0.257$); therefore, I pooled food delivery data over the entire day by brood for estimation of mean rates of food delivery for analyses of diet.

Patterns of food delivery.- During the period of linear growth (2-10 days) for Black Terns, mean rates of total food delivery did not differ among enclosed and natural nests at Carlton Bog ($P = 0.274$) and Douglas Pond ($P = 0.541$). At Carlton Bog, large insect deliveries were greater ($P < 0.001$) at enclosed nests, whereas small insect ($P = 0.002$) and small fish ($P = 0.002$) rates of delivery were greater at natural broods. At Douglas Pond, large insect rates of delivery were also greater ($P = 0.035$) at enclosed broods, whereas delivery rates of large fish were greater at natural broods (Table 1.3).

Food delivery rates varied greatly among colonies and years ranging from 9.05 items brood^{-1} hr^{-1} at Great Moose to 23.72 items brood^{-1} hr^{-1} at Messalonskee Lake for 1998-2000 (Table 1.4). Year, colony, and age effects are complex with numerous
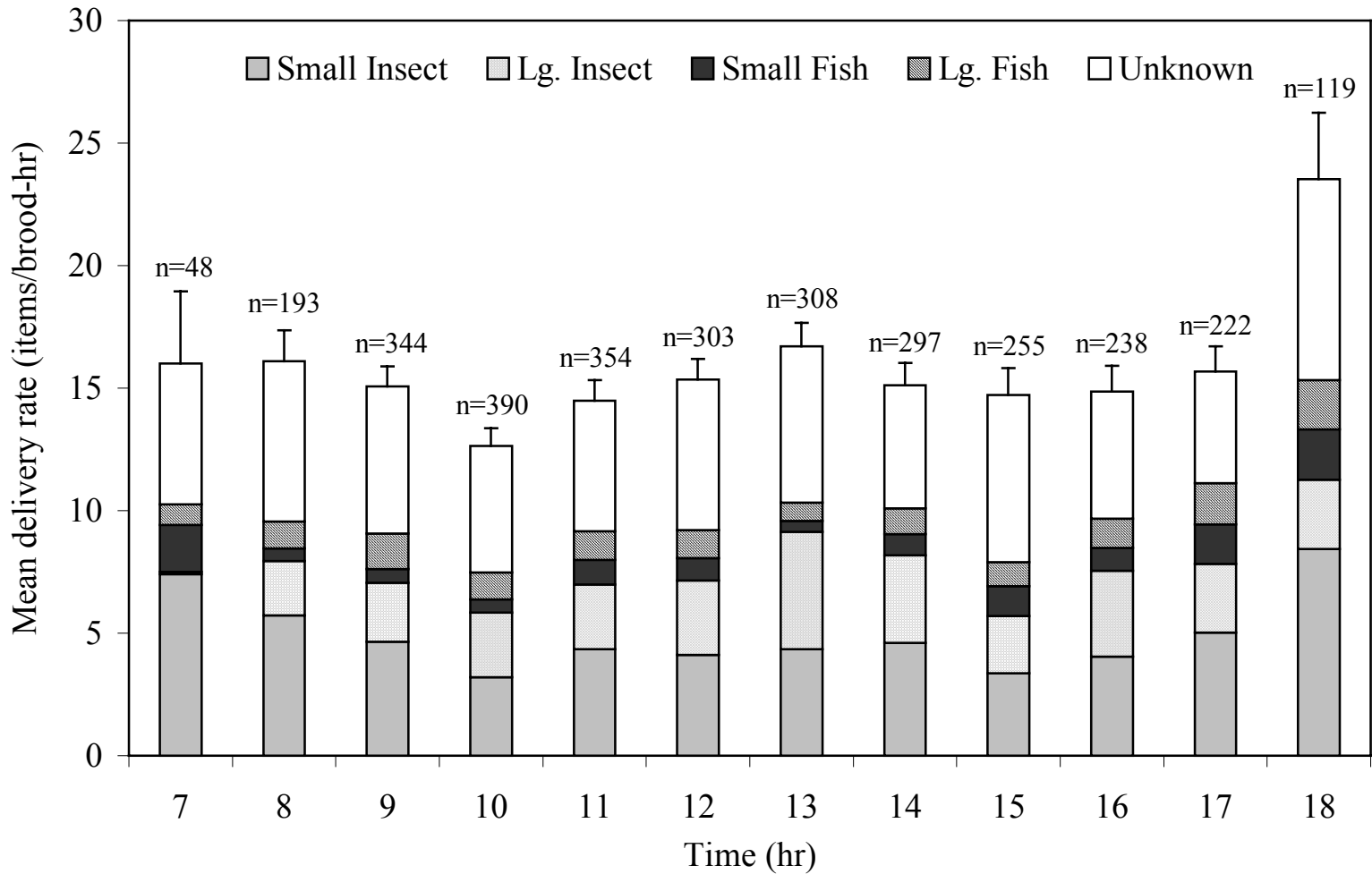
Figure 1.3. Hourly mean rate of food delivery by forage type to 57 broods between 12 June-16 July, 1999-2000. Error bars represent ±1 *SE* of the total and sample sizes are the total number of 15-minute observation periods.
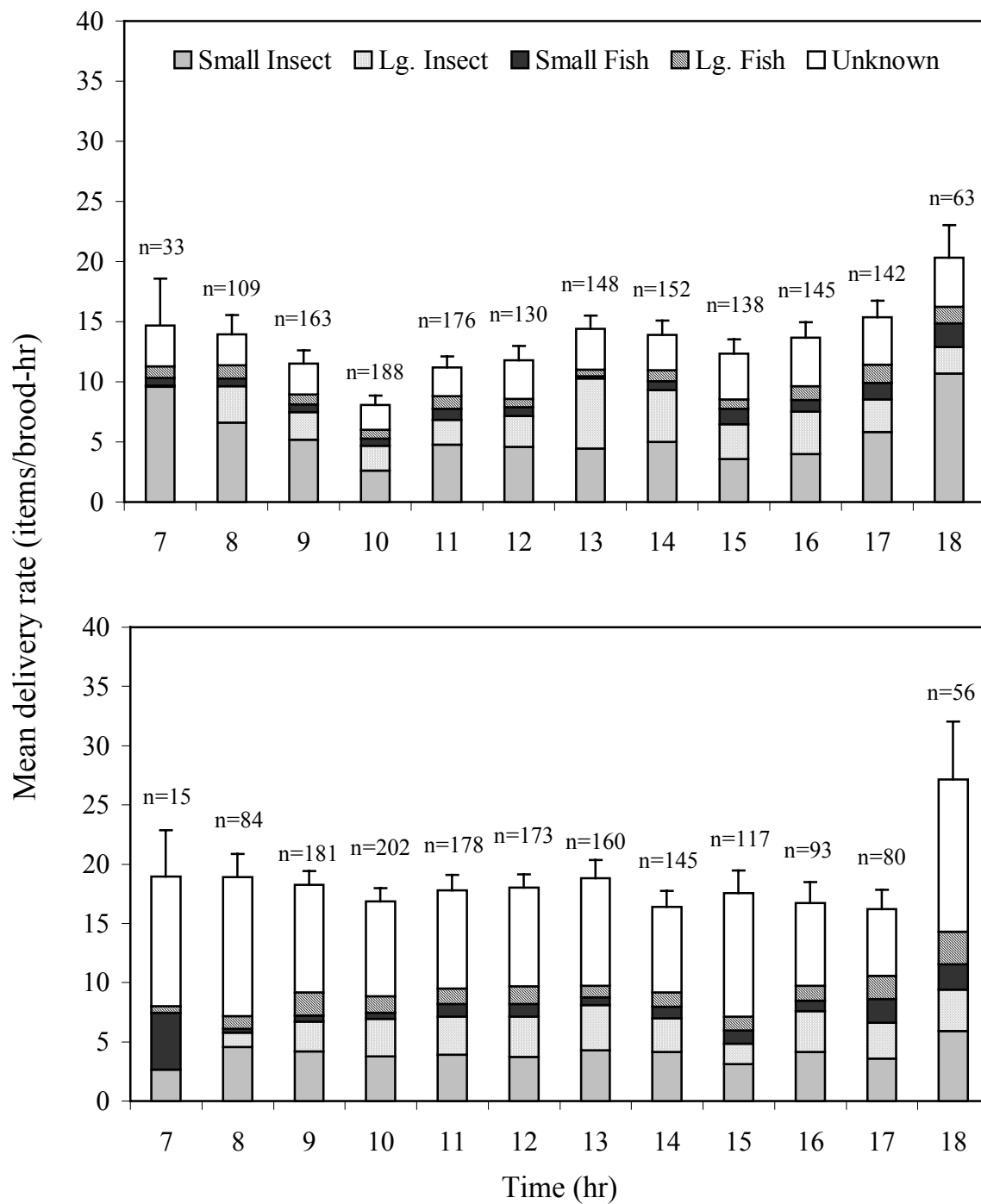
Figure 1.4. Hourly mean rate of food delivery by forage type to 17 enclosed broods (top) and 40 natural broods (bottom) between 12 June-16 July, 1999-2000. Mean rates of food delivery can't be compared directly between enclosed and natural broods because of differences in the proportion of broods from colonies and ages of broods. Error bars represent ±1 *SE* of the total and sample sizes are the number of 15-minute observation periods.

Table 1.3. Mean rates of food delivery (items brood^{-1} hr^{-1}) and insect to fish ratios for Black Tern broods during the period of linear growth (2-10 days) in 1999 and 2000.

Colony (No. nests)	n[a]	Mean delivery rate (SE)					Insect/ fish
		Small insect	Large insect	Small fish	Large fish	Total	
Douglas Pond total (21)	75	7.35 (0.80)	2.02 (0.51)	1.73 (0.35)	2.22 (0.27)	13.31 (0.98)	4.36 (0.83)
enclosed broods (11)	53	7.77 (1.05)	2.33 (0.70)	1.58 (0.33)	1.38 (0.18)	13.06 (1.21)	5.35 (1.13)
natural broods (10)	22	6.32 (1.07)	1.26 (0.49)	2.11 (0.92)	4.22 (0.66)	13.92 (1.67)	1.96 (0.62)
Carlton Bog total (19)	66	9.36 (1.14)	8.70 (1.30)	1.13 (0.34)	1.31 (0.21)	20.32 (1.50)	18.01 (3.01)
enclosed broods (5)	26	4.59 (0.81)	12.96 (2.26)	0.06 (0.06)	1.05 (0.29)	18.67 (2.19)	31.41 (6.36)
natural broods (14)	40	12.47 (1.64)	5.93 (1.42)	1.82 (0.54)	1.48 (0.29)	21.37 (2.03)	9.50 (1.93)
Messalonskee Lake[b] (8)	27	11.44 (1.60)	7.35 (1.13)	4.20 (0.73)	2.30 (0.47)	25.29 (2.41)	3.88 (1.16)

[a] Sample size is the total number of observation-days.
[b] Observations at Messalonskee Lake were of natural broods.

Table 1.4. Mean delivery rates (items brood^{-1} hr^{-1}) by forage type and the ratio of insects to fish in the diet of enclosed and natural broods at 5 colonies during 1997-2000.

Year	Colony	n[b]	Mean delivery rate[a] (SE)					Insect/ fish
			Small insect	Large insect	Small fish	Large fish	Total	
1997	Carlton Bog	76					5.35 (0.82)	0.88 (0.07)
	Douglas Pond	69					0.677 (0.10)	1.25 (0.10)
	Madawaska Pond	82					1.211 (0.13)	1.20 (0.09)
1998	Douglas Pond	45					18.31 (1.47)	8.75 (1.21)
1999	Carlton Bog	32	16.05 (1.80)	0.21 (0.10)	2.99 (1.05)	0.88 (0.24)	20.17 (1.88)	8.77 (2.26)
	Douglas Pond	74	6.85 (1.01)	1.50 (0.52)	1.86 (0.36)	2.11 (0.289)	12.32 (1.28)	4.42 (0.99)
2000	Carlton Bog	93	5.84 (0.64)	9.06 (0.97)	0.39 (0.11)	2.15 (0.29)	17.17 (1.17)	13.26 (2.24)
	Douglas Pond	35	6.76 (1.074)	2.30 (0.30)	0.74 (0.16)	1.77 (0.32)	11.31 (1.28)	5.07 (0.95)
	Great Moose	12	5.43 (1.36)	2.17 (0.66)	0.08 (0.08)	1.37 (0.50)	9.05 (1.32)	5.03 (1.53)
	Madawaska Pond	2	8.40 (1.35)	4.68 (4.10)	0.39 (0.39)	0.78 (0.20)	14.25 (5.25)	6.83 (3.17)
	Messalonskee Lake	33	10.73 (1.35)	6.51 (1.01)	3.80 (0.63)	2.68 (0.43)	23.72 (2.07)	3.40 (0.96)
1999-2000	All colonies	281	7.947 (0.49)	4.585 (0.43)	1.509 (0.19)	1.971 (0.14)	15.904 (0.68)	7.846 (0.88)

[a] Delivery rates are independent of brood age (0-21+ days post-hatch)
[b] Sample size is the total number of brood-observation days.

statistical interactions (Figure 1.5, Table 1.5). Rates of deliveries for most food types and
total deliveries were not consistent across years (1999 vs. 2000) and colonies (Douglas
vs. Carlton) (Table 1.5); and delivery rates of food types relative to age exhibited
different patterns by colony (Figure 1.5). Delivery rates of small insects ($P = 0.011$) and
fish ($P < 0.001$) were greater in 1999, balanced by lower rates of large insect delivery ($P = 0.030$). Delivery rates at Carlton Bog tended to be greater ($P < 0.001$) than Douglas
Pond, particularly insects. In contrast, Douglas tended to have greater rates of fish
delivery. Food delivery rate increased with age (Figure 1.6), but was dependent on the
colony (Figure 1.5, Table 1.5). At Carlton Bog, there was a trend of increasing delivery
rates to age 10 days and insects dominated in the diet. In contrast, Douglas Pond
exhibited slightly increasing or stable delivery rates to age 4 days and fish dominated the
diet.

Table 1.5. The effects of year, colony, and age on rates of food delivery by forage type
for 26 broods (2-10 days) in Carlton Bog and Douglas Pond during 1999-2000

	Small insect[a]	Large insect[a]	Small fish[a]	Large fish[a]	Total[a]
Year	0.011	0.000	0.030	ns	ns
Colony	0.001	0.024	ns	ns	0.000
Age[b]	ns	0.001	ns	ns	ns
Year*colony	0.000	0.000	ns	ns	ns
Year*age	0.001	ns	ns	ns	0.004
Colony*age	ns	ns	0.001	ns	ns
Brood(year*colony*age)[c]	0.000	0.000	ns	0.013	0.000
r^2	0.636	0.834	0.517	0.441	0.699

[a] Columns contain P-values and model r^2 for $\alpha < 0.05$ resulting from separate nested ANOVA by forage
type (n = 142) (Table C.2).
[b] Age is a categorical value defined as young (2-5 days) and old (6-10 days), based on the age of A-chicks.
[c] Brood was nested within year, colony, and age.
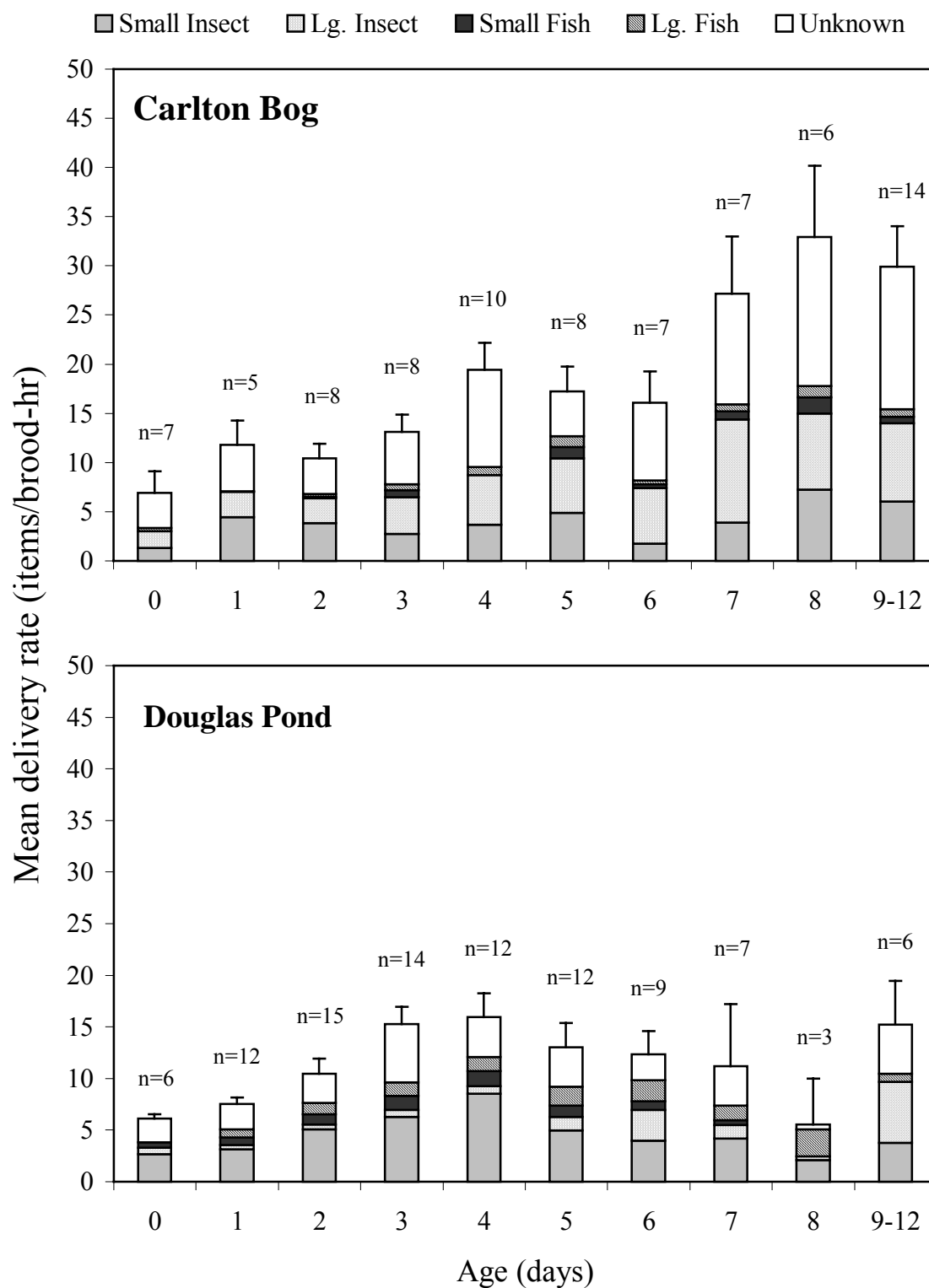
Figure 1.5. Age dependent patterns of food delivery at Carlton Bog (top) and Douglas Pond (bottom) between 12 June-16 July, 1999-2000. Error bars represent ±1 *SE* of the total and sample sizes are the number of brood-days.
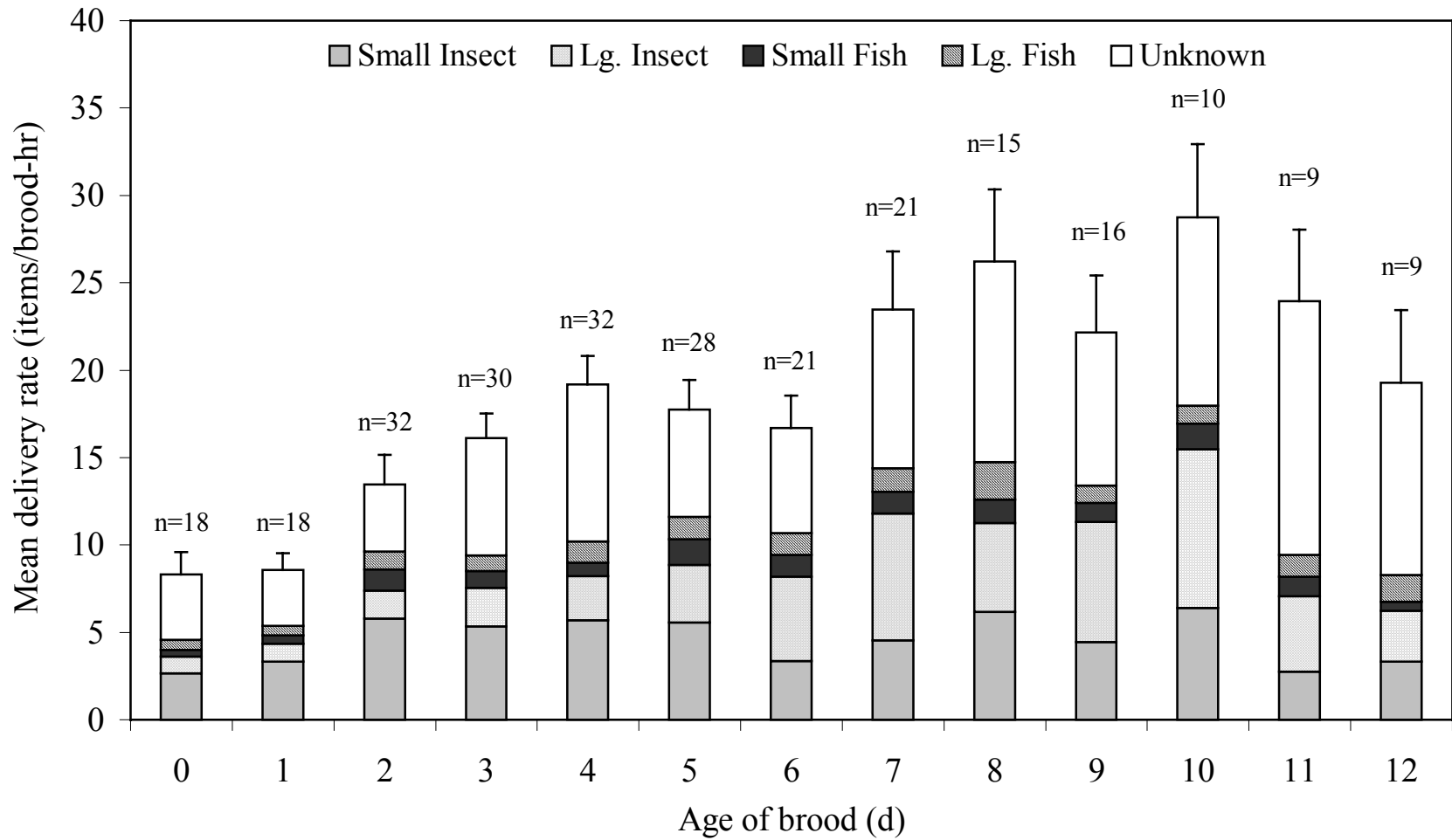
Figure 1.6. Daily mean rate of food delivery to 50 broods in Douglas Pond, Carlton Bog, and Messalonskee Lake between 12 June-16 July, 1999-2000. Error bars represent ±1 *SE* of the total and sample sizes are the number of brood-days.

Chick Growth-Food Provisioning Relationship

Net daily change in brood weight was best predicted by small insect, large insect, and large fish delivery rates and mean daily temperature ($P < 0.001$, n = 88, $r^2 = 0.232$). Small fish delivery rate was not a significant predictor variable ($P = 0.915$) and was excluded from the model. Initially, we included average age of the brood as a model term (Phillips and Hamer 2000), which improved model-r^2 substantially (0.397); however, residuals were non-normal ($P = 0.020$) and heteroscedastic; and furthermore, age was correlated with rate of large fish delivery ($r = 0.421$, $P = 0.000$) violating assumptions of independence. Therefore, I dropped age from the model, which resulted in the reduced model (Table 1.6).

Table 1.6. Results of stepwise multiple linear regression analysis of food delivery rates and mean daily temperatures on daily weight gain in 16 enclosed broods of Black Tern (0-10 days) during 1999-2000 in Maine (n = 88 brood-days).

|	Coefficient	SE	t	P
Constant	-1.647	4.244	-0.388	0.699
Small insects	0.180	0.083	2.178	0.032
Large insects	0.342	0.109	3.124	0.002
Large fish	1.404	0.426	3.294	0.001
Mean daily temperature	0.427	0.199	2.142	0.035

Insect Sampling

There was not a trend in total insect abundance during the peak nestling period from 13 June to 18 July 1999 ($P = 0.442$, n = 19, $r^2 = 0.035$). However, Coleopterids increased ($P < 0.001$, $r^2 = 0.569$), Hemipterids ($P < 0.001$, $r^2 = 0.627$) and Tricopterids ($P = 0.063$, $r^2 = 0.188$) decreased, and Ephemeroptids ($P = 0.363$, $r^2 = 0.049$) and Dipterids ($P = 0.950$, $r^2 = 0.001$) fluctuated throughout the season (Figure 1.7).
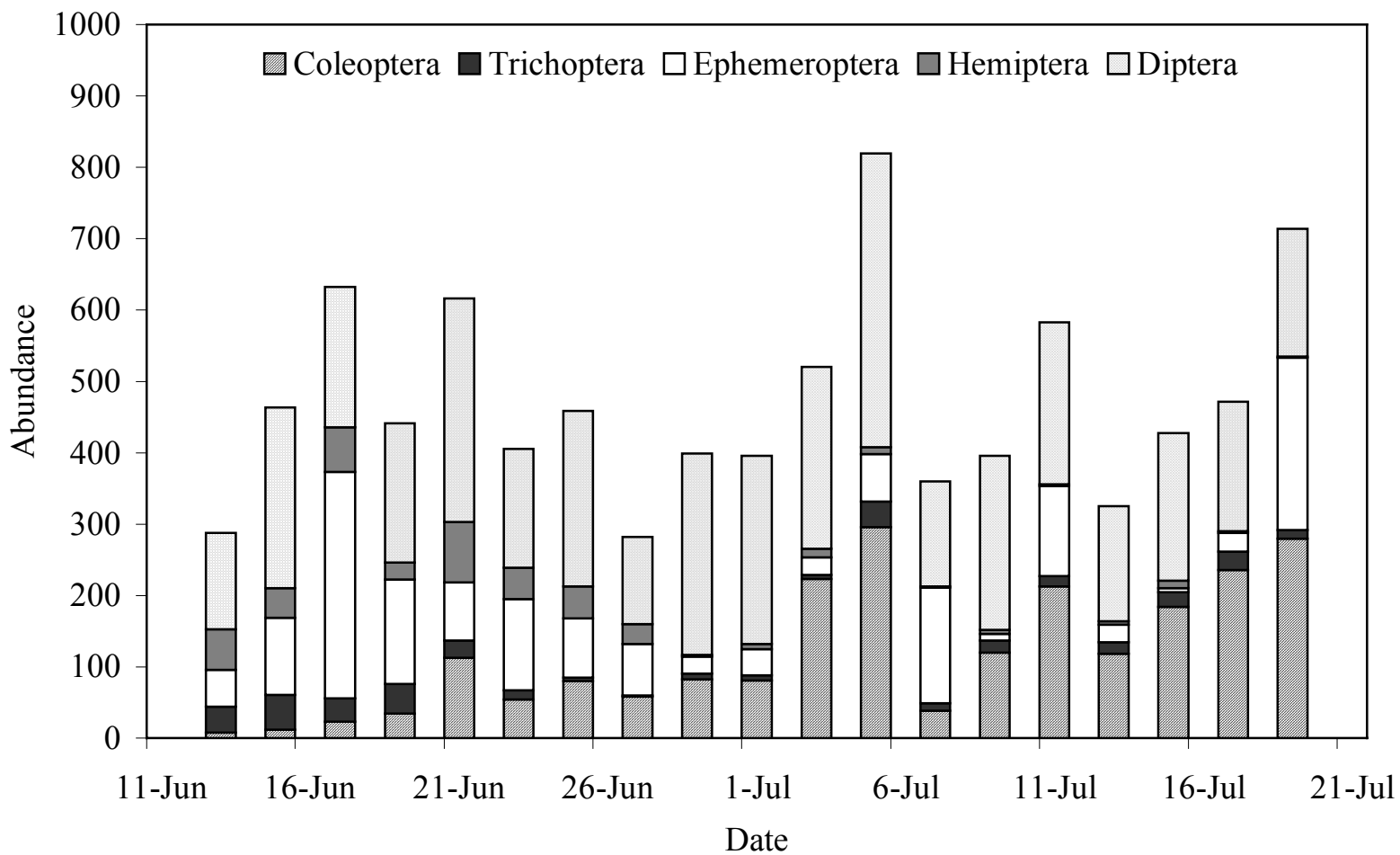
Figure 1.7. Seasonal variation in aerial insect abundance of the 5 most abundant orders sampled using 4 aerial sticky traps at 0.3 m and 0.9 m above initial water level at Douglas Pond in 1999.

Model Sensitivity Analysis

In general, growth rates were more sensitive to parameters affecting energy

acquisition for insect parameters than fish (Table 1.7). Growth rate was most sensitive to

a 20% deviation in total food delivery rates and, the greatest proportion of this change

could be attributed to a change in delivery rate of large insects (14%) and to a lesser

extent large fish (2%). Growth is next most sensitive to insect assimilation efficiency

(15%). The sensitivity to fish length was moderate (8%) and fish assimilation efficiency

was low (3%). Growth rate was equally sensitive to mass of forage types and delivery

rates as was energy conversions and assimilation efficiencies (Table 1.7).

Table 1.7. Sensitivity (% deviation in growth rate) of chick growth rates to 20% variation
in baseline values of feeding parameters in a Black Tern energetics model.

Parameter	Baseline value	Variation in parameter	
		-20%	+20%
Delivery rate or mass[a]			
Small insect	0.0037	-0.5	0.4
Large insect	0.0815	-15.1	14.4
Small fish	0.034	-0.3	0.3
Large fish	0.31	-2.2	2.2
Total		-18.3	17.2
Energy conversion or assimilation efficiency[b]			
Fish	4.079	-2.5	2.5
Insect	24.2	-15.6	14.8
Length of large fish	0.0037	-5.8	8.4

[a] Delivery rates and masses are equivalent mathematically in the model and yield the same sensitivity
results so are presented only once with baseline values given for masses.
[b] Energy conversions and assimilation efficiencies are equivalent mathematically in the model and yield the
same sensitivity results so are presented only once with baseline values given for energy conversion only.

Discussion

Black Terns are not food-limited in most years and locations. Growth rates of chicks from Douglas Pond and Carlton Bog colonies, the 2 largest colonies, were similar to growth rates previously documented in other colonies in North American and Europe (Bailey 1977, Dunn 1979, Chapman Mosher 1986, Beintema 1997). Furthermore, I found little evidence of severe C-chick disadvantage and observed no instances of starvation of any chicks. Growth rates of C-chicks were less than A-chicks, but well above rates of C-chicks lost to starvation in Europe (3.32 g/d, Beintema 1997) and within 3 years of growth measurements only 2 chicks of 55 (3.6%) grew at rates below the rate (3.32 g/d) indicative of starvation. Although, I only studied growth up to 10 days, Beintema (1997) found that Black Tern chicks that starved rarely survived beyond 10 days, and evidence of starvation usually is observed within the first few days following hatch in marine terns (Nisbet et al. 1999). I also observed no difference in growth rates between Carlton Bog and Douglas Pond despite widely differing food habits in these colonies.

Growth rates varied among broods but were not affected by hatch date. Variability in growth rates among broods can result from genetic variability (Alatalo et al. 1990), parental quality (Gaston et al. 1983, Nisbet 1995, 1998), brood size (LeCroy and LeCroy 1974, Emms and Verbeek 1991, Robinson and Hamer 2000), initial egg mass (Nisbet et al. 1995), and food quality (Hulsman and Smith 1988, Massias and Becker 1990, Golet et al. 2000), but is probably not an important factor determining productivity of Black Terns. Chapman Mosher (1986) reported slower growth of chicks later in the season in one year and Beintema (1997) gave anecdotal evidence of reduced growth rates during cold, rainy weather later in the season. My study was primarily conducted during

the early part of the breeding season; therefore, late season variability, if it occurred, was

not included. Additionally, both 1999 and 2000, when the majority of growth data were

collected, were warm and dry and food apparently abundant resulting in sufficient growth

of chicks. However, reduced food availability due to poor seasonal conditions could

occur in some years leading to food-limited growth, although it has not yet been observed

in Maine.

I detected no decline in aerial insect abundance during the peak nestling period.

Some insect orders did decline throughout the season, but total insect abundance varied

little. Additionally, I did not measure insect emergence, which is a better measure of

large insects such as dragon and damselflies (Chapman Mosher 1986). Also, variation in

insect emergence may not be predictable with peak abundances occurring at different

times each year (Chapman Mosher 1986). Variation in availability of fish as prey may

change seasonally as well, but has not been studied with respect to Black Terns.

Temperature may have a positive influence on weight gain in Black Tern chicks,

potentially through regulation of insect availability (Bryant 1978, Rauter et al. 2000) or

energetic costs of thermoregulation (Klaassen 1994, Goodbred and Holmes 1996).

However, mean temperature was not correlated with delivery rates and was probably not

the cause of this relationship. Instead, warm temperatures allow chicks to convert a

greater proportion of energy intake to growth (Goodbred and Holmes 1996, Rauter et al.

2000). Klaassen (1994) demonstrated that Arctic Tern chicks breeding in a temperate

colony required less energy for thermoregulation than Arctic Tern chicks breeding in a

polar colony with only a slight increase in brooding by adults. Brooding offsets

thermoregulatory costs until full thermoregulatory capability is reached (Klaassen 1994),

which is presumably reached by Black Terns by age 8 days when adult brooding drops to 6% of daylight hours (Cuthbert 1954).

Food delivery data were accurate and not observer-biased. Omission errors most often resulted from unobserved food deliveries that occurred simultaneously at another nest in the observation group (Pers. obs.), but were infrequent and consistent between observers and could be largely ignored as sampling error. Commission errors occurred most often because adults were incubating and not feeding and because chicks frequently refused to eat some food items. Errors of commission may be correctable with observer training and experience. While videography was useful for determining error rates, it is not recommended for food delivery monitoring because chick position, lighting, resolution, and loss of external clues (e.g., foraging location) prevented adequate food identification. Feeding data collected at natural nests (not enclosed) did not allow observers to distinguish chicks within a brood, but was effective at collecting food habits data over many nests and allowed observers to use external clues.

I believe that estimating total delivery rates for food categories based on ratios of known items in diets and total food deliveries was appropriate because of the high accuracy rates I observed in the video study as well as the lack of any obvious bias in unknown food categories. This method of estimating total deliveries by forage type did not alter the relative proportions of foods in the diets of chicks with one minor exception. In relatively few cases where adults delivered only one food type per day, I used the mean ratios of dietary items for that brood for all days to estimate total delivery rates by forage types.

Black Terns feed young both fish and insect prey (Cuthbert 1954, Goodwin 1960, Dunn 1979, Chapman Mosher 1986, Beintema 1997) and variation in diet (e.g., Douglas vs. Carlton in Maine) may affect chick growth rates. Large fish contribute roughly 4 times more energy per item to weight gain than large insects and 8 times more than small insects because of greater average weight and assimilation efficiency. The importance of providing large food items was supported by sensitivity analysis of growth rate; however, in my study I found that growth rate was most affected by changes in delivery rate (or mass) of large insects, followed by large fish. Delivery of insects may be more energetically profitable for adults where availability of fish is limited (Welham and Ydenberg 1993), but if fish are completely lacking in the diet, tern chicks may be grow less well as a result of calcium deficiency (Beintema 1997). Fish were provided at all colonies in Maine so it was impossible to test the effects of impoverishment of this food type, although this effect has not been demonstrated in Black Terns in North America and may depend on habitat. I observed adequate growth rates in Douglas Pond and Carlton Bog despite a wide range of ratios of insect to fish deliveries suggesting that growth rates are not strongly influenced by chick diets in Maine. Furthermore, during this study the proportion of fish in the diets of Black Terns in Maine was within the range described generally in literature in North America and Europe (0-34%, Cuthbert 1954, Goodwin 1960, Dunn 1979, Chapman Mosher 1986, Beintema 1997, Bernard 1999).

Colony-specific food habits are probably shaped by local food availability and adult capture efficiency. I observed that early in growth, chicks are only able to feed on small items because they are unable to swallow larger food items; however, chicks grow rapidly and are soon able to handle large prey items. Insects are generally very abundant

in freshwater wetlands and provide a good source of food, particularly large insects (e.g., odonates) which have higher energy content per item than small insects (e.g., dipterids) (Bell 1990) and are therefore more profitable for adults (Welham and Ydenberg 1993). Increasing small insect delivery rates 20% in the model increased growth rates of tern chicks less than 1%, a very poor return on investment of time and energy. Growth rate was generally more sensitive to changes in large insects and fish. Deviation in rates of large fish delivery may not have affected growth rates as much because these items were much less numerous in the diet; however, fish still represent a very important part of the Black Tern diet and may be more important where proportions of fish are greater in the diet (e.g., Douglas Pond). Welham and Ydenberg (1993) showed that Black Terns maximize the net energy gained per unit of energy expended while foraging, resulting in the lowest delivery rate to the nest possible and requiring adults to provide the highest energy per unit forage (i.e. large items). Variable food habits may reflect the need for adults to maximize efficiency because of differences in food availability among habitats.

Food delivery rates varied during the day and generally peaked in the early evening for all forage types except for large insects, High rates in the evening probably were the result of changing availability of prey or energetic needs of chicks (Pearson 1968, O'Connor 1984, Emms and Verbeek 1991, Stienen et al. 2000). A peak late in the day may buffer chicks against not being fed overnight (O'Connor 1984). Large insect delivery peaked at midday, which may be an artifact of emergence patterns (Orians 1985). Rates of food delivery generally increase to age 10, consistent with observations from the Netherlands where delivery rates peaked at age 10-12 (Beintema 1997) and Michigan where the rate of delivery increased until at least day 8 (Cuthbert 1954). This

pattern corresponds with the period of linear growth during which adults must increase

food delivery to chicks as yolk reserves decrease and maximum growth rate is reached.

However, there were differences between colonies. The peak delivery rates occurred at

age 4 in Douglas Pond and at age 10 in Carlton Bog. The high use of fish at Douglas

Pond may have allowed adults to decrease food delivery rate in contrast to Carlton Bog,

which may be energetically advantageous for adults at Douglas Pond (Welham and

Ydenberg 1993).

Insect delivery rates were more variable, whereas fish delivery rates remained

more consistent between years. Insect availability may respond more quickly and

strongly to environmental variability than fish. However, in the Netherlands, Beintema

(1997) attributed annual differences in the rates of fish deliveries to variation in fish

availability and suspected that climatic or anthropogenic factors had reduced fish

abundance. Chapman Mosher (1986) found that odonate emergence was highly variable

within and among years, which she suggested affected fledging success but not patterns

of food delivery at the nest. Bernard (1999) found that odonate abundance was greater at

impoundments used by Black Terns in New Brunswick, but reported only that they were

more numerous in the diet than fish (38% vs. 14% respectively). Differences in the diets

of Black Terns is likely a result of habitat differences affecting food availability, but as

long as sufficient food resources are available, Black Tern chicks should grow well

irrespective of the wide range in diets.

Conclusions

Black Tern productivity is probably not limited by food resources in most years and colonies in North America, because growth rates of Black Terns were similar between years and colonies in Maine and other studies in North American and large variation in chick diets (fish vs. insects) had no detectable effect on growth rates. Large food items were particularly important to the diet of Black Tern chicks allowing adults to efficiently feed young while maintaining adequate rates of growth. In some cold or wet years, large prey may be limited which could affect growth of Black Tern chicks. However, given average conditions food resources are not likely to be limited, but additional evidence of feeding patterns in poor habitat and/or years with poor weather may be necessary to determine the long-term effects of weather and poor habitat quality on growth of Black Tern chicks.

Implications For Maine

Black Terns were not food limited in Maine during this study. Food limitation probably plays only a minor role in the long-term success of this species. Three major lines of evidence support this conclusion: (1) growth rates of Black Tern chicks in Maine are comparable to rates of growth in other regions, (2) hatching asynchrony resulted in minimal third-chick disadvantage, and (3) I encountered no cases of starvation in any colony at any time, despite substantial differences in feeding patterns among colonies, suggesting that as long as adequate fish or insect prey are available in Maine, Black Tern chicks will grow well and productivity will not be reduced.

Chapter 2

AVAILABILITY OF POTENTIAL HABITAT FOR BLACK TERNS IN MAINE

Introduction

Black Terns (*Chlidonias niger surinamensis*) nest semicolonially in emergent wetlands, predominantly in the prairie-pothole region of central North America (Dunn and Agro 1995). The Maine population is disjunct from the core of the range, and the breeding population in Maine is currently distributed among 8 colony sites. Nesting by Black Terns was first reported in Maine in 1946 (Grover 1946) and populations have been low (<100 pairs) since then, though survey data are limited (Gibbs and Melvin 1990; D. McDougal, Unpubl. data). The availability and distribution of suitable breeding habitat in Maine is not known and may be important for understanding the current status and future potential of the population in Maine.

Identifying potential Black Tern habitat requires information on both local-scale and landscape-scale characteristics. Terns require emergent wetlands at least 5 ha in size and preferably greater than 20 ha (Brown and Dinsmore 1986, Hickey and Malecki 1997, Naugle et al. 1999a). Black Terns nest in shallow water substrate with 25-80% vegetative cover near open water pools (Chapman Mosher 1986, Hickey and Malecki 1997, Bernard 1999). It appears that emergent vegetation can vary among nesting colonies as long as appropriate vegetative structure is available. Landscape-scale features such as wetland isolation are also important in determining Black Tern habitat potential (Hickey and

Malecki 1997, Naugle et al. 1999a,b). Naugle et al.'s (1999b) study found that Black

Terns would nest in smaller wetlands when many additional potential wetlands were

located nearby but would not nest in small isolated wetlands. I used information from the

literature to develop a model of potential Black Tern habitat and used digital National

Wetlands Inventory (NWI) data to determine the availability of potential breeding habitat

for Black Terns in Maine. Specifically, the objectives were to (1) identify potential

wetland habitat for Black Tern nesting in Maine and (2) rank the potential of individual

wetlands. This information would be valuable for prioritizing future field surveys and

developing management strategies for Black Terns.

Methods

I identified suitable Black Tern habitat using a geographic information system

(GIS) analysis of NWI data. The identification of habitat and ranking criteria were

developed from a literature review of Black Tern habitat and 89 study site descriptions.

All manipulations of NWI data and wetland identification were accomplished using

ArcInfo 8.0 (ESRI Corp., Redlands, CA) (Appendix E).

I re-classified Cowardin classes from NWI maps (Cowardin et al. 1979) into more

general wetland classes (e.g., lacustrine open water) that were relevant to current

information on Black Tern habitat and to reduce map complexity (Table 2.1, Appendix

E). Complete reviews of tern habitat are provided later in methods. Patches of palustrine

emergent wetland were further classified by flooding regime, an essential criterion for

Black Tern habitat (Bergman et al. 1970, Naugle et al. 1999). Flooding regimes were

Table 2.1. Wetland classification scheme used in this study to re-classify delineated wetland patches from NWI maps.

New classification[a]	Cowardin system/subsystem (class)[c]	Flooding regime[f]
Lacustrine shore	L2 (RS, US, EM)	
Lacustrine open[b]	L1 (RB, UB, AB), L2 (RB, UB, AB, OW)	
Palustrine forested	P (FO)	
Palustrine open[b]	P (RB, UB, AB, OW)	
Palustrine scrub shrub	P (SS)	
Palustrine emergent permanent	P (EM[d])	h, k
Palustrine emergent semipermanent	P (EM[d])	f, g, z
Palustrine emergent seasonal	P (EM[d])	c, d, e, y
Palustrine emergent temporary	P (EM)	a, b, j, w
Palustrine other	P (ML, US, EM[e])	r, s, t, u, v

[a] This classification system was used in this study for purposes of simplifying and combining Cowardin classifications (Cowardin et al. 1979).
[b] A wide latitude of classes was allowed for use as open water, feeding sites.
[c] These are standard abbreviations used in NWI maps based on the classification system developed by Cowardin et al (1979) and presented here as they are found in NWI data.
[d] Also contained the mixed classes FO/EM or EM/FO and SS/EM or EM/SS.
[e] Only tidal emergent wetlands were placed in this category.
[f] Symbols used to describe the flooding regime in Cowardin et al. (1979) for emergent wetland and grouped here into categories based on presence and duration of standing water.

grouped into 4 flooding classes (permanent, semipermanent, seasonal, and temporary) based on the presence and duration of standing water (Table 2.1). I combined adjacent patches of palustrine (scrub-shrub, semipermanently flooded emergent, seasonally flooded emergent, temporarily flooded emergent; excluding forested and all others) and open water lacustrine wetland into wetland complexes and classified these complexes according to the most persistent palustrine emergent wetland type they contained (e.g., semipermanent, temporary) (Kantrud and Stewart 1984, Naugle et al. 1999a). Criteria were applied to these wetland complexes from which potential habitat was chosen.

Following data manipulations, potential wetland complexes were selected and
individually ranked according to the criteria below.

Habitat Suitability Criteria

The presence of emergent wetland having semipermanently flooded water
regimes (hereafter semipermanent wetland) has been identified as an important factor
determining Black Tern presence in South Dakota (Naugle et al. 1999a). These authors
demonstrated that when wetland complexes were classified according to the most
persistent flooding regime that emergent wetland patches contained within the complex
(permanent, semipermanent, seasonal, and temporary), Black Terns were primarily
associated with wetlands having a semipermanent water regime. Bergman et al. (1970)
also described potential Black Tern habitat as semipermanent and Kantrud and Stewart
(1984) found 72% of nests in semipermanent wetlands in North Dakota. Descriptions of
study areas for Black Tern research indicates that the species composition of emergent
vegetation can vary greatly among occupied breeding sites (Table 2.2). Therefore, I
identified suitable habitat in part based on the presence of semipermanent emergent
vegetation and did not consider species composition as a criterion.

Close proximity to open water appears to be an important characteristic of Black
Tern habitat (e.g., Cuthbert 1954, Dunn 1979, Firstencel 1987, Mazzocchi and Capuano
1993, Maxson 1994); and most study sites in Table 2.2 are associated with lakes, ponds,
or rivers with large open water areas. Large open water pools are sources of fish and
odonates (Chapman Mosher 1986), and when open water is in close proximity to nesting

Table 2.2. Characteristics of study sites in published and unpublished reports on Black Terns in North America.

Location (source)[a]	Area (ha)[b]	Dam present[c]	No. breeding pairs[d]	Dominant emergent vegetation	Nesting area characteristics[e]
BRITISH COLUMBIA (1)					
Duck Lake		yes		cattail, bulrush, reed-canary grass	25% standing veg., 33% open water
Leach Lake		yes		cattail, bulrush, reed-canary grass	25% standing veg., 33% open water
Corn Creek		yes		cattail, horsetail, sedge	25% standing veg., 33% open water
Elizabeth Lake	100	yes	34	bulrush	large amounts of open water
CALIFORNIA (2)					
Gould L.	10530		300		
INDIANA (3)					
Horseshoe L.			8	cattail, reed spp.	muck islands, 50% open water
Butts L.			2	cattail, reed spp.	muck islands, 50% open water
Backwaters			3	cattail, reed spp.	muck islands, 50% open water
Souseley L.			2	cattail, reed spp.	muck islands, 50% open water
Calumet			3	cattail, reed spp.	muck islands, 50% open water
Orr L.			3		muck islands, 50% open water
IOWA					
Dewey Pasture (4)	5.3		8	cattail, burreed, bulrush	
Herst Is. L. Outlet (4)	405			cattail, burreed, bulrush	
Rush L. (5)				cattail	hemi-marsh
Dan Green Slough (5)				cattail	hemi-marsh
KANSAS (6)					
Pool 3, Cheyenne Bottoms			8		
MAINE[e, f]					
Douglas P. (7)	227	yes	30	cattail, bulrush, sedge	hemi-marsh
Madawaska WMA (7)	107	yes	22	sedge	hemi-marsh
Carlton Bog (7)	431	yes	22	sedge	hemi-marsh
Plymouth P. (7)	572	yes	14	sedge	hemi-marsh
Gr. Moose L. (7)	1800	yes	33	sedge, bulrush	hemi-marsh
Messalonskee L. (7)	1786	yes	22	sedge	hemi-marsh
Bangor Bog (7)			1	cattail	hemi-marsh
Mainstream P. (7)	184	yes	7	sedge	
Huntley Brook Fl. (7)	8272		6	sedge	

Table 2.2. Continued.

Location (source)[a]	Area (ha)[b]	Dam present[c]	No. breeding pairs[d]	Dominant emergent vegetation	Nesting area characteristics[e]
Upper Mud L. (8)	3262		1	sedge	
Portage L. (h)	1163				
Corundel Marsh (8)			3	cattail	
MICHIGAN (9)					
Indian R. Marsh		yes	27	cattail, bulrush	within 7 m open water
MINNESOTA					
Burnham Cr. WMA (10)	176	yes	20	bulrush, cattail, whitetop, sedge	
Aggassiz NWR S. (11)	410	yes	40	cattail, bulrush	within 7 m open water
Aggassiz NWR W. (11)	209	yes	20	cattail, bulrush	within 7 m open water
Madsen (11)	411	yes	60	cattail, bulrush	within 7 m open water
Middle CCC (11)	36	yes	12	cattail, bulrush	within 7 m open water
Parker (11)	265	yes	40	cattail, bulrush	within 7 m open water
Boller L. (12)			6		
MONTANA (13)					
Black Tern P.			6	canary reed grass	
NEBRASKA (14)					
Inland Lagoon			6	bulrush	
NEW BRUNSWICK (15)					
McAllister Marsh		yes	13	cattail, horsetail, sedge, buckbean	near open water
Jemseg Flats		yes	13	cattail, horsetail, sedge, buckbean	near open water
Round Pond		yes	15	cattail, horsetail, sedge, buckbean	near open water
Duffies 2 Marsh		yes	4	cattail, horsetail, sedge, buckbean	near open water
Boyds Marsh		yes	12	cattail, horsetail, sedge, buckbean	near open water
Lower Babbits		yes		cattail, horsetail, sedge, buckbean	near open water
NEW YORK					
Lakeview, Floodwood (16)			10	grass spp., cattail, sedges, bulrush	20-25% open water, near open water
Lakeview, North Sandy (16)			11	grass spp., cattail, sedges, bulrush	20-25% open water, near open water
Perch R., Lower (17)		yes	56	burreed, cattail, pickerelweed	50% emergent veg.
Perch R., Upper (17)		yes	41	burreed, cattail, pickerelweed	50% emergent veg.
Perch R., Stone Mill (17)		yes	23	burreed, cattail, pickerelweed	50% emergent veg.

Table 2.2. Continued.

Location (source)[a]	Area (ha)[b]	Dam present[c]	No. breeding pairs[d]	Dominant emergent vegetation	Nesting area characteristics[e]
Wilson Bay Marsh (18)			14	grass spp., cattail, sedges, purple loosestrife, bulrush	20-25% open water, near open water
Tonawanda, Paddy II (19)	21.6	yes	20	cattail, burreed	
Tonawanda, Paddy III (20)	18.7	yes	6	cattail, burreed	
Tonawanda, Wood (20)		yes	18	cattail, burreed	
Tonawanda, Cinnamon (20)	152	yes	4	cattail, burreed	
Tonawanda, Feeder (20)	110	yes	6	cattail, burreed	
Tonawanda, Meadville (20)	42	yes	10	cattail, burreed	
Tonawanda, Ruddy (20)	138	yes	3	cattail, burreed	
Iriquois, Cayuga (19)	142.4	yes	28	cattail, burreed	
Iriquois, Knowlesville (20)	18.4	yes	7	cattail, burreed	
Iriquois, Mohawk (20)	548	yes	1	cattail, burreed	
Iriquois, Ringneck (20)		yes	3	cattail, burreed	
Oak Orchard, Windmill (19)	120	yes	15	cattail, burreed	
Oak Orchard, Oxbow (20)	56	yes	4	cattail, burreed	
Yanty Creek (21)	36		13	cattail	near open water
North P. (22)	1813			cattail	
NORTHWEST TERRITORIES					
Brackett L. (23)	375		15	sedges spp., horsetail, marestail, bulrush	
Slave Delta (24)			6		
Trout Rock P. (24)			10		
OREGON					
Fern Ridge Res. (25)			12	cattail, bulrush, canary grass	
Sycan Marsh (26)	9306			bulrush, sedge spp., tufted hairgrass	
ONTARIO (27)					
Long Point	15		32		near open water
VERMONT (28)					
Missiquoi		yes	43		
Mud Cr.		yes	7	cattail	
Memphremagog			4		
Dead Cr.		yes	18		
WISCONSIN					
E. Twin L. (29)	34.4		12	cattail, bulrush	
Lundy P. (29)	17.1		4	cattail, bulrush	
Hatfield L. (29)	40.9		5	cattail, bulrush	
Oakbridge L. (29)	71.4		11	cattail, bulrush	
Goose P. (29)	7.9		5	cattail, bulrush	
Gust WPA (29)	8.3		2	cattail, bulrush	
Flater WPA (29)	23.6		3	cattail, bulrush	

Table 2.2. Continued.

Location (source)[a]	Area (ha)[b]	Dam present[c]	No. breeding pairs[d]	Dominant emergent vegetation	Nesting area characteristics[e]
Big Muskego L. (30)	1036			cattail, bulrush, wild rice, pickerelweed	
Winnebago Pool (31)			145	cattail, burred, bulrush	mix of mudflats, emergent veg., and shallow open water
L. Butte des Morts (31)			14	cattail, burred, bulrush	
Trempeleau NWR (32)			57		
Rush L. (33)	1250		100	cattail, bulrush	1-2 m from open water
Dunn's Marsh (34)	11.33		12	cattail, burreed, bulrush	
YUKON (35)					
Blind L.			25	bulrush	

[a] Sources: 1 = Chapman Mosher (1986); 2 = Lederer (1976); 3 = Rabenold (1986, 1987); 4 = Provost (1947); 5 = Bergman et al. (1970); 6 = Parmelee (1961); 7 = this study; 8 = Pierson (1983); 9 = Cuthbert (1954); 10 = Delehanty and Svedarsky (1993); 11 = Maxson (1994); 12 = Laurent (1993); 13 = Richardson (1967); 14 = Harris (1931); 15 = Bernard (1999); 16 = Mazzochi and Capuana (1993), Knutson (1991); 17 = Mazzochi et al. (1997); 18 = Mazzochi and Capuana (1993); 19 = Hickey (1997), Hickey and Malecki (1997); 20 = Hickey (1997); 21 = Firstencel (1987); 22 = Goodwin (1960); 23 = Barrett and Kay (1997); 24 = Sirois and Fournier (1993); 25 = Papish (1993); 26 = Stern (1987); 27 = Dunn (1979); 28 = Shambaugh (1996); 29 = Faanes (1979); 30 = Hoffman (1926); 31 = Mossman et al. (1988); 32 = Laurent (1993); 33 = Bailey (1977); 34 = Sandburg (1968); 35 = Eckert (1996).
[b] Area calculations were not specified in study area descriptions. They may or may not include adjacent open water. Area descriptions from this study (Maine) include open water and are based on the size of the wetland complex, not nesting patch (excluding forested wetland on the periphery of wetland complexes).
[c] Presence of a dam or impoundment of some kind.
[d] Based on either the largest number of nests or one half largest number of adults reported for that colony, whichever was larger.
[e] Nesting area characteristics are the authors' descriptions.
[f] Nesting pair data from (D. McDougal, Unpubl. data).

areas, travel time for adults feeding chicks is reduced increasing parental efficiency (Welham and Ydenberg 1993). Gibbs and Melvin (1990) report that the mean area of open water associated with used Black Tern habitat in Maine (25.4 ± 17.4 ha) was significantly larger than the area of open water in unused wetlands (9.9 ± 25.9 ha). However, because habitat occupancy is dependent on overall wetland size (Brown and Dinsmore 1986, Naugle et al. 1999b), it is not clear if the mean open water area reported by Gibbs and Melvin (1990) can be used as criterion. Categorization of open water into palustrine vs. lacustrine systems is based upon the size of the wetland (Cowardin et al. 1979); therefore, I accepted both open water categories. I used an arbitrary minimum size of 1 ha of palustrine or lacustrine open water because of the lack of information on the minimum requirement for area of open water required by nesting Black Terns.

The size of breeding colonies is positively correlated with wetland size (Brown and Dinsmore 1986, Naugle et al. 1999b). Bernard (1999) found that terns did not nest in impoundments smaller than 20 ha in New Brunswick. Brown and Dinsmore (1986) reported 83% occupancy of wetlands >20 ha in size, declining to 42% at 11-20 ha, 33% for 5-10.9 ha, and did not colonize wetlands <5 ha. Terns would nest in wetlands <20 ha only when these wetlands were not isolated. This finding was later supported by Naugle et al. (1999b) who reported a mean area of 18.9 ha for occupied wetland complexes in South Dakota, but area-occupancy was a function of wetland density and total area of semipermanent wetland. It appears that Black Terns require large nesting areas, but will use smaller sites when other wetlands are nearby (Naugle et al. 1999b). I reviewed study site descriptions for Black Terns outside of Maine (Table 2.2) and found that the minimum area of occupied sites was 5.3 ha ($\xi = 777$ ha, median = 105 ha). However,

mean wetland area from study site descriptions may be misleading because authors often included large areas of open water that may not be used by terns. Nevertheless, a large median value and minimum wetland size suggests strong size dependence. Therefore, I used a minimum area of 5 ha for wetland complexes including open water as a criterion for potential habitat. Potential wetlands were selected from the modified NWI dataset using these criteria.

Ranking Scheme

It is clear that there is a wetland size-occupancy relationship for Black Terns (Figure 2.1); therefore, I used the following ranking criteria for total wetland area based on literature value averages and the median study area size from Table 2.2: suitable wetlands ≥5 ha but <20 ha were assigned rank 1; wetlands ≥20 ha but <105 ha (median area), rank 2; and ≥105 ha, rank 3.

Total area of semipermanent emergent wetland within a complex also is an important identifier of potential wetland habitat for Black Terns (Naugle et al. 1999a); therefore, I also ranked suitable sites according to total area in semipermanent emergent wetland within a wetland complex and assigned ranks from 0 to 3 by quartiles of the distribution of these values. The highest quartile was assigned rank 3 on the basis that they have greater area of potential nesting habitat and lower quartiles were assigned lesser ranks (2-0) accordingly.

Large contiguous patches of semipermanent emergent wetland within a complex may be more suitable as nesting habitat than fragmented patches. Hickey and Malecki
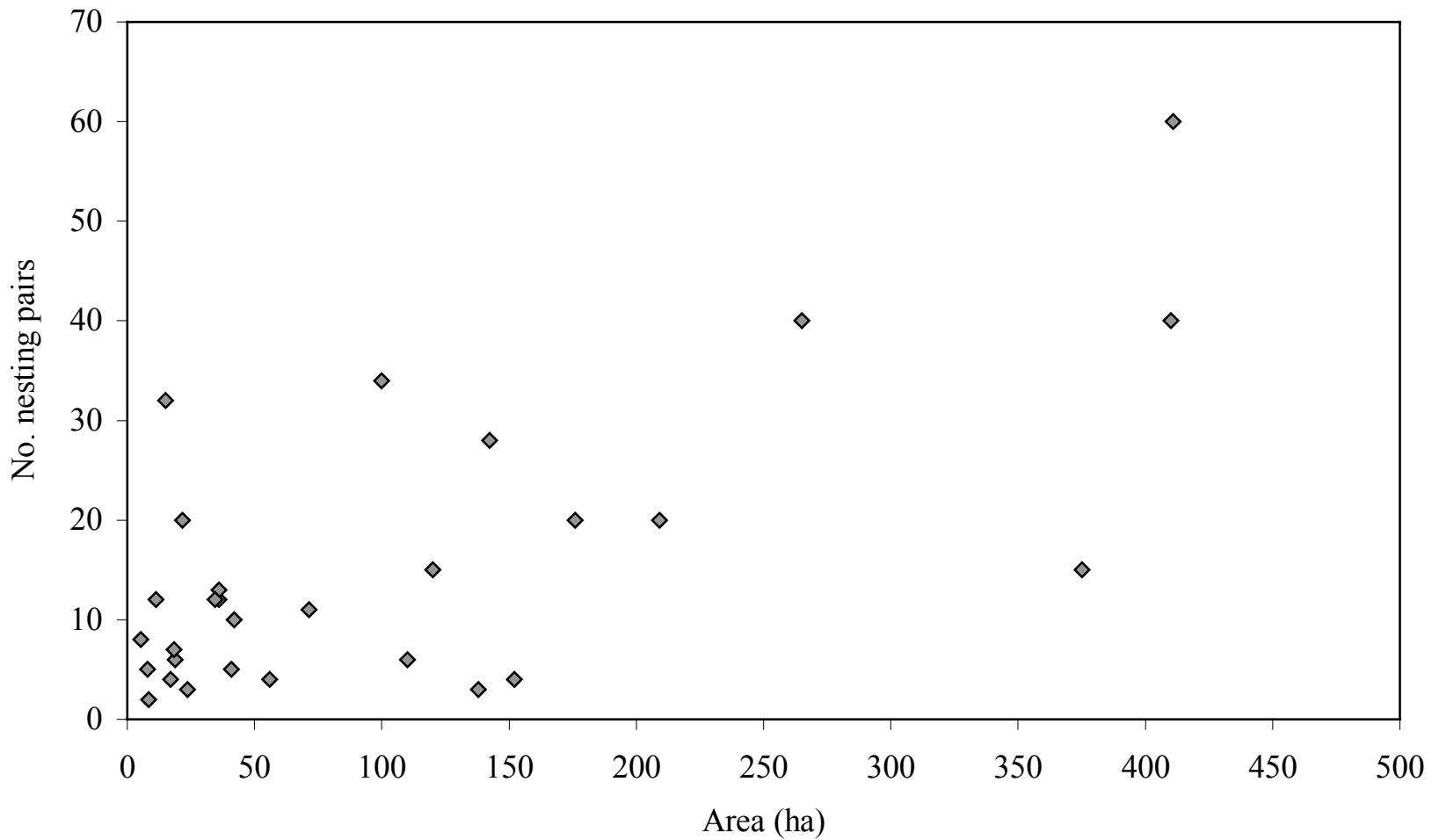
Figure 2.1. Relationship between the number of nesting Black Terns and the area of wetland habitat based on study site descriptions from published and unpublished accounts. Two study sites above 500 ha were excluded for clarity.

(1997) found that nesting areas were not smaller than 5 ha and most were larger than 20 ha. Also, because Black Terns are semi-colonial nesters with widely spaced nests (Cuthbert 1954, Dunn 1979), larger patch areas may allow larger colonies and larger colonies could enhance protection against predation (Macikunas 1993). Because of the lack of information on patch size requirement, I ranked suitable sites with respect to the largest patch of semipermanent emergent wetland within a single complex and assigned ranks from 0 to 3 by quartiles with 3 being the largest patch size.

Naugle et al. (1999b) demonstrated that wetland occupancy was dependent on the density and total area of semipermanent and seasonal wetland complexes within a 25.9 km^2 cell. These authors identified 4 patterns: (1) low density-small area (LDSA), (2) high density-small area (HDSA), (3) low density-large area (LDLA), and (4) high density-large area (HDLA). Minimum area of occupancy depended on landscape pattern with HDLA landscapes requiring the smallest minimum area (6.5 ha), LDLA requiring 15.4 ha, and HDSA requiring 32.6 ha. LDSA landscapes were rarely occupied and were not considered in my analysis. I included this occupancy pattern as a criterion by calculating semipermanent and seasonal wetland area densities within 25-km^2 cell grids and assigning 4 area-density rankings based upon the median area and density of semipermanent and seasonal wetlands for all grids (Naugle et al. 1999b). Individual wetland complexes were assigned rankings of LDLA = 0, HDLA = 1, LDHA = 2, HDHA = 3 by their inclusion in cell grids. Total rank scores were calculated from the sum of individual ranks. Total ranks could range from 1 to 12.

Results

I identified 730 potential nesting wetlands from approximately 280,000 wetland complexes in Maine (Figure 2.2, Table D.1). Potential colony sites were distributed throughout the state, but areas of high concentrations of these sites occurred in coastal eastern, central, and north-central Maine (Figure 2.2). Potential wetland complexes ranged in size from 5 to 30,864 ha (ξ = 415 ha, median = 45 ha). The area of semipermanent emergent wetland patches within complexes ranged from 0.04 to 228 ha (ξ = 6.5 ha, median = 1.3 ha), with the proportion of semipermanent type ranging from 0.0001–0.91 of the total wetland area often in >1 patch (ξ = 3.1, median = 1), with the most fragmented wetland having 180 patches. The average area of the largest semipermanent emergent wetland patch in a wetland complex was 3.5 ha (maximum = 151 ha). Fifty-one wetland complexes had large total areas of semipermanent emergent wetland (>20 ha, Figure 2.3) and were concentrated in central and eastern coastal Maine. Most current colony sites are found in central and eastern Maine and Black Terns colonize 7 high potential wetland complexes (13.7% of the total) identified in this study. Few wetlands (11 of 51) with >20 ha of semipermanent emergent wetland occurred greater than 80 miles from the coast. In contrast, most wetlands (574 of 730) had less than 5 ha of semipermanent emergent wetland and were well distributed throughout the state (Figure 2.3).

Total rankings were nearly normally distributed (Figure 2.4). Highly ranked wetland complexes were larger, had more semipermanent emergent wetland and larger patches of semipermanent emergent wetland (Figure 2.5a-c).
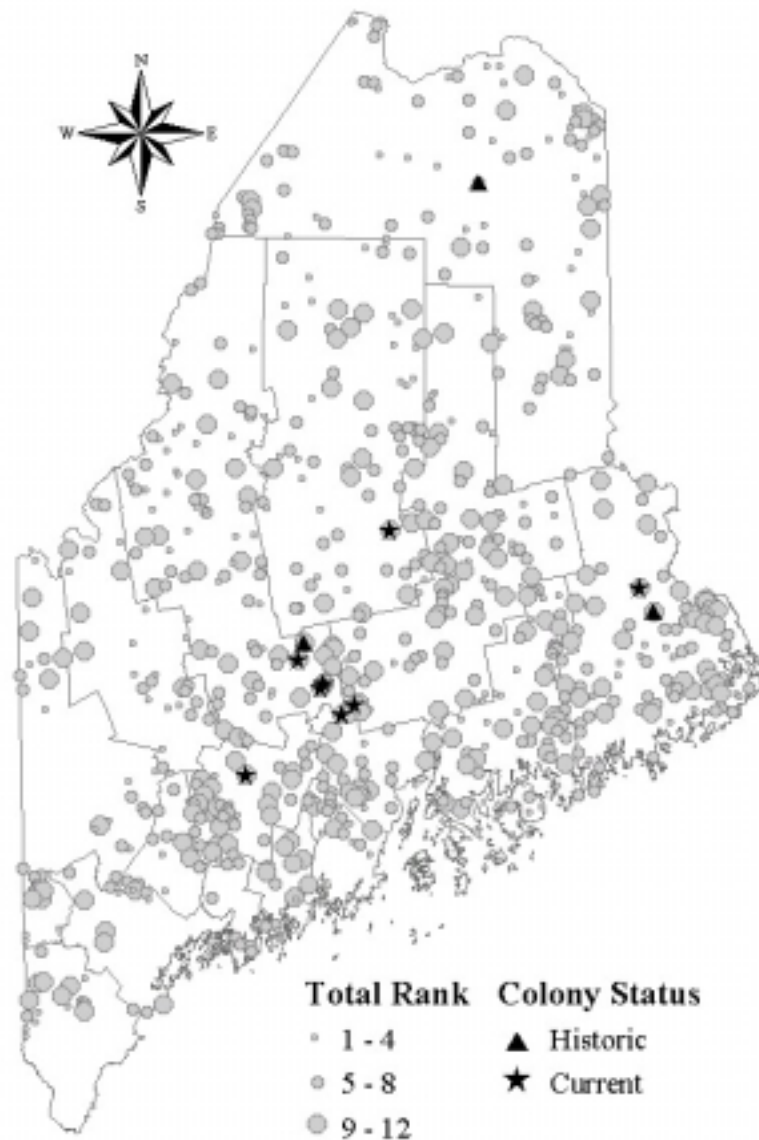
Figure 2.2. Location and categorized ranks of 730 wetland complexes identified as potential habitat for Black Terns in Maine. Stars indicate current use and triangles indicate historic use of a wetland site by Black Terns. Penjajawoc Marsh and Corundel Marsh, 2 sites where breeding terns have occasionally been observed in small numbers, are not included on this figure because they were not identified as potential habitat.
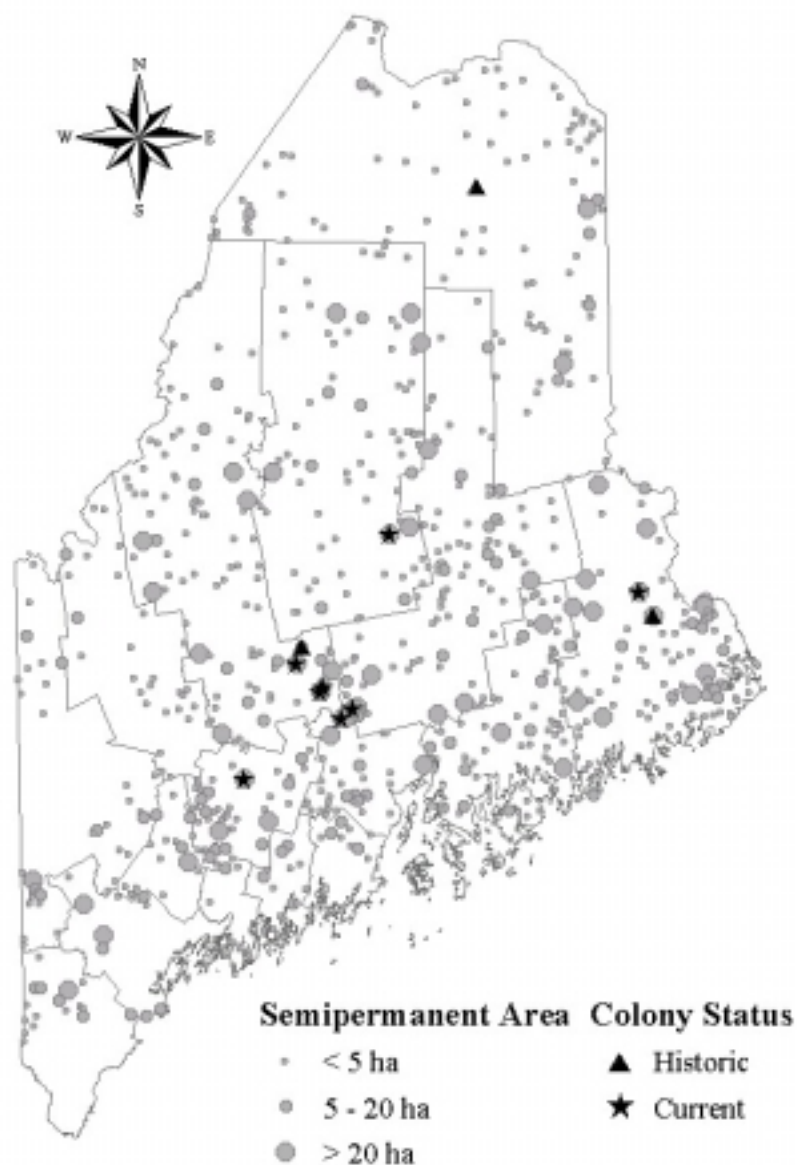
Figure 2.3. Location and area of semipermanent wetland of 730 wetlands identified as potential habitat for Black Terns in Maine. Stars indicate current use and triangles indicate historic use of a wetland site by Black Terns. Penjajawoc Marsh and Corundel Marsh, 2 sites where breeding terns have occasionally been observed in small numbers, are not included on this figure because they were not identified as potential habitat.
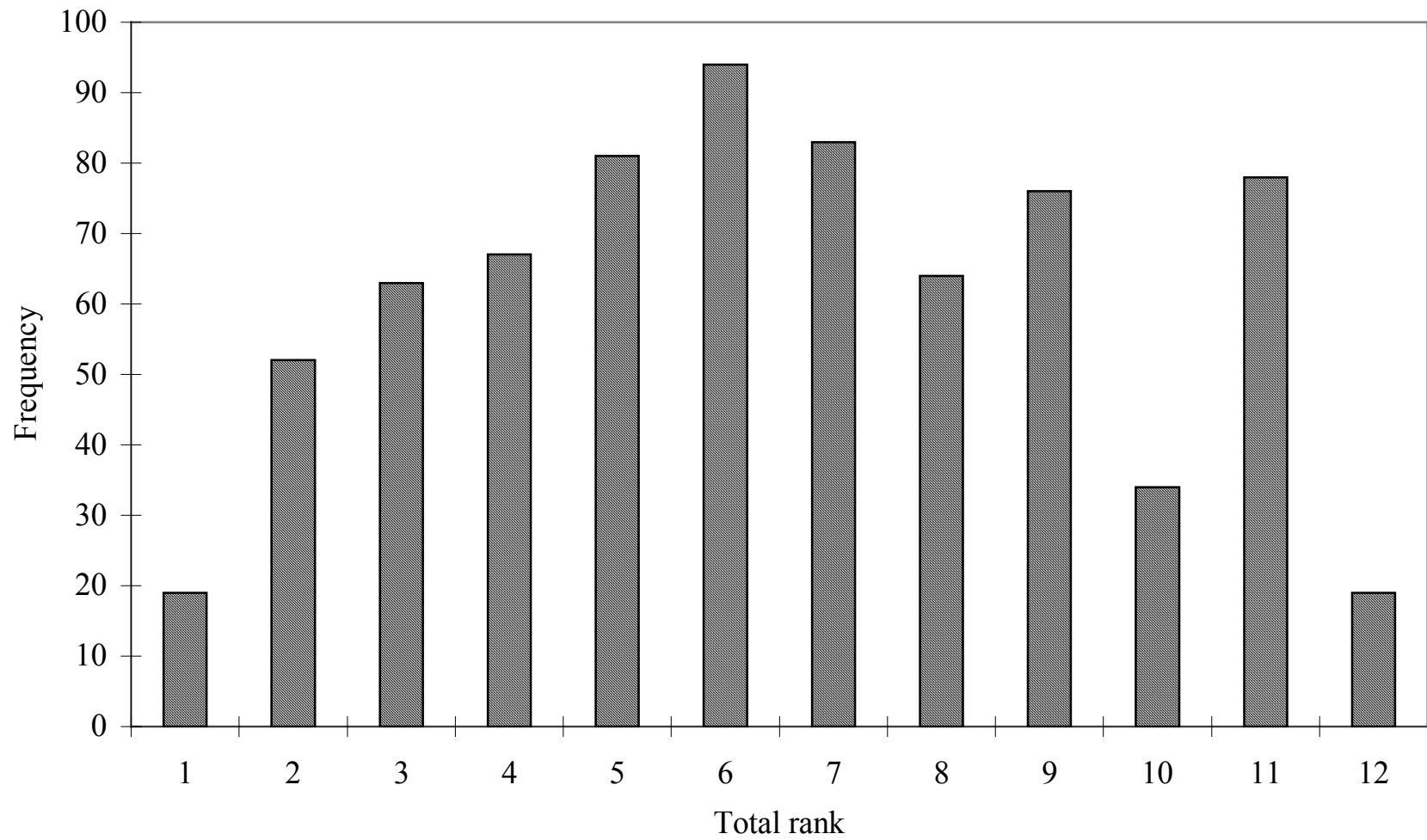
Figure 2.4. The distribution of total rankings from the analysis of potential Black Tern habitat in Maine.
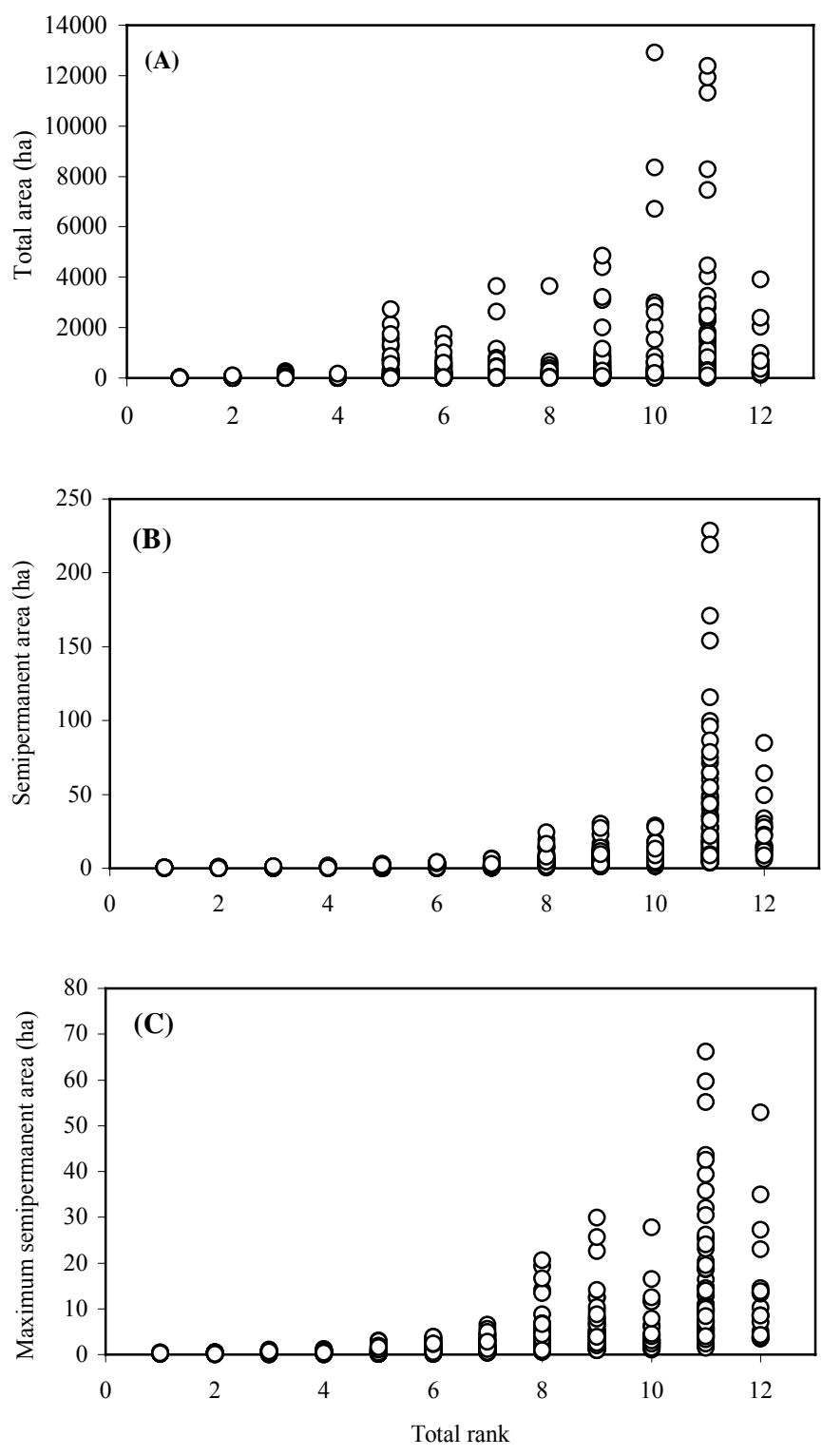
Figure 2.5. Distributions of (A) total area (B) total semipermanent wetland area and (C) maximum semipermanent patch size vs. the total ranks for wetlands identified as potential habitat. Figure (A) excludes the largest wetland complex of 30,864 ha and figure (C) excludes a single wetland having a maximum patch size of 151 ha.

Discussion

Both local habitat characteristics and landscape factors are important in determining the potential of wetlands as Black Tern nesting habitat (Hickey and Malecki 1997, Naugle et al. 1999a). Naugle et al. (1999a) correctly classified suitable habitat (22-78%) less often than unsuitable habitat (76-100%), and suitable habitat was often misidentified using landscape scale features because of local scale conditions such as poor vegetative conditions not easily identified by GIS. However, on a local scale, Hickey and Malecki (1997) were only able to correctly classify 77.2% of all plots as suitable within a nesting area. They suggested that poor model performance was due to habitat features at other temporal and/or spatial scales (e.g., landscape-scale). Social structure, group adherence, and site tenacity were also suggested as possible confounding factors not included in their model. Given that occupancy is determined by factors at 2 scales, my coarse-grained analysis likely produced a larger list of potential sites than actually occurs. Surveys to assess habitat quality are needed to refine this assessment of potential habitat.

National Wetland Inventory maps represent a single point in time, and anthropogenic factors and wetland succession may influence present day habitat suitability. The creation of farms and drainage of wetlands in southern and northeastern Maine has likely contributed to wetland change that could confound results of this analysis. For example, Corundel Marsh in Corinna and Penjajawoc Marsh in Bangor were not identified as being potential sites but had records of breeding terns. These may be cases where wetland succession has occurred as a result of anthropogenic

manipulation. Corundel Marsh last had nesting terns in 1968. This site has very dense emergent stands of cattail (D. McDougal, Pers. comm.) that Black Terns will not nest in (Linz and Blixt 1997), which may have been the result of wetland succession due to changes in water regime. Digital NWI maps are based on more recent aerial photographs, which may not be representative of wetland conditions in the 1960's. A pair of terns was confirmed breeding on Penjajawoc Marsh in 1999. According to NWI data, scrub-shrub vegetation is the predominant wetland vegetation with little to no open water, yet Gibbs and Melvin (1990) suggest that larger pools of open water with emergent vegetation may have been present since 1989. Aerial photography of Penjajawoc Marsh probably was taken before this transformation resulting in inaccuracy of this wetland classification. It must be emphasized that this study is temporally limited by the age of aerial photographs used in the production of NWI data; they provide a single record in time and lack the ability to forecast change and therefore the long-term potential of wetlands as Black Tern habitat. Overall, however, the model appears to perform well at selecting potential colony sites in Maine. Twelve of 14 wetlands (85.7%) previously colonized by at least one nesting pair were identified as potential habitat.

This study strongly suggests that Maine has additional potential habitat for Black Terns to colonize. Potential habitat is distributed throughout Maine, but is particularly concentrated along coastal central and eastern Maine and less common in the extreme southwest, western mountains, and northern regions. Potential colony sites appear to be most strongly associated with major rivers drainages flowing through central Maine (i.e. the Penobscot and Kennebec river drainages) and low-lying coastal plains. The creation of floodplains and alluvial processes associated with rivers and low topography and

depressions from erosion and glacial action contributed to the abundance of potential

wetland habitat in these areas (Tiner 1998).

Potential habitat does not appear to be limiting expansion of Black Terns in

Maine. Relatively large wetland complexes with >20 ha semipermanent emergent

wetland may have the highest potential (Hickey and Malecki 1997) and occurred within

5-40 km of current and historic colony sites. Therefore, there is potential for expansion

and/or movement. Additional habitat with less than 20 ha of semipermanent emergent

wetland may also be utilized in areas of high heterogeneity (Naugle et al. 1999b),

suggesting that many more sites have potential for colonization inland of the coastal

plain. Black Terns have recently expanded their range north and westward in Canada

(Sirois and Fournier 1993, Barrett and Kay 1997, Cooper and Campbell 1997) suggesting

that range expansion into previously unoccupied habitat can occur; and Stern (1987) has

shown that local movement is also common among Black Terns. The availability of

potential habitat suggests that expansion of the population is limited by poor productivity

and small population size. Also, Black Terns may not colonize new wetlands as long as

adequate nesting substrate is available in current colonies.

The approach used in this study reflects the synthesis of many bodies of work

across the range of this species. However, most of the study area descriptions and habitat

studies used to develop methods in this study were from colonies closer to the periphery

of this species' range rather than the core in the prairie-pothole region (Dunn and Agro

1995, Peterjohn and Sauer 1997). Despite the limited amount of information from core

areas of the range of Black Terns, characteristics of their nesting habitat are generally

similar, which suggests that this model has applicability for assessing Black Tern breeding habitat in other states and provinces in North America.

Management Implications

Protection of potential habitat near existing colonies will be important for expansion and growth of the Black Tern population. Future work to assess potential habitat should begin near current nesting colonies because these sites may have the greatest probability of colonization. I believe rankings provide resource managers a good index of the potential of wetlands as breeding habitat for Black Terns. However, I recommend ground or aerial surveys to determine the true potential of wetlands with high rankings because this was a coarse-grained analysis. Highly ranked wetlands were not always the largest wetlands, but generally had greater amounts of total semipermanent emergent wetland area and larger maximum patch size. Because of the presence of a large number of potential colony sites, it may be necessary to first prioritize surveys of highly ranked wetland complexes followed by lower ranked wetlands if they are near other colony sites and/or in areas of high wetland density.

Resource managers should protect wetland habitat not merely at the local scale but should manage potential habitat at the landscape scale, which includes protecting not only current tern nesting habitat but also the surrounding upland and nearby wetlands. Novak (1992) suggests protecting all current and historic breeding wetlands ≥5 ha in states where Black Terns are endangered, but I would advise protection of current breeding wetlands and their surrounding uplands and nearby wetlands with areas of

semipermanent emergent wetland >20 ha in the event that current colony sites become

unsuitable for nesting terns. Locally, maintenance of appropriate vegetative structure and

nesting substrate is important, which could be achieved through intentional or natural

draw-downs (Hickey 1997). All colony sites in Maine have water level control structures

that may allow resource managers to maintain an appropriate composition and density of

vegetation. If current sites are maintained and protected as high quality habitat for Black

Terns and the population expands, then further colonization of additional habitat may

follow in nearby wetlands as long as this habitat is protected as well.

Chapter 3

EFFECTS OF LONG-TERM WATER LEVEL DYNAMICS ON NESTING

SUCCESS OF BLACK TERNS IN MAINE

Introduction

Black Terns often nest in freshwater wetlands characterized by dynamic water levels, which can have deleterious effects on nesting success (Bergman et al. 1970, Bailey 1977, Chapman Mosher 1986). Flooding from rain events is a major source of nest losses (Dunn and Agro 1995) because Black Terns (*Chlidonias niger*) nest only 2-5 cm above water level (Bergman et al. 1970, Dunn 1979, Davis and Ackerman 1985). Black Tern nests are built on both buoyant material such as dead wetland vegetation or rootstock and fixed substrates such as muskrat lodges, feeding stations, and mudflats (Cuthbert 1954, Bergman et al. 1970, Bailey 1977, Dunn 1979). Floating substrates may prevent losses from minor increases in water level but may not float enough to prevent losses from rapidly rising water levels or severe flooding events (Pers. obs.).

Many studies have reported substantial nest losses in Black Tern colonies from water level increases or wave action with estimates ranging from 3-40% (Cuthbert 1954, Bergman et al. 1970, Bailey 1977, Dunn 1979, Macikunas 1993, Hickey 1997, Mazzocchi et al. 1997). The frequent reports of losses from flooding suggest long-term consequences to Black Tern populations. The greatest nest loss reported from weather was 40% in New York followed by a 24% loss in the following year (Hickey 1997).

Chapman Mosher (1986) reported 4 consecutive years of nest loss from weather in British Columbia with losses decreasing from 27.1% to 13.5% over the 4 years because of improving weather conditions and better control of water levels. A Black Tern (*C. n. niger*) colony in Lithuania annually lost 15-30% of all nests from water level fluctuations over a 7-year period (Macikunas 1993). While these accounts demonstrate that substantial nest losses from water level changes occur, they did not estimate the frequency of nest losses or evaluate long-term effects on breeding success and ultimately the potential for limiting population growth. Long-term analyses would provide a basis for evaluating climatic patterns as limiting factors for threatened Black Tern populations. A better knowledge of the long-term consequences of flooding on nest losses and the precipitation patterns that produce such events are essential to ensure the stability of the population of Black Terns.

The Black Tern population in Maine is small (<100 pairs) and while the population appears to have been stable since at least 1994 (D. McDougal, Unpubl. data), the rate of population growth is sensitive to changes in productivity (Servello 2000). Flooding events in 1997 and 1998 resulted in substantial nest loss in colonies in Maine suggesting the potential for significant reduction in productivity in some years from flooding, but the long-term effects of flooding are not known. The goal of this study was to evaluate the importance of water level dynamics and precipitation on the breeding productivity of Black Terns. The specific objectives were to (1) identify seasonal patterns of water level dynamics at colony sites and relationships to local precipitation; (2) determine the long-term potential for daily nest losses due to water level increases during the breeding season at Douglas Pond, the largest colony in Maine; and (3) determine the

long-term potential for nest losses in Maine based on the relationship between precipitation and water level.

Study Area

I conducted research in 7 Black Tern colonies in Maine during 1999-2000 (Figure 3.1). Douglas Pond, Palmyra was the largest colony with approximately 30 breeding pairs followed by the next largest colony Carlton Bog, Troy with approximately 24 pairs. The number of breeding pairs ranged from 4-20 at the remainder of the study sites: Messalonskee Lake, Belgrade; Great Moose Lake, Harmony; Huntley Brook Flowage, Princeton; Madawaska Pond, Palmyra; and Plymouth Pond, Plymouth.

All colony sites are dammed, which influences water level dynamics. At Messalonskee Lake, a hydroelectric dam strictly controls water levels. Douglas pond is an impoundment of the Sebasticook River. Water levels are controlled in this colony by the dam upstream at Great Moose Lake, a dam impounding the river downstream and a dam on Indian River, a tributary. Madawaska Pond, Plymouth Pond, and Carlton Bog have smaller dams, which are regulated little except in the spring or fall. Madawaska Pond is in a Wildlife Management Area and is managed by the Maine Department of Inland Fisheries and Wildlife. Carlton Bog is part of the Wildlife Refuge System and is managed by the U.S. Fish and Wildlife Service (USFWS). Huntley Brook Flowage is part of a larger lake system that is influenced by at least 2 hydroelectric dams.

Figure 3.1. Black Tern nesting colonies referred to in this study in Maine (1999-2000). Douglas Pond and Madawaska Pond and Plymouth Pond and Carlton Bog were not separated at this scale.

Terns nest locally within patches of emergent wetland with semipermanent water regimes (hereafter referred to as semipermanent emergent wetland). Douglas Pond (227 ha) has 44 ha of semipermanent emergent wetland bordering 85 ha of open water in 3 large patches. Great Moose Lake (1800 ha) has 43 ha of semipermanent emergent wetland mostly in a large area along the northern periphery of the lake, but the lake is largely unvegetated open water (1552 ha). Madawaska Pond (106 ha) contains 14 ha of semipermanent emergent wetland in a thin strip along the edge of 21 ha of open water. Carlton Bog (431 ha) has 75 ha of semipermanent emergent wetland bordering 113 ha of open water that has dense mats of vegetation. Plymouth Pond (253 ha) has 32 ha of semipermanent emergent wetland bordering 100 ha of heavily vegetated open water in the one cove where terns nest. Messalonskee Lake (1786 ha) has 55 ha of semipermanent emergent wetland in a large bog at the southern end of the lake and the remainder (1469 ha) is primarily open water. Huntley Brook Flowage (8271 ha) has 47 ha of semipermanent emergent wetland predominantly in a single patch adjacent to 6955 ha of open water.

At Great Moose Lake and Douglas Pond, Black Terns nest in semipermanent emergent areas dominated by river bulrush (*Scirpus* spp.) and sedge (*Carex* spp.) with smaller patches of cattail (*Typha* spp.). At Carlton Bog, Madawaska Pond, Messalonksee Lake, Plymouth Pond, and Huntley Brook Flowage terns nest in areas dominated by *Carex* spp. and *Sphagnum* spp. and feed in open water areas predominantly vegetated by pickerelweed (*Pontederia cordata*), yellow pond-lily (*Nuphar variegatum*) and fragrant water-lily (*Nymphaea odorata*).

Methods

Water Level and Precipitation Data

Water levels were recorded during the nesting season typically every 2 days and varied between 1-10 days at Douglas Pond, Carlton Bog, and Plymouth Pond and Messalonskee Lake in 1999-2000 and at Great Moose Lake, Madawaska Pond, and Huntley Brook in 2000. Water levels were measured using calibrated stakes placed in wetlands at the start of each field season. I obtained historical water flow data (1929-1999) for the Sebasticook River for a flow gauge near Pittsfield, ME (station number 01049000) from the United States Geological Survey (Water Resources of Maine, Historical streamflow data. Accessed 12 December 2000).

Local precipitation was measured using a Tru-Chek® Rain Gauge (Ben Meadows Company, Canton, GA) affixed to a stake 1.5 m from the ground in Palmyra, ME in 1999 and Newport, ME in 2000. I obtained historical precipitation data (1929-1999) in central Maine from 4 weather stations: Augusta Airport (Cooperative ID No. 170275), Corinna (Cooperative ID No. 171628), Farmington (Cooperative ID No. 172765), and Waterville Treatment Plant (Cooperative ID No. 179151) through the National Climatic Data Center (NCDC: Weather station website. Accessed 12 April 2000).

Statistical Analyses

All statistical functions were carried out in Systat 9.0 (SPSS Science, Chicago, IL) unless otherwise noted. An alpha level of 0.05 was used for all tests.

Water level and precipitation.- Flow rate data (in cubic feet per second) were converted to gauge height using a relationship developed from conversion tables provided by the USGS Water Resources Division (Augusta, ME) for periods between 1958-1965, 1965-1971, 1971-79, 1979-1995, and 1995-1999. Conversion relationships were similar for all 5 periods; therefore, I averaged values over the 5 periods and developed a single conversion relationship. The discharge rate-gauge height relationship (Eqn. 1) was based on the double rectangular hyperbolic function in Sigma Plot 2000 (SPSS Science, Chicago, IL), where y = gauge height, x = discharge, a = 2.0026, b = 23.880, c = 2.2941, d = 1274.124, and e = 0.0007, r^2 = 0.9999.

$$y = \frac{ax}{bx} + \frac{cx}{dx} + e \tag{1}$$

Gauge height data were used in all following analyses. To determine the applicability of historical flow data for assessing potential nest loss I tested for a relationship between the USGS gauge data and water levels measured in this study (1999-2000) using Spearman rank correlation. I calculated annual (1960-1999) precipitation means and standard errors from the average data of all weather stations for the period 15 May-15 July and mean daily precipitation by averaging over all years between 1960-1999 for the period 15 April-15 August. I analyzed daily precipitation data for seasonal trends using linear regression analysis.

Estimating potential nest loss from water levels.- I estimated the potential for nest loss due to water level increases at Douglas Pond based on (1) historical water level data and (2) nesting success and chronology data (1997-2000) for all Black Tern nests in

Maine. For nest chronology data, I used data from nests of Black Terns in Maine colonies

with known fates for the period 26 May-15 July because this was the period when

adequate nesting and environmental data existed. First, I calculated the average

percentage of nests present each day during the nesting season by calculating the running

total of incubated nests over 21-day periods, based on the average incubation period for

Black Terns (Dunn and Agro 1995). Secondly, I calculated maximum water level

increases within prior 21 days for each date. Then for each day of the season, I

determined the proportion of years at Douglas Pond when water level increases produced

catastrophic, moderate, and low levels of nest losses. I defined low-level losses as 6%

loss of available nests at Douglas Pond based on a flooding event that occurred on 11

June 1999; similarly, moderate-level losses were defined as 56% nest loss based on a 20

June 1997 event, and catastrophic-level losses were defined as 94% nest loss based on a

15 June 1998 event. Considerably fewer nests (36%, 8 of 22) were lost during the

catastrophic event at Madawaska, Carlton, Messalonskee, and Great Moose colonies; and

only 6 of 41 nests (15%) were lost at Carlton, Messalonskee and Great Moose colonies

during the moderate event (Madawaska and Plymouth had no loss). Threshold values

were conservatively estimated from maximum water level increases within 7 days prior

to the 3 nest-loss events in 1997-1999 and therefore do not correspond with actual dates

of nest loss. I used threshold levels of 0.42 m for low-loss events, 0.70 m for moderate-

loss events, and 1.31 m for catastrophic-loss events. For each day between 26 May-15

July I determined the proportion of years during 1960-1999 with water levels equal to or

exceeding threshold values at each level of loss. Because Black Terns often initiate nests

in at least two distinct nesting periods as a result of late nesting or re-nesting (Bailey

1977, Chapman Mosher 1986, Mazzochi et al. 1997), I estimated the proportion of years of loss during early (May 15-June 15) and late nesting periods (June 16-July 15). Finally, I calculated an index of the relative effects of each loss-level by multiplying the estimated proportion of years with loss on each day by the proportion of nests present on each day and by the proportion of nests lost for each type of flooding event (e.g., 0.56 for moderate events) times 100.

I compared relative effects of low, moderate and catastrophic loss events on each day using the Wilcoxon signed rank test (Zar 1984). I assumed independence of flooding events, which is not accurate (e.g., catastrophic-loss events always contain low-loss events), but allowed me to compare relative effects of low, moderate, and catastrophic events. I also determined if there was a trend in the probability of nest losses during the season using linear regression analysis with arc sine transformed proportion of years as the dependent value and Julian date as the predictor variable for each flooding level. Finally, I calculated the cumulative number of potential nests lost for each loss-level through the period of study as a measure of the total seasonal effect on nesting success.

Estimating potential nest loss from precipitation.- I also determined the potential for nest loss directly from precipitation data. I determined the best linear relationship (highest r^2 value) by regression analyses between water level and precipitation using time-lagged (0 to 7 days) and up to 20-day-cumulative precipitation data derived from the central Maine data set. I determined threshold values for the 3 loss-levels described above on the same day they were established for water level. Using these values I selected all years with precipitation greater than or equal to the threshold value and compared this list with that generated by water level data alone.

Results

Local Water Level Dynamics and Precipitation

Water levels decreased gradually during the 1999 and 2000 breeding seasons at all wetlands except Huntley Brook, Messalonskee Lake, and Douglas Pond, and Plymouth Pond in 2000 (Figure 3.2). Water levels fluctuated greatly at Douglas Pond and remained nearly stable at other sites. Precipitation was similar in 1999 (ξ = 3.78 mm, *SE* = 0.89) and 2000 (ξ = 2.51 mm, *SE* = 0.80) but was generally greater later in the breeding season in 1999 (Figure 3.2). During 1999-2000, precipitation early in the breeding season (before July 1) resulted in relatively large increases in water levels in Douglas Pond, but not in other wetlands. Water levels recorded during this study and those obtained from the USGS gauging station were highly correlated (r = 0.936, n = 47) during 1999-2000; therefore, historical water level data were appropriate for this study if past data were largely unaffected by dam operations. I found no seasonal trend in precipitation (Figure 3.3, r^2 = 0.004, n = 123, *P* = 0.499).

In Douglas Pond, water levels varied substantially among and within years during the period 1960-1999 (Figure 3.4). Patterns of wet and dry periods lasting several years were evident. During May 15-July 15, water level changes ranged from 0.5 m in 1977 to nearly 3 m in 1984, but more typically varied 1 m during this period (ξ = 1.09 m, median = 0.93 m). Water levels followed trends in yearly seasonal precipitation closely (Figure 3.4), but daily precipitation had only a weak relationship with water level (r^2 = 0.008, n = 2480, *P* < 0.001). Cumulative precipitation for the prior 16 days provided the best prediction of water levels at Douglas Pond (r^2 = 0.524, n = 2480, *P* < 0.001).
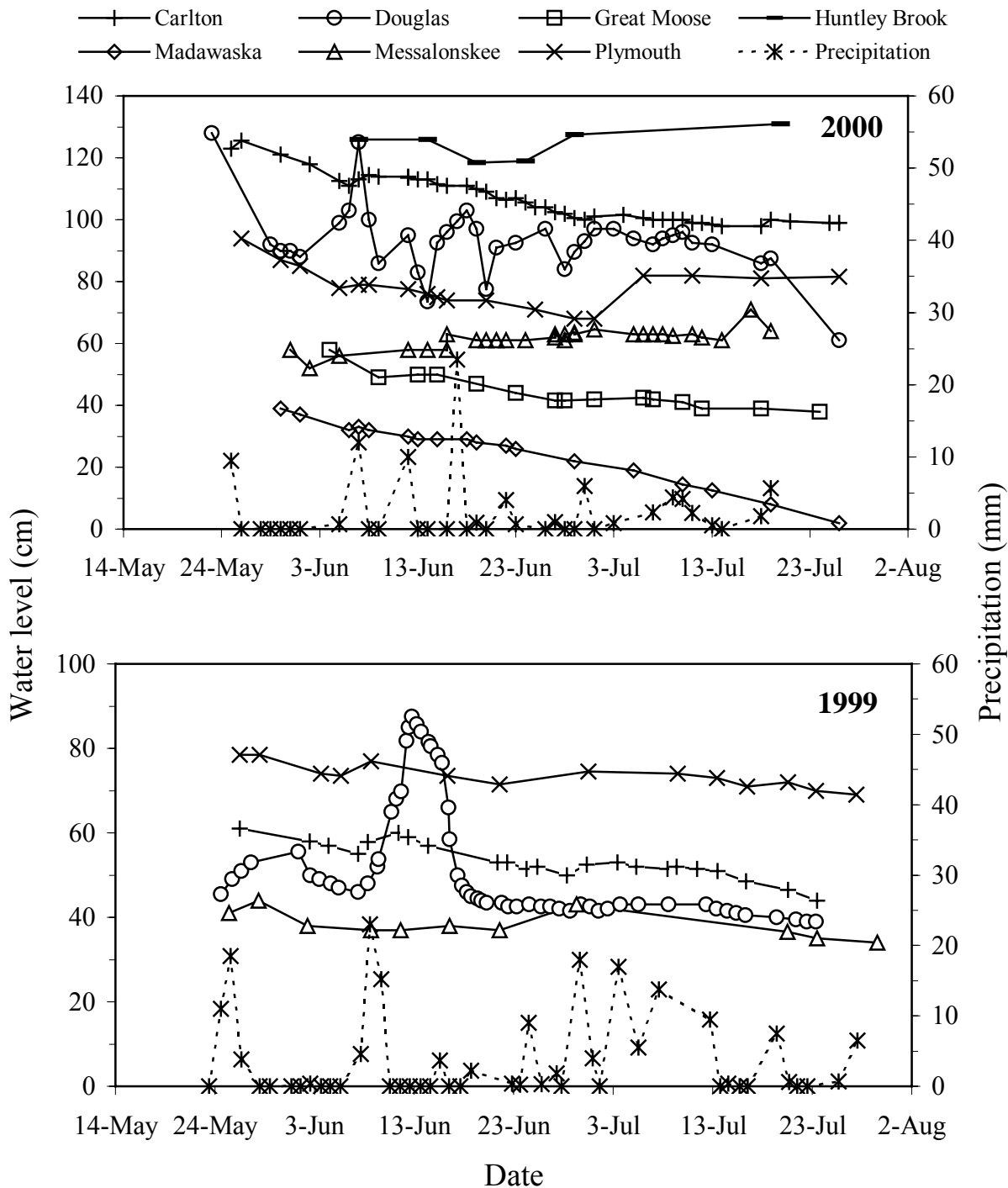
Figure 3.2. Water level dynamics and precipitation in Black Tern colonies in Maine during the breeding season. Water levels at Carlton, Douglas, Great Moose, Huntley Brook, Madawaska, Messalonskee, and Plymouth colonies and precipitation in Newport, ME in 2000 (top) and water levels at Carlton, Douglas, Messalonskee, and Plymouth and precipitation in Palmyra, ME in 1999 (bottom). Absolute water levels are not directly comparable among wetlands but are indicative of relative water level dynamics.
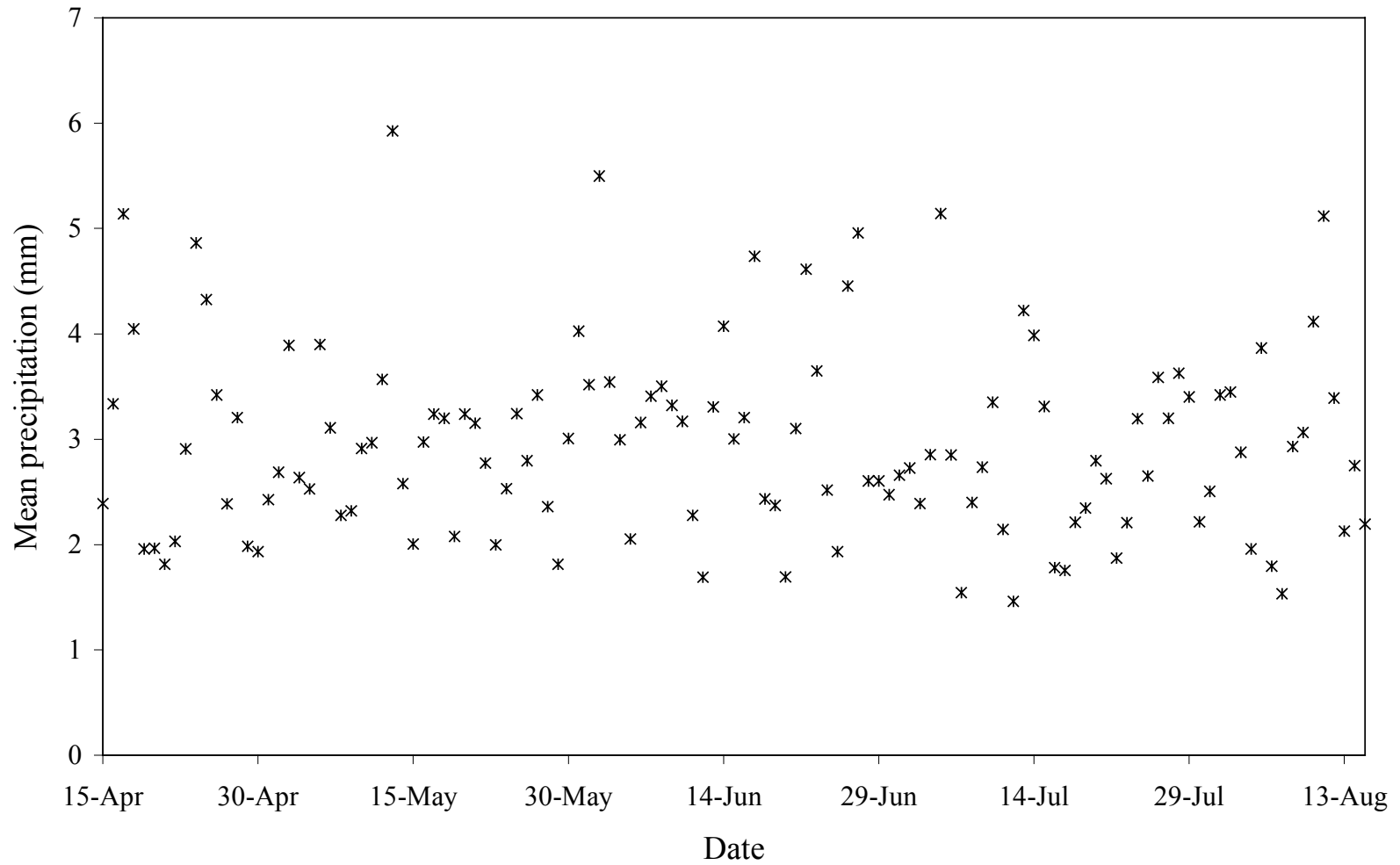
Figure 3.3. Mean daily precipitation in central Maine during April 15 to August 15, 1960-1999. There was not a trend in rainfall patterns during this period ($r^2 = 0.004$, n = 123, $P = 0.399$, linear regression).
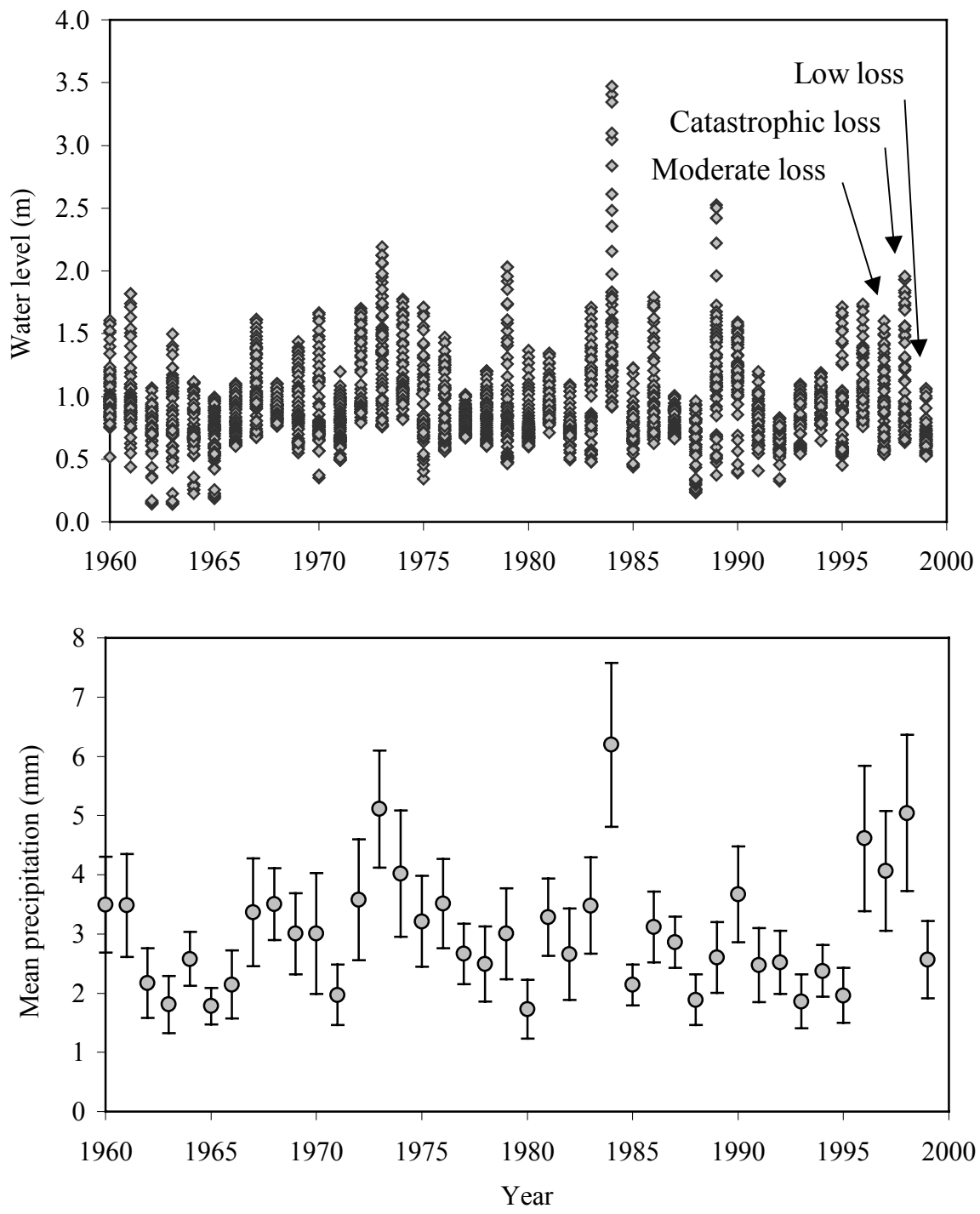
Figure 3.4. Annual variability in water levels (top) and precipitation (bottom) during 15 May-15 July at Douglas Pond, Maine. Patterns of wet and dry periods lasting several years are evident by higher (or lower) than average mean water levels and precipitation. Error bars are ±1 *SE*.

Potential For Nest Loss

The percentage of nests present peaked on 15 June and then declined steadily (Figure 3.5). There was no seasonal trend in the probability of potential nest losses due to low or catastrophic-level flooding events ($P > 0.05$) during 26 May-15 July (Figure 3.6), but the probability of moderate flooding events declined slightly as the nesting season progressed ($r^2 = 0.463$, n = 69, $P < 0.001$).

For 1960-1999, the probability of low, moderate, and catastrophic nests losses from flooding was 70%, 38%, and 13% respectively. The probability of nest losses was similar between the early and late nesting periods (Table 3.1). The daily potential loss of nests during 26 May-15 July at Douglas Pond is greater for moderate flooding than low ($z = 5.58$, n = 50, $P < 0.001$) and catastrophic flooding events ($z = 5.113$, n = 50, $P < 0.001$) (Figure 3.7). On a long-term basis, moderate flooding events result in greater daily rates of nest loss than low-level or catastrophic flooding events, particularly during the peak nesting period.

Table 3.1. Predicted nest losses at Douglas Pond due to 3 levels of water level increases during the early and late nesting periods and the cumulative potential for loss during the nesting season.

| Loss event | Threshold water level[a] increase (m) | No. of years of loss (%)[b] | | | Cumulative loss potential[d] |
		Early[c]	Late[c]	Both	
Low	0.42	19 (48)	19 (48)	28 (70)	16
Moderate	0.70	10 (25)	8 (20)	15 (38)	51
Catastrophic	1.31	2 (5)	3 (8)	5 (13)	12

[a] Maximum change in water level over the previous 21 days.
[b] Number of years (of 40) having at least one day of water level change above the threshold value.
[c] Early = 15 May to 15 June, Late = 16 June to 15 July.
[d] The cumulative daily loss potential represents the total daily potential calculated from the daily nest availability, daily probability of nest loss and proportion of nests lost for each loss event over the entire period from 26 May to 15 July.
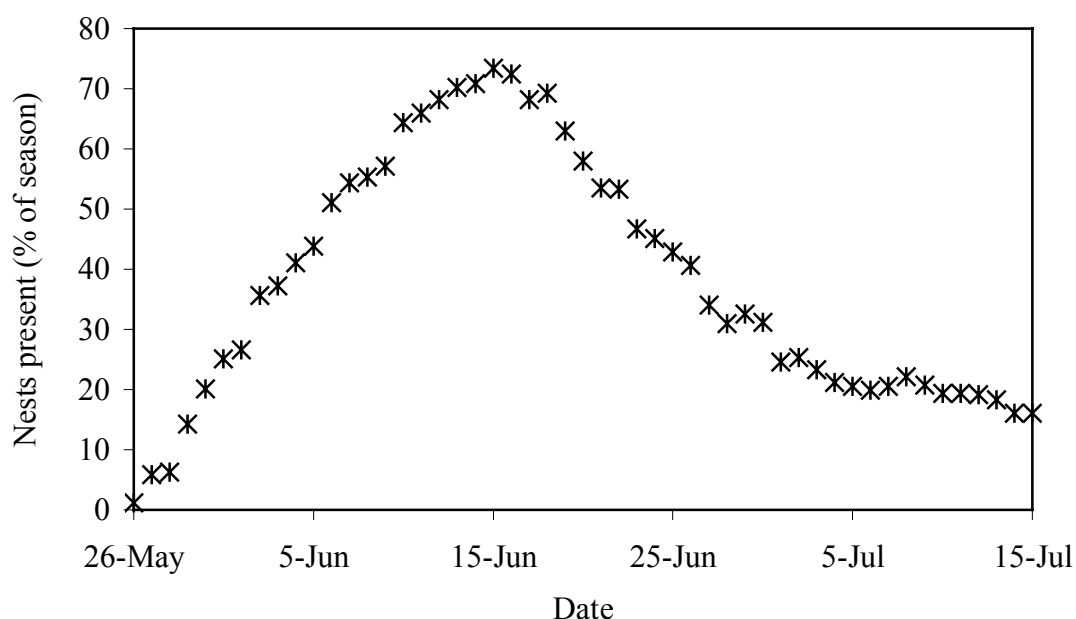
Figure 3.5. Mean daily percentage of nests present during 26 May-15 July, 1997-2000. Nest presence data were based on dates nests were found at all colonies in Maine and therefore represents an index of daily nest presence.
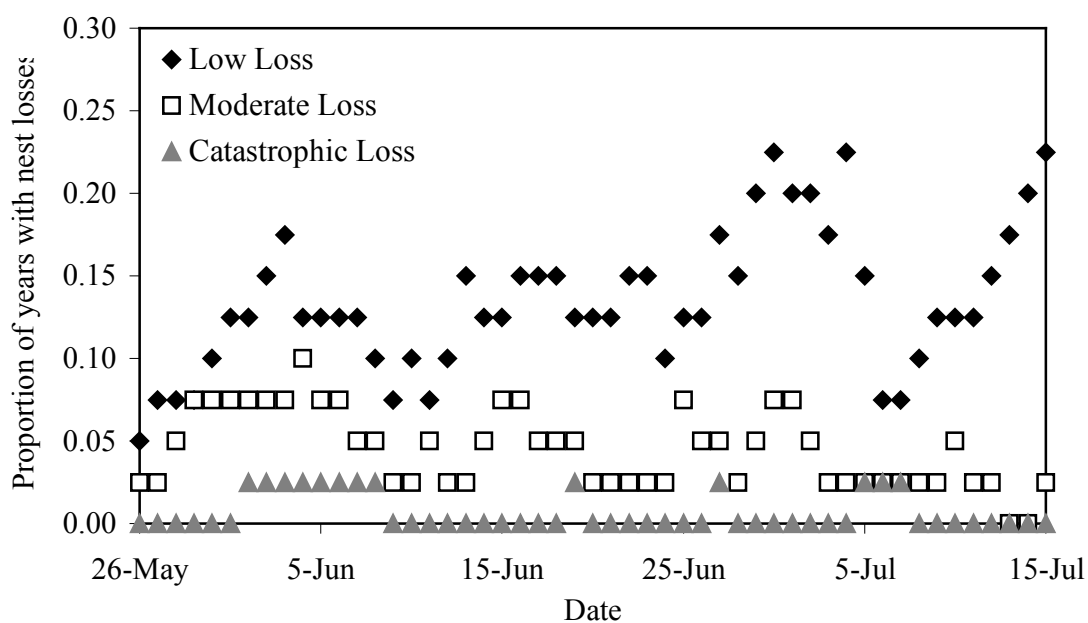
Figure 3.6. Probability of daily nest losses (low, moderate, and catastrophic) from water level increases during 26 May-15 July at Douglas Pond, ME. Each point represents a single daily probability of loss at each of 3 levels, but note that these loss levels were not independent of one another. The proportion of years of moderate loss decreased slightly during the season ($r^2 = 0.463$, n = 69, $P < 0.001$).
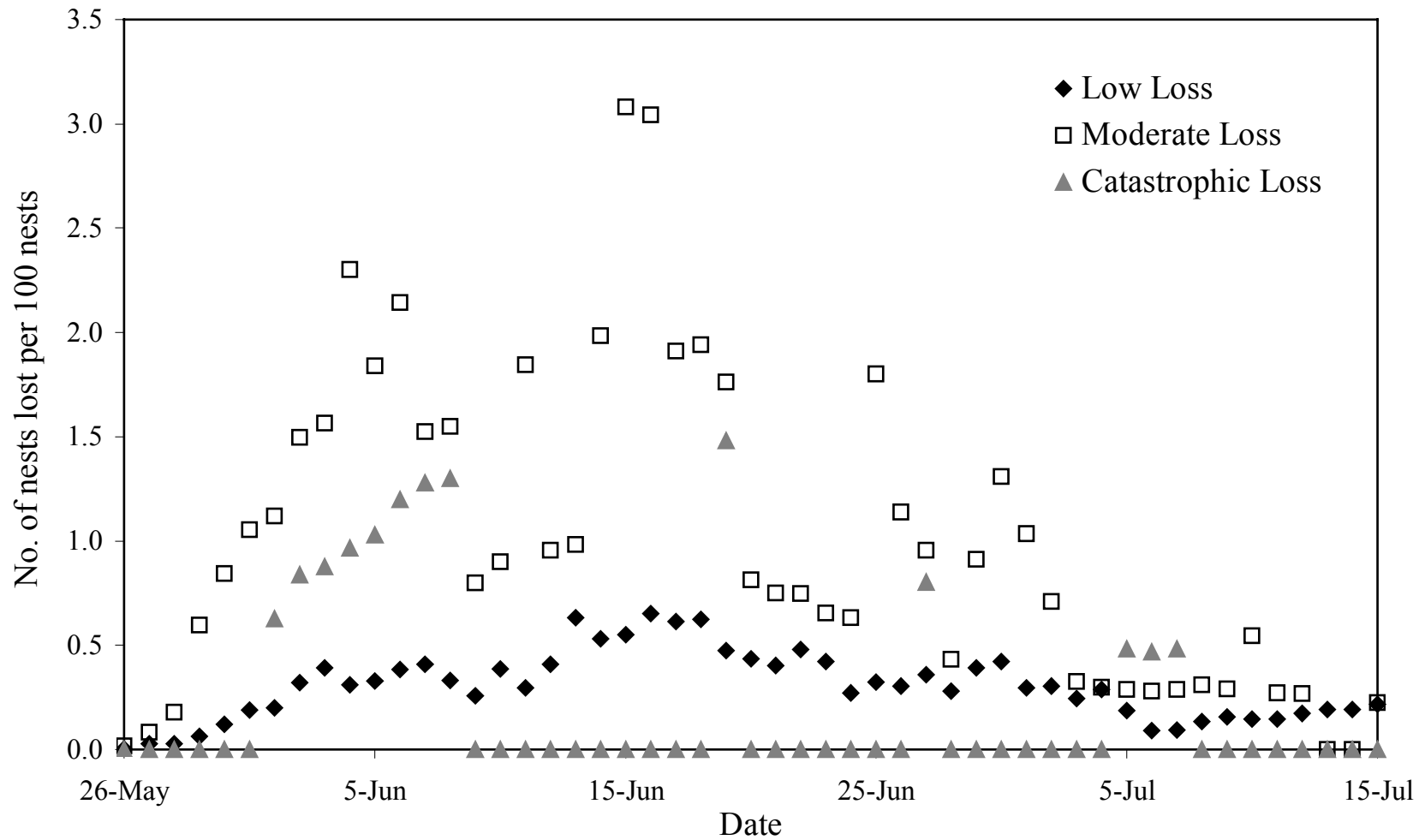
Figure 3.7. The relative effects of predicted low, moderate, and catastrophic nest losses at Douglas Pond, ME during 26 May-15 July. Each point is a function of its daily potential for nest losses, the percentage of nests present, and the proportion of nests lost at each loss-level (e.g., 0.56 at moderate levels). Note that loss levels are not independent of one another.

Prediction of Nest Loss from Precipitation

Rainfall during 16 days prior to measured water levels adequately predicted most flooding events at Douglas Pond identified by water level data for the period 15 May-15 July, 1960-1999. All low-level flooding events, 11 of 15 moderate, and 3 of 5 catastrophic flooding events were identified by cumulative rainfall over the prior 16-day. Low-level events were often over-predicted (11 of 39), but over-predictions were infrequent with moderate events (1 of 12) and did not occur with catastrophic events. In general, prediction errors were uniform over the breeding season.

Discussion

The probability of nest loss from flooding in Black Tern colonies appears to be high throughout their range. Chapman Mosher (1986), Macikunas (1993), and Hickey (1997) reported between 13-40% nest losses in colonies during each year of the 4, 7, and 2 years of their studies. Additional evidence of annual nest loss from flooding has been reported by Bailey (1977) and anecdotally by Cuthbert (1954), Bergman et al. (1970), Dunn (1979), Rabenold (1987), Delehanty and Svedarsky (1993) and, Mazzocchi and Capuano (1993). Flooding is so pervasive among Black Tern colonies that I found only 3 studies of nesting success that reported no known losses of nests from flooding from New York (Firstencel 1987), Minnesota (Maxson 1994), and New Brunswick (Bernard 1999). At Douglas Pond, Maine's largest colony, some level of flooding and nest loss was predicted to occur in nearly all years. Water level increases of 0.42 m that would produce relatively low levels of nest losses occurred frequently, moderate levels of flooding and nest losses occurred less frequently but have the potential to cause >50% nest loss of

nests present in Douglas Pond during the breeding season and 15% nest loss in other colonies and are cumulatively more important. Catastrophic flooding events occurred much less often (13% of years), but their capacity to destroy nearly all nests in Douglas Pond could decrease productivity significantly if they occur during peak nesting. Flood events that had greater water level increases than the 1998 event used as the catastrophic threshold event occurred in 1984 and 1989 and may have caused extensive nest losses in all Maine colonies in those years.

Black Terns are particularly susceptible to nest losses from flooding because nests are placed close to the surface of the water, nests are loosely constructed, nests are initiated over a long period, and flooding events occur throughout the breeding season. Black Terns nest only a few centimeters above the water in small cup-like nests (Bergman et al. 1970, Dunn 1979, Davis and Ackerman 1985), but often are built from buoyant substrates such as dead vegetation or rootstock (Cuthbert 1954, Bergman et al. 1970, Dunn 1979) that often prevents loss to low and moderate increases in water level (Pers. obs.). When terns nest on fixed substrate such as muskrat mounds and mudflats (Cuthbert 1954, Bergman et al. 1970) even small increases in water level increase the risk from flooding. Also, nest placement may change in response to changing water level since terns appear to prefer to nest adjacent to open water (Cuthbert 1954, Dunn 1979, Chapman Mosher 1986, Firstencel 1987), and water levels may change the location of nesting substrate relative to open water (F. Servello, Unpubl. data). If water levels decline after nest construction, risk of losses to flooding may decrease. However, because of shifting availability of nesting substrates, seasonally declining water levels are not likely to reduce nest losses from flooding. Therefore, the threat from flooding should be

relatively constant throughout the nest initiation (May-July, Dunn and Agro 1995) and incubation periods (21 days; Goodwin 1960, Bergman et al. 1970).

Overall, moderate flooding events appear to be more detrimental to long-term nesting success than low and even catastrophic flooding events, when considering the cumulative seasonal potential for nest losses. Moderate flooding events may be most important because they occur frequently and likely affect all colonies. The potential number of nests lost to flooding is dependent largely on the presence of nests. Although there is a slightly greater risk of moderate nest losses from flooding early in the season preceding the peak-nesting period, i.e. approximately the third week in June (Chapman Mosher 1986, Hickey 1997), the frequency of moderate flooding events could cause substantial population-wide nest losses throughout the season, which could greatly reduce long-term productivity of Black Terns. Rain events that result in low-levels of nest losses at Douglas Pond will have little affect on nesting success in other colonies and therefore have insignificant long-term consequences in Maine. Catastrophic flooding events likely cause nearly total nest loss at Douglas Pond and high rates of nest loss at all colonies in years in which these events occur, but they occur so infrequently and are not likely to strongly affect long-term productivity of terns in Maine. However, periods of zero probability of catastrophic nest loss during some portions of the nesting season may be misleading and would likely be greater than zero during the nesting season if longer period (e.g., 100 year) data sets were used to calculate these probabilities. Nevertheless, the basic conclusion that catastrophic events occur rarely and have little long-term effect on productivity would likely remain the same.

I believe that other colonies in Maine will have similar patterns of nest losses to Douglas Pond, but proportionally lower rates of nest losses because of differences in hydrology and nesting chronology in each wetland. Despite the lack of historical water level data for other wetlands, these results probably can be extended to other colonies in central Maine because (1) precipitation accurately predicted moderate and catastrophic nest loss events identified by water level increase at Douglas Pond and (2) precipitation capable of causing moderate and catastrophic flooding are likely to be large, widespread events experienced by all colonies except perhaps Huntley Brook Flowage. The response of water levels to precipitation is unique in each colony due to complex hydrological dynamics resulting from differences in position in the watershed, sediments, characteristics of vegetation, geology, elevation, and topography (Tiner 1998). The consequences of flooding events at each colony are also related to temporal patterns in nesting, which varies among wetlands (F. Servello, Unpubl. data).

Black Terns often nest in impounded wetlands (Chapter 2), which may provide excellent nesting substrate and food resources and therefore enhance the quality of nesting habitat; however, dam regulation may exaggerate effects of flooding by increasing the frequency and duration of flood events (Richter et al. 1996) or may cause long periods of low water levels in downstream wetlands (Sparks 1995). Dams change the way wetlands respond to precipitation by altering downstream hydrology, which can reduce active floodplains and shoreline vegetation and decrease biodiversity (Richter et al. 1996, Nilsson and Roland 1997, Nilsson and Berggren 2000). However, dams also allow water levels control and growth of emergent vegetation (Craighead and Craighead 1949, Kadlec 1962, Hickey 1997), which may be beneficial for terns.

The effects of dam and their operation are unique to each wetland, which makes it extremely difficult to predict how wetland systems will respond to dam management (Nilsson and Berggren 2000). For example, Douglas Pond, which has both upstream and downstream dams, frequently has large fluctuations in water levels because of its small size and position on the main stem of the Sebasticook River. Messalonskee Lake is a much larger lake and is controlled by a single large hydroelectric dam, but loses fewer nests to flooding because water level fluctuations are likely moderated by its size. Madawaska Pond and Carlton Bog are small wetlands like Douglas Pond and have smaller dams that are seasonally controlled, which probably accounts for smaller water level fluctuations and fewer nests lost to flooding. The interactions between dams and hydrology in response to precipitation events are complex and unique to each wetland, and further study is needed to better understand the risks of nest loss in each system.

Multi-annual patterns of high and low water levels may be a very important component of long-term productivity patterns in Black Terns. The duration of periods of high or low water levels may be a key factor in determining long-term productivity in Maine tern colonies. Precipitation trends may be a result of climatic phenomena affecting the northeast such as El Nino/La Nina (ENSO) or the North Atlantic Oscillation (NAO), which are just beginning to be understood and appreciated by scientists as having consequences for the survival and fitness of wildlife and plant species (e.g., Henen et al. 1998, Jaksic and Lazo 1999, Milner et al. 1999, Post and Stenseth 1999a,b, Wright et al. 1999). A period of above average precipitation could result in reduced annual success for the population in Maine and lead to a population decline. Stochastic weather processes may push an already low population to extinction when sustained periods of nest loss

from flooding reduce productivity (Newton 1998). Alternatively, periods of low water levels resulting from below average precipitation may increase access to nests and chicks by predators (Proulx et al. 1987, Dunn and Agro 1995). Evidence of this effect in Maine is suggested by increased predation during dry years in several colonies (F. Servello, Unpubl. data).

Flooding is not unique to Black Terns, but is inherent in the reproductive histories of several species of freshwater wetland-nesting bird species: Least Tern (Sidle et al. 1992, Kirsch 1996), Piping Plover (Sidle et al. 1992, Smith and Renken 1993, Espie et al. 1998), Snowy Plover (Warriner et al. 1986), Northern Shoveler, Redhead, American Coot, Western Grebe (Wolf 1955), and Canada Goose (Williams and Marshall 1937, Craighead and Craighead 1949, Wolf 1955). Wetland bird species are adapted to dynamic water levels in wetlands to some degree. The relative protection and rich abundance of food resources typically available in these environments may offset long-term effects of nest loss from flooding. However, extended periods of reduced breeding success in combination with below average productivity and small population size may lead to declines or even local population extinction (Newton 1998) as has been reported recently with Piping Plovers and Least Terns. For example, the reproductive success of Piping Plovers nesting at Lake Diefenbaker, Saskatchewan has been reduced by nest losses from flooding below the estimated level required for a sustainable population (Espie et al. 1998). For Least Terns nesting on sandbars, flooding is the most important factor causing poor reproductive success (Kirsch 1996). Recent population modeling of Black Terns (Servello 2000) has suggested that nesting success of this species may be at least as important to population growth as fledging rate, and chick survival may have to be

exceptionally high to offset low rates of nest success. Therefore, if the population of

Black Terns in Maine experiences extended periods of poor nesting success from

flooding then the Black Tern populations in Maine may be similarly at risk.

Management Implications

Any steps that would mitigate the effects of extreme water level increases

associated with large rain events during the period of tern nesting would help to increase

nesting success for Black Terns in Maine. Stabilization of water levels is one alternative

but would require information on the influence of dams on water level dynamics in

individual wetlands and on water control options. Minimizing erratic water level

fluctuations could allow nesting terns to cope better with water levels increases that were

large or too rapid. More information also is needed on the relationships between nest

losses and water level dynamics in all Maine wetlands to better understand the need for

water level management for Black Terns.

Nesting platforms established prior to the breeding season may be beneficial in

some wetlands where water level control is difficult. Nest platforms have the benefit of

increasing buoyancy of nests while reducing potential loss from flooding. Successful use

of platforms has been documented in some wetlands (Chapman Mosher 1986, Faber

1996, Mazzocchi and Hickey 1997); however, a more detailed study of their effectiveness

and design is advised before their use (Shuford 1999). In wetlands with an abundance of

natural nesting sites adult terns may not utilize nest platforms. A more intensive approach

would be to make natural nests more stable by placing buoyant material under each nest

to enhance flotation during flooding events (Shuford 1999). Black Terns are very tolerant to disturbance at the nest (A. Gilbert, Pers. obs.) and adults would likely accept such manipulations.

LITERATURE CITED

Alatalo, R. V., L. Gustafsson, and A. Lundberg. 1990. Phenotypic selection on heritable size traits: environmental variance and genetic response. Am. Nat. 135: 464-471.

Bailey, P. F. 1977. The breeding biology of the Black Tern (*Chlidonias niger surinamensis* Gmelin). M.S. Thesis, University of Wisconsin-Oshkosh, Oshkosh, WI.

Barrett, G. M. and D. G. Kay. 1997. Northern extension to the known breeding range of the Black Tern, *Chlidonias niger*, in the Northwest Territories. Can. Field-Nat. 111: 469-471.

Beintema, A. J., T. Baarspul, and J. P. de Krijger. 1996. Calcium deficiency in Black Terns *Chlidonias niger* nesting on acid bogs. Ibis 139: 396-397.

_____. 1997. European Black Terns (*Chlidonias niger*) in trouble: examples of dietary problems. Colonial Waterbirds 20: 558-565.

Bell, G. P. 1990. Birds and mammals on an insect diet: a primer on diet composition analysis in relation to ecological energetics. Studies in Avian Biology 13: 416-422.

Bergman R. D., P. S. Swain, and M. W. Weller. 1970. A comparative study of nesting Forster's and Black Terns. Wilson Bull. 82: 435-444.

Bernard, L. 1999. Habitat selection and breeding success of Black Terns (*Chlidonias niger*) in impounded wetlands in New Brunswick. M.S. Thesis. University of New Brunswick, Frederickton, N.B.

Brown, M. and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. J. Wildl. Manage. 50: 392-397.

Bryant, D. M. 1978. Environmental influences on growth and survival of nestling House Martins *Delichon urbica*. Ibis 120: 271-283.

Castro, G., N. Stoyan, and J. P. Myers. 1989. Assimilation efficiency in birds: a function of taxon or food type? Comp. Biochem. Physiol. 92A: 271-278.

Chapman Mosher, B. A. 1986. Factors influencing reproductive success and nesting strategies in Black Terns. Ph.D. Dissertation. Simon Fraser University, Burnaby, B.C.

Cooch, E. G., D. B. Lank, A. Dzubin, R. F. Rockwell, and F. Cooke. 1991. Body size variation in Lesser Snow Geese: environmental plasticity in gosling growth rates. Ecology 72: 503-512.

Cooper, J. M. and R. W. Campbell. 1997. Surveys of selected and traditional Black Tern (*Chlidonias niger*) colonies in British Columbia in 1996. Colonial Waterbirds 20: 574-581.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Unpubl. report, U.S. Fish and Wildlife Service, Washington, DC.

Craighead, F. C. and J. J. Craighead. 1949. Nesting Canada Geese on the upper Snake River. J. Wildl. Manage. 13: 51-64.

Cuthbert, N. L. 1954. A nesting study of the Black Tern in Michigan. Auk 71: 37-63.

Davis, T. A. and R. A. Ackerman. 1985. Adaptations of Black Tern (*Chlidonias niger*) eggs for water loss in a moist nest. Auk 102: 640-643.

Delehanty, D. J. and W. D. Svedarsky. 1993. Black Tern colonization of a restored prairie wetland in northwestern Minnesota. Prairie Nat. 25: 213-218.

Drent, R. H., M. Klaassen, and B. Zwaan. 1992. Predictive growth budgets in terns and gulls. Ardea 80: 5-17.

Dunn, E. H. 1979. Nesting biology and development of young in Ontario Black Terns. Can. Field-Nat. 93: 276-281.

_____. and D. J. Agro. 1995. Black Tern (*Chlidonias niger*). *in* A. Poole and F. Gill, eds. The birds of North America, No. 147. The Academy of Natural Sciences, Philadelphia and the American Ornithologists' Union, Washington, DC.

Eckert, C. D. 1996. Blind Lake's Black Terns. Yukon Warbler 4:10-11.

Emms, S. K. and N. A. M. Verbeek. 1991. Brood size, food provisioning and chick growth in the Pigeon Guillemot *Cepphus columba*. Condor 93: 943-951.

Espie, R. H. M., P. C. James, and R. M. Brigham. 1998. The effects of flooding on Piping Plover *Charadrius melodus* reproductive success at Lake Diefenbaker, Saskatchewan, Canada. Biol. Cons. 86: 215-222.

Faanes, C. A. 1979. Status of the Black Tern in western Wisconsin. Passenger Pigeon 41: 124-128.

Faber, R. A. 1996. Impacts of artificial nest platforms and water levels on hatching success in Black Terns. Abstract Only. Colonial Waterbirds Soc. Bull. 20: 53.

Firstencel, H. 1987. The Black Tern (*Chlidonias niger* Linn.): breeding ecology in upstate New York and results of pesticide residue analyses. M.S. thesis. SUNY-Brockport, Brockport, NY.

Gaston, A. J., G. Chapdelaine, and D. G. Noble. 1983. The growth of Thick-billed Murre chicks at colonies in Hudson Strait: inter- and intra-colony variation. Can. J. Zool. 61: 2465-2475.

Gibbs, J. P. and S. M. Melvin. 1990. An assessment of wading birds and other wetland avifauna and their habitats in Maine. Unpubl. report, Maine Dept. Inland Fisheries and Wildl., Bangor, ME.

Golet, G. H., K. J. Kuletz, D. B. Roby, and D. B. Irons. 2000. Adult prey choice affects chick growth and reproductive success in Pigeon Guillemots. Auk 117: 82-91.

Goodbred, C. O. and R. T. Holmes. 1996. Factors affecting food provisioning of nestling Black-throated Blue Warblers. Wilson Bull. 108: 467-479.

Goodwin, R. E. 1960. A study of the ethology of the Black Tern, *Chlidonias niger surinamensis* (Gmelin). Ph.D. Dissertation. Cornell University, Ithaca, NY.

Grover, A. L. 1946. Black Tern nesting in Maine. Bull. Maine Audubon Soc. 2: 108-109.

Harris, A. T. 1931. The Black Tern. Oologist 48:142-143.

Henen, B. T., C. C. Peterson, I. R. Wallis, K. H. Berry, and K. A. Nagy. 1998. Effects of climatic variation on field metabolism and water relations of desert tortoises. Oecologia 117: 365-373.

Hickey, J. M. 1997. Breeding biology and population dynamics of the Black Tern in Western New York. M.S. Thesis. Cornell University, Ithaca, NY.

_____. and R. A. Malecki. 1997. Nest site selection of Black Tern in western New York. Colonial Waterbirds 20: 582-95.

Hoffman, P. W. 1926. Nesting of the Black Tern in Wisconsin. Auk 43: 86-87.

Hulsman, K. and G. Smith. 1988. Biology and growth of the Black-naped Tern *Sterna sumatrana*: an hypothesis to explain the relative growth rates of inshore, offshore and pelagic feeders. Emu 88: 234-242.

Jaksic, F. M. and I. Lazo. 1999. Response of a bird assemblage in Semiarid Chile to the 1997-1998 El Nino. Wilson Bull. 111: 527-535.

Johnston, R. D. 1993. Effects of diet quality on the nestling growth of a wild insectivorous passerine, the House Martin *Delichon urbica*. Functional Ecology 7: 255-266.

Kadlec, J. A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43: 267-281.

Kantrud, H. A. and R. E. Stewart. 1984. Ecological distribution and crude density of breeding birds on prairie wetlands. J. Wildl. Manage. 48: 426-437.

Kirsch, E. M. 1996. Habitat selection and productivity of least terns on the lower Platte River, Nebraska. Wildl. Monogr. 132: 1-48.

Klaassen, M. 1994. Growth and energetics of tern chicks from temperate and polar environments. Auk 111: 525-544.

Knutson, M. G. 1991. Characteristics of Black Tern (*Chlidonias niger*) nesting habitat at Lakeview Wildlife Management Area, New York. Kingbird 41: 228-236.

Kolander, T. D., D. W. Willis, and B. R. Murphy. 1993. Proposed revision of the standard weight (W_s) equation for smallmouth bass. N. Am. J. Fish. Manage. 13: 398-400.

Krebs, J. R. and M. I. Avery. 1984. Chick growth and prey quality in the European Bee-eater (*Merops apiaster*). Oecologia 64: 363-368.

Laurent, S. M. 1993. Impact of water level on Black Tern (*Chlidonias niger*) hatching success. B.A. Thesis, St. Mary's College, Winona, MN.

LeCroy, M. and C. T. Collins. 1972. Growth and survival of Roseate and Common Tern chicks. Auk 89:595-611.

_____. and S. LeCroy. 1974. Growth and fledging in the Common Tern (*Sterna hirundo*). Bird Banding 45: 326-340.

Lederer, R. J. 1976. The breeding populations of piscivorous birds of Eagle Lake. Am. Birds 30: 771-772.

Linz, G. M. and D. C. Blixt. 1997. Black Terns benefit from cattail management in the northern Great Plains. Colonial Waterbirds 20: 617-621.

Macikunas, A. 1993. Hatching success and replacement success of the Black Tern (*Chlidonias niger*) of the Kaunas Sea. Acta Ornitologica Lituanica 7-8: 107-114.

Massias, A. and P. H. Becker. 1990. Nutritive value and growth in Common Tern *Sterna hirundo* chicks. Ornis Scand. 21: 187-194.

Maxson, S. J. 1994. Habitat selection and nesting success of Black Terns at Agassiz NWR. Unpubl. report, Minnesota Dept. of Natural Resources, Wetland Wildlife Populations and Research Group, Bemidji, MN.

Mazzocchi, I. M. and J. J. Capuano III. 1993. Black tern (*Chlidonias niger*) investigations in New York state, Unpubl. report, New York State Dept. of Environ. Conserv., Div. Fish and Wildl., Watertown, NY.

_____. and J. M. Hickey. 1997. Black Tern (*Chlidonias niger*) in northern New York, 1996. Unpubl. report, New York State Dept. Environ. Conserv., Div. Fish, Wildl., and Marine Resources, Watertown, NY.

_____, J. M. Hickey, and R. L. Miller. 1997. Productivity and nesting habitat characteristics of the Black Terns in northern New York. Colonial Waterbirds 20: 596-603.

Milner, J. M., D. A. Elston, and S. D. Albon. 1999. Estimating the contributions of population density and climatic fluctuations to inter-annual variation in survival of Soay sheep. J. Anim. Ecol. 68: 1235-1247.

Monaghan, P., J. D. Uttley, M. D. Burns, C. Thaine, and J. Blackwood. 1989. The relationship between food supply, reproductive effort and breeding success in Arctic Terns *Sterna paradisaea*. J. Anim. Ecol. 58: 261-274.

Mossman, M. J., A. F. Techlow III, T. J. Ziebell, S. W. Matteson and K. J. Fruth. 1988. Nesting gulls and terns of Winnebago Pool and Rush Lake, Wisconsin. Passenger Pigeon 50: 107-117.

National Climatic Data Center. NCDC: Weather station Augusta State Airport. [http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20009756] Accessed 12 April 2000.

_____. NCDC: Weather station Corinna. [http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20009810] Accessed 12 April 2000.

_____. NCDC: Weather station Farmington. [http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20009788] Accessed 12 April 2000.

_____. NCDC: Weather station Waterville Treatment Plant. [http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20009779] Accessed 12 April 2000.

Naugle, D. E., K. F. Higgins, M. E. Estey, R. R. Johnson, and S. M. Nusser. 1999a. Local and landscape-level factors influencing Black Tern habitat suitability. J. Wildl. Manage. 64: 253-260.

_____, K. F. Higgins, S. M. Nusser, and W. C. Johnson. 1999b. Scale-dependent habitat use in three species of prairie wetland birds. Landscape Ecology 14: 267-276.

Neter, J., M. H. Kutner, C. J. Nachtsheim, and W. Wasserman. 1996. Applied linear statistical models. 4th ed., Irwin, Chicago.

Newton, I. 1998. Population limitation in birds. Academic Press, San Diego, CA.

Nilsson, C. and J. Roland. 1997. Long-term responses of river-margin vegetation to water-level regulation. Science 276: 798-801.

_____. and K. Berggren. 2000. Alterations of riparian ecosystems caused by river regulation. Bioscience 50: 783-792.

Nisbet, I. C. T., J. S. Hatfield, W. A. Link, and J. A. Spendelow. 1999. Predicting chick survival and productivity of Roseate Terns from data on early growth. Waterbirds 22: 90-97.

_____, J. A. Spendelow, and J. S. Hatfield. 1995. Variations in growth of Roseate Tern chicks. Condor 97: 335-344.

_____, J. A. Spendelow, J. S. Hatfield, J. M. Zingo, and G. A. Gouch. 1998. Variations in growth of Roseate Tern chicks: II. early growth as an index of parental quality. Condor 100: 305-315.

Novak, P. G. 1992. Black Tern, *Chlidonias niger*. Pp. 149-169 *in* K. S. Schneider and D. M. Pence, eds. The Birds of North America, No. 140. Acad. Nat. Sci., Philadelphia, and Am. Ornithol. Union, Washington DC.

O' Connor, R. J. 1984. The growth and development of birds. John Wiley and Sons, New York, NY.

Orians, G. H. 1985. Finding and capturing food. *in* Blackbirds of the Americas. University of Washington Press, Seattle, WA.

Papish, U. 1993. Black Terns nest at Fern Ridge Reservoir, Lane County, Oregon. Oregon Birds 19: 97-98.

Parmelee, D. F. 1961. A nesting colony of Black Terns in Kansas. Kansas Ornith. Soc. 12: 25-27.

Pearson, T. H. 1968. The feeding biology of sea-bird species on the Farne Islands, Northumberland. J. Anim. Ecol. 37: 521-552.

Peterjohn, B. G. and J. R. Sauer. 1997. Population trends of Black Terns from the North American Breeding Bird Survey, 1966-1996. Colonial Waterbirds 20: 566-573.

Phillips, R. A. and K. C. Hamer. 2000. Growth and provisioning strategies of Northern Fulmars *Fulmarus glacialis*. Ibis 142: 435-445.

Pierson, E. C. 1983. Black Terns nesting in Maine. Unpubl. report, Maine Critical Areas Program, State Planning Office, Augusta, ME.

Post, E. and N. C. Stenseth. 1999a. Climatic variability, plant phenology, and northern ungulates. Ecology 80: 1322-1339.

_____. 1999b. Large-scale climatic fluctuations and population dynamics of moose and white-tailed deer. J. Anim. Ecol. 67: 537-543.

Proulx, G., J. A. McDonnell, and F. F. Gilbert. 1987. The effect of water level fluctuations on muskrat, *Ondatra zibethicus*, predations by mink, *Mustela vison*. Can. Field-Nat. 101: 89-92.

Provost, M. W. 1947. Nesting of birds in the marshes of northwest Iowa. Am. Midland Naturalist 38: 485-503.

Rabenold, P. P. 1986. 1986 survey of Black Terns (*Chlidonias niger*) breeding in Indiana. Unpubl. report, Nongame and Endangered Wildl. Program, Indiana Dept. Nat. Resources, Indianapolis, IN.

_____. 1987. 1987 survey of Black Terns (*Chlidonias niger*) breeding in Indiana. Unpubl. report, Nongame and Endangered Wildl. Program, Indiana Dept. Nat. Resources, Indianapolis, IN.

Rauter, C. M., P. A. Brodmann, H. –U. Reyer. 2000. Provisioning behaviour in relation to food availability and nestling food demand in the Water Pipit *Anthus spinoletta*. Ardea 88: 81-90.

Richardson, F. 1967. Black Tern nest and egg moving experiments. Murrelet 48: 52-56.

Richter, B. D., J. V. Baumgartner, J. Powell, and D. P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology 10: 1163-1174.

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

Robinson, J. A. and K. C. Hamer. 2000. Brood size and food provisioning in Common Terns *Sterna hirundo* and Arctic Terns *S. paradisaea*: consequences for chick growth. Ardea 88: 51-60.

Sage, R. D. 1982. Wet and dry-weight estimates of insects and spiders based on length. Am. Midl. Nat. 108: 407-411.

Sample, B. E., R. J. Cooper, R. D. Greer, and R. C. Whitmore. 1993. Estimation of insect biomass by length and weight. Am. Midl. Nat. 129: 234-240.

Sandburg, E. 1968. A study of Dunn's Marsh near Madison. Passenger Pigeon 30: 79-83.

Schaffner, F. C. 1986. Trends in Elegant Tern and Northern Anchovy populations in California. Condor 88: 347-354.

Servello, F. A. 2000. Population research priorities for Black Terns developed from modeling analysis. Waterbirds 23: 2000.

Shambaugh, N. 1996. Current status and future research and management needs of the Black Tern in Vermont. Unpubl. report, Nongame and Nat. Heritage Program, Vermont Dept. of Fish and Wildl., Waterbury, VT.

Shuford, W. D. 1999. Status assessment and conservation plan for the Black Tern in North America. Unpubl. report, U. S. Fish and Wildlife Service, Denver, CO.

Sidle, J. G., D. E. Carlson, E. M. Kirsch, and J. J. Dinan. 1992. Flooding: mortality and habitat renewal for Least Terns and Piping Plovers. Colonial Waterbirds 15: 132-136.

Sirois, J. and M. A. Fournier. 1993. Clarification of the status of the Black Tern (*Chlidonias niger*) in the Northwest Territories, Canada. Colonial Waterbirds 16: 208-212.

Smith, J. W. and R. B. Renken. 1993. Reproductive success of Least Terns in the Mississippi River Valley. Colonial Waterbirds 16: 39-44.

Sparks, R. E. 1995. Need for ecosystem management of large rivers and their floodplains. Bioscience 45: 168-182.

Stern, M. A. 1987. Site tenacity, mate retention and sexual dimorphism in Black Terns. M.S. Thesis, Oregon State University, Corvallis, OR.

Stienen, E. W. M., P. W. M. van Beers, A. Brenninkmeijer, J. M. P M. Habraken, M. H. J. E. Raaijmakers, and P. G. M. van Tienen. 2000. Reflections of a specialist: patterns in food provisioning and foraging conditions in Sandwich Terns *Sterna sandvicensis*. Ardea 88: 33-49.

Tiner, R. W. 1998. In search of swampland: a wetland sourcebook for the Northeast. Rutgers University Press, New Brunswick, NJ.

United States Geological Survey. Water Resources of Maine, Historical streamflow data for 01049000 - Sebasticook River near Pittsfield, Maine. [http://water.usgs.gov/nwis-w/me/?statnum=01049000] Accessed 12 December 2000.

Warriner, J. S., J. C. Warriner, G. W. Page, and L. E. Stenzel. 1986. Mating systems and reproductive success of a small population of polygamous Snowy Plovers. Wilson Bull. 98: 15-37.

Welham, C. V. J. and R. C. Ydenberg. 1993. Efficiency-maximizing flight speeds in parent Black Terns. Ecology 74: 1893-1901.

Williams, C. S. and W. H. Marshall. 1937. Goose nesting studies on Bear River migratory waterfowl refuge. J. Wildl. Manage. 1: 77-86.

Winkler, D. W. and F. R. Adler. 1996. Dynamic state variable models for parental care: I. a submodel for the growth of the chicks of passerine birds. J. Av. Biol. 27: 343-353.

Wolf, K. 1955. Some effects of fluctuating and falling water levels on waterfowl production. J. Wildl. Manage. 19: 13-23.

Wright, S. J., C. Carrasco, O. Calderon, and S. Paton. 1999. The El Nino Southern Oscillation, variable fruit production, and famine in a tropical forest. Ecology 80: 1632-1647.

Zar, J. H. 1984. Biostatistical analysis. 2nd ed. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Appendix A. Black Tern chick growth modeling.

Table A.1. Mean rates of food delivery (items brood^{-1} hr^{-1}) by age to Black Tern broods in Maine colonies between ages 0 and 8 days during 1999-2000.

Age	Small insect	Large insect	Small fish	Large fish
0	4.666	1.628	0.865	0.671
1	5.343	1.819	0.810	0.958
2	8.023	2.173	1.713	1.489
3	8.571	3.369	1.719	1.838
4	11.759	3.624	1.238	2.135
5	7.172	4.477	2.188	1.781
6	5.803	6.544	1.896	1.619
7	8.137	9.176	2.627	1.727
8	11.580	7.057	2.339	2.918
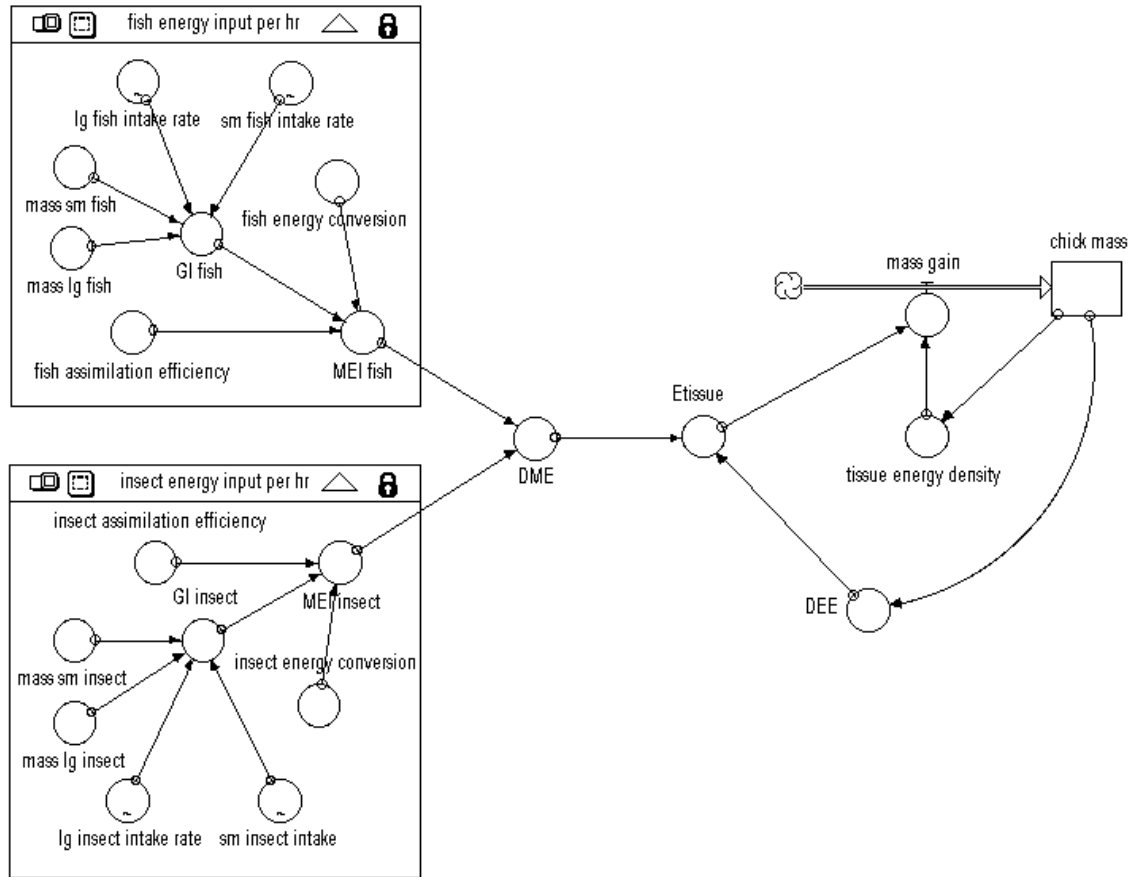
Figure A.1. Diagrammatic model of Black Tern chick growth using Stella 5.1.1.

Appendix B. Growth rates of Black Tern chicks in Maine and factors that affect them.

Table B.1. Linear growth rates of Black Tern chicks between ages 2-10 days during 1998-2000 in colonies in Maine.

Year	Colony	Nest	Hatch order	Growth rate (g/d)[a]	n[b]	r^2	P
1998	Carlton	23	A	4.614	5	0.979	0.001
1998	Carlton	23	B	3.863	5	0.994	0.000
1998	Carlton	23	C				
1998	Carlton	33	A	4.786	3	0.991	0.060
1998	Carlton	33	B	4.191	3	0.989	0.068
1998	Carlton	33	C				
1998	Carlton	35	A	4.563	3	0.995	0.043
1998	Douglas	38	A	5.261	5	0.985	0.001
1998	Douglas	38	B	4.985	5	0.958	0.004
1998	Douglas	38	C	4.506	5	0.952	0.004
1998	Douglas	221	A	4.053	7	0.983	0.000
1998	Douglas	221	B	3.183	7	0.988	0.000
1998	Douglas	221	C	2.651	6	0.943	0.001
1998	Douglas	228	A	4.426	9	0.978	0.000
1998	Douglas	228	B	4.502	8	0.987	0.000
1999	Douglas	43	A	4.326	8	0.992	0.000
1999	Douglas	43	B	4.864	7	0.988	0.000
1999	Douglas	43	C	4.542	6	0.988	0.000
1999	Douglas	48	AB	4.384	4	0.999	0.000
1999	Douglas	48	AB	5.088	8	0.996	0.000
1999	Douglas	48	C	4.425	6	0.983	0.000
1999	Douglas	79	A	5.715	7	0.988	0.000
1999	Douglas	79	B	5.193	7	0.987	0.000
1999	Douglas	79	C	5.822	6	0.987	0.000
1999	Douglas	101	AB	4.536	8	0.991	0.000
1999	Douglas	101	AB	4.935	8	0.994	0.000
1999	Douglas	101	C	3.755	7	0.997	0.000
1999	Douglas	130	A	4.879	7	0.972	0.000
1999	Douglas	130	B	4.057	6	0.973	0.000
1999	Douglas	130	C	3.553	6	0.989	0.000
1999	Douglas	139	A	6.106	5	0.975	0.002
1999	Douglas	139	B	4.937	5	0.989	0.001
1999	Douglas	139	C	4.065	4	0.931	0.035
1999	Douglas	301	AB	3.717	3	0.989	0.068
1999	Douglas	301	AB	4.560	3	0.979	0.093
2000	Carlton	7	AB	4.832	7	0.988	0.000
2000	Carlton	7	AB	4.902	7	0.979	0.000
2000	Douglas	8	AB	3.724	6	0.995	0.000

Table B.1. Continued.

Year	Colony	Nest	Hatch order	Growth rate (g/d)[a]	n[b]	r^2	P
2000	Douglas	8	AB	4.284	6	0.991	0.000
2000	Douglas	8	C	4.660	5	0.987	0.001
2000	Carlton	36	A	4.640	6	0.987	0.000
2000	Carlton	36	B	4.587	6	0.966	0.000
2000	Carlton	36	C	4.668	4	0.977	0.012
2000	Douglas	64	A	3.757	4	0.996	0.002
2000	Douglas	64	B	4.261	3	0.999	0.019
2000	Douglas	64	C				
2000	Carlton	69	AB	4.878	8	0.976	0.000
2000	Carlton	69	AB	5.228	8	0.992	0.000
2000	Carlton	69	C	4.484	7	0.986	0.000
2000	Douglas	76	A	4.434	6	0.987	0.000
2000	Douglas	76	B	4.260	5	0.993	0.000
2000	Douglas	76	C	3.456	4	0.934	0.033
2000	Carlton	83	A	5.118	6	0.994	0.000
2000	Carlton	83	B	4.953	6	0.984	0.000
2000	Carlton	83	C	3.750	5	0.960	0.003
2000	Carlton	121	AB	3.406	4	0.984	0.008
2000	Carlton	121	AB	4.121	6	0.998	0.000
2000	Carlton	121	C	3.687	6	0.995	0.000

[a] Linear regressions that are significant at $\alpha < 0.10$.
[b] The number of measurement days in the regression.

Table B.2. Mean square error table for the results of nested ANOVA on the effects of hatch order on linear growth rates of Black Terns chicks in Maine during 1998-2000 at Douglas Pond and Carlton Bog.

Effect	df	MS	F	P
Hatch Order	3	0.893	5.393	0.031
Brood (Hatch Order)	44	0.437	2.638	0.090
Error	7	0.166		

Appendix C. Food delivery patterns of Black Terns in Maine.

Table C.1. Diurnal variation in rates of food delivery to Black Tern nests in 1999 and 2000.

Forage Type	F	P	n	Hourly differences in delivery rates[a]
All (total)	3.231	0.000	3071	18 > 10, 11, 15, 16; 13 > 10
Small insect	3.274	0.000	3071	18 > 9, 10, 12, 15, 16
Large insect	7.046	0.000	3071	7 < 10-18, 8 < 12-14, 13 > 7-11,15, 17
Small fish	3.732	0.000	3071	18 > 8-10, 12-14, 16; 17 > 13
Large fish	3.690	0.000	3071	18 > 10-15; 17 > 13
Unknown	1.106	0.351	3071	

[a] Results of Tukey's multiple comparison test for $\alpha < 0.05$.

Table C.2. Mean squares table for nested ANOVA for factors affecting ranked rates of food delivery to Black Tern broods between 2 and 10 days old at Douglas Pond and Carlton Bog during 1999 and 2000.

	Effect	df[a]	MS	F	P
Small insect	Year	1	16956.63	6.760	0.011
	Colony	1	27422.78	10.933	0.001
	Age	1	6798.07	2.710	0.103
	Year*colony	1	78151.36	31.158	0.000
	Year*age	1	29877.52	11.912	0.001
	Colony*age	1	217.77	0.087	0.769
	Brood(year*colony*age)	39	6132.29	2.445	0.000
	Error	96	2508.23		
Large insect	Year	1	166827.87	147.101	0.000
	Colony	1	5997.50	5.288	0.024
	Age	1	12668.68	11.171	0.001
	Year*colony	1	49965.07	44.057	0.000
	Year*age	1	518.50	0.457	0.501
	Colony*age	1	3331.14	2.937	0.090
	Brood(year*colony*age)	39	3440.42	3.034	0.000
	Error	96	1134.10		
Small fish	Year	1	12212.86	4.852	0.030
	Colony	1	8771.96	3.485	0.065
	Age	1	2777.86	1.104	0.296
	Year*colony	1	1911.53	0.759	0.386
	Year*age	1	7090.49	2.817	0.097
	Colony*age	1	30424.26	12.087	0.001
	Brood(year*colony*age)	39	3257.01	1.294	0.156
	Error	96	2517.15		
Large fish	Year	1	112.15	0.034	0.855
	Colony	1	10326.44	3.086	0.082
	Age	1	1115.77	0.333	0.565
	Year*colony	1	122.63	0.037	0.849
	Year*age	1	9441.76	2.822	0.096
	Colony*age	1	46.65	0.014	0.906
	Brood(year*colony*age)	39	5904.16	1.764	0.013
	Error	96	3346.36		
Total	Year	1	867.22	0.424	0.517
	Colony	1	74356.67	36.326	0.000
	Age	1	642.28	0.314	0.577
	Year*colony	1	6032.44	2.947	0.089
	Year*age	1	17539.55	8.569	0.004

Table C.2. Continued.

Effect	df[a]	MS	F	P
Colony*age	1	2219.01	1.084	0.300
Brood(year*colony*age)	39	6454.07	3.153	0.000
Error	96	2046.95		

[a] Only nests with >2 sampling days were used.

Appendix D. Potential Black Tern colony sites in Maine.

Table D.1. Potential Black Tern colony sites in Maine identified in this study.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Total Area > 105 ha, Total Semipermanent Area > 20 ha									
West Grand Lake	T6 ND BPP (15)		11930.49	(3)	228.73	(3)	43.53	(3)	11
Flagstaff Lake	Flagstaff Twp (13)		7460.72	(3)	218.99	(1)	10.71	(1)	11
Bull Pond	Codyville Plt (15)		796.98	(3)	170.89	(2)	150.96	(1)	11
Fourth Machias Lake	T5 ND BPP (15)		1599.67	(3)	154.12	(3)	35.78	(3)	11
Nicatous Lake	T40 MD (5)		2929.14	(3)	115.59	(3)	42.52	(3)	11
Millinocket Lake	T8 R9 WELS (11)		1237.43	(3)	99.72	(1)	12.71	(1)	11
Mountain Catcher Pond	Trout Brook Twp (10)		2270.53	(3)	95.86	(0)	9.55	(0)	11
Horseshoe Pond	T5 R9 NWP (11)	1998-2000	579.03	(3)	86.34	(2)	66.24	(2)	11
Magurrewock Brook	Calais (15)		130.36	(3)	84.94	(3)	52.85	(3)	12
Sabattus Pond	Wales (1)		823.15	(3)	78.80	(3)	59.67	(3)	11
Carlton Bog	Troy (14)	1980-2000	431.57	(3)	74.64	(2)	24.02	(3)	11
Pleasant Lake	Stetson (10)		531.82	(3)	71.38	(1)	30.47	(1)	11
Plymouth Pond	Plymouth (10)	1989-2000	320.02	(3)	64.59	(1)	25.30	(1)	11
Chamberlain Lake	Eagle Lake Twp (11)		11309.73	(3)	64.41	(2)	32.05	(2)	11
Bishop Pond	Fort Fairfield (2)		230.08	(3)	64.33	(3)	35.00	(3)	12
1000 Acre Heath	T3 R1 NBPP (10)		906.07	(3)	59.93	(2)	55.16	(2)	11
Messalonskee Lake	Belgrade (6)	1946-2000	1785.70	(3)	54.67	(3)	19.49	(3)	11
Fields Pond	Orrington (10)		233.08	(3)	54.34	(3)	26.20	(3)	11
Millinocket Lake	T2 R8 WELS (10)		3898.56	(3)	49.50	(2)	14.54	(2)	12
West Outlet Indian Pond	Sapling Twp (13)		139.61	(3)	49.01	(0)	39.32	(0)	11
Cobbosseecontee Lake	Monmouth (6)		2919.88	(3)	47.75	(2)	18.64	(2)	11
Huntley Brook Flowage	No 21 Twp (15)	1970-2000	8271.98	(3)	46.51	(2)	4.07	(1)	11
Douglas Pond	Palmyra (13)	1977-2000	226.82	(3)	44.21	(2)	23.18	(2)	11
Davis Pond	Holden (10)		427.48	(3)	43.70	(1)	14.45	(1)	11
Great Moose Lake	Hartland (13)	1988-2000	1800.31	(3)	43.23	(2)	20.38	(2)	11
Upper Mud Lake	Alexander (15)	1973-1995	3261.87	(3)	40.51	(2)	14.41	(2)	11
Third Machias Lake	T43 MD BPP (15)		1793.49	(3)	36.02	(3)	16.36	(3)	11

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Total	(rank)	Total semipermanent	(rank)	Maximum semimpermanent	(rank)	Total rank
						Area in ha[b] (rank)			
Crooked Brook Flowage	Danforth (15)		822.93	(3)	34.88	(3)	7.09	(2)	11
Gardner Lake	Marion Twp (15)		2472.43	(3)	34.75	(3)	7.48	(3)	11
Baker Pond	T5 R6 BKP WKR (13)		193.16	(3)	33.81	(3)	23.00	(2)	12
Round Pond	Plymouth (10)		252.55	(3)	32.36	(3)	18.73	(3)	11
Meduxnekeag Lake	New Limerick (2)		586.32	(3)	32.23	(3)	7.36	(3)	11
Great Heath	T18 MD BPP (15)		2383.33	(3)	30.05	(3)	13.52	(3)	12
Bog Stream	Mercer (13)		131.91	(3)	29.97	(3)	29.97	(3)	9
Gilman Pond	Lexington Twp (13)		223.41	(3)	29.02	(0)	11.57	(0)	10
Brassua Lake	Tomhegan Twp (13)		4019.68	(3)	28.17	(0)	10.04	(0)	11
Merrit Pond	Beddington (15)		527.60	(3)	27.77	(3)	5.76	(3)	11
West Bay Pond	Gouldsboro (5)		201.74	(3)	27.58	(3)	6.99	(3)	12
Stowers Meadows	Stockton Springs (14)		120.84	(3)	27.31	(2)	25.62	(2)	9
Great Works Pond	Edmunds Twp (15)		196.05	(3)	27.30	(3)	27.21	(3)	12
Moosehead Lake	Moosehead Lake (11)		30864.21	(3)	27.11	(3)	5.76	(2)	11
Seboeis Lake	T4 R9 NWP (11)		2380.55	(3)	22.99	(3)	8.91	(3)	11
Little Togus Pond	Augusta (6)		552.43	(3)	22.52	(3)	13.81	(3)	12
Lake Arrowhead	Waterboro (16)		684.74	(3)	21.79	(3)	4.19	(3)	12
Sebago Lake	Raymond (3)		12374.18	(3)	21.72	(3)	9.96	(3)	11
Unity Pond	Burnham (14)		1110.78	(3)	21.28	(3)	18.77	(3)	11
Graham Lake	Mariaville (5)		4476.64	(3)	21.19	(3)	3.94	(3)	11
Total Area < 105 ha, Total Semipermanent Area > 20 ha									
Holt Pond	Naples (3)		34.47	(2)	27.77	(3)	27.77	(3)	10
Magurrewock Brook	Calais (15)		52.92	(2)	26.87	(3)	25.53	(3)	11
Bog Pond	Fryeburg (9)		52.68	(2)	24.26	(3)	20.59	(3)	8
Mulligan Stream	Saint Albans (13)		75.79	(2)	22.55	(3)	22.55	(3)	9
Total Area > 105 ha, Total Semipermanent Area < 20 ha									
Upper Pond	Lincoln (10)		335.96	(3)	19.72	(3)	13.06	(3)	11
Middle Lead Mountain Pond	T28 MD (5)		256.47	(3)	18.71	(3)	9.41	(3)	11
Manhanock Pond	Parkman (11)		303.79	(3)	18.23	(3)	11.03	(3)	11
Skitacook Lake	T4 R3 WELS (2)		212.08	(3)	18.11	(3)	9.80	(3)	11
Partridge Brook Flowage	East Millinocket (10)		105.02	(2)	17.54	(1)	9.45	(0)	11

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)		Total semipermanent		Maximum semimpermanent		Total rank
			Total						
Boyd Lake	Orneville Twp (11)		748.78	(3)	17.52	(3)	14.71	(3)	11
Ruffingham Meadow	Searsmont (14)		156.26	(3)	17.12	(3)	11.60	(3)	10
Second Chain Lake	T26 ED BPP (15)		733.38	(3)	16.43	(3)	5.56	(3)	11
Canada Falls Lake	Pittston Academy Grant (13)		1003.55	(3)	16.06	(3)	5.25	(2)	11
Pleasant Pond	Brownfield (9)		255.20	(3)	15.65	(3)	13.95	(3)	11
Little Indian Pond	Saint Albans (13)		636.08	(3)	15.58	(2)	6.86	(2)	11
Blood Brook	Chester (10)		202.33	(3)	15.24	(0)	8.50	(0)	12
Jackson Pond	T3 R11 WELS (11)		532.98	(3)	14.85	(0)	10.25	(0)	12
North Pond	Norway (9)		230.06	(3)	14.65	(3)	10.37	(3)	11
First Pond	Blue Hill (5)		127.76	(3)	14.43	(3)	2.79	(2)	8
Madawaska Pond	Palmyra (13)	1972-2000	106.72	(2)	13.86	(2)	6.38	(2)	10
Fahi Pond	Embden (13)		168.02	(3)	13.78	(1)	4.51	(2)	11
Hadley Lake	East Machias (15)		995.89	(3)	13.62	(3)	13.35	(3)	12
Kennebago Lake	Davis Twp (4)		863.59	(3)	13.33	(3)	5.08	(3)	11
Roberts Pond	Lyman (16)		202.12	(3)	13.16	(3)	12.48	(3)	10
Scammon Pond	Eastbrook (5)		269.09	(3)	13.04	(3)	4.73	(3)	11
Crooked Pond	Lincoln (10)		670.40	(3)	13.03	(1)	3.45	(2)	12
Sebasticook Lake	Newport (10)		2031.35	(3)	12.87	(0)	3.59	(0)	12
Spencer Lake	Hobbstown Twp (13)		860.63	(3)	12.81	(0)	2.87	(0)	10
Mattaseunk Lake	Molunkus Twp (2)		402.75	(3)	12.50	(3)	5.58	(3)	11
Stink Pond	T7 R11 WELS (11)		112.24	(3)	12.36	(0)	12.36	(1)	9
Maxy Brook	Howland (10)		151.99	(3)	12.19	(2)	4.65	(2)	9
Dresden Bog	Dresden (8)		175.48	(3)	11.64	(3)	6.57	(3)	9
Quantabacook Lake	Searsmont (14)		472.77	(3)	11.41	(1)	3.81	(1)	12
Parker Pond	Brooksville (5)		174.23	(3)	11.27	(3)	6.87	(3)	9
Lovejoy Pond	Fayette (6)		156.18	(3)	10.93	(3)	7.59	(3)	9
Brandy Pond	T39 MD (5)		341.46	(3)	10.53	(3)	9.39	(3)	11
Roaring Lake	Whiting (15)		269.34	(3)	10.50	(3)	3.60	(3)	12
Pedumcook Lake	T1 R9 WELS (11)		8358.13	(3)	10.46	(3)	2.32	(2)	10
Spednic Lake	T11 R3 NBPP (15)		2058.16	(3)	10.24	(0)	2.16	(0)	10
Buker Pond	Litchfield (6)		205.03	(3)	9.40	(3)	7.03	(3)	11

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Total		Total semipermanent		Maximum semimpermanent		Total rank
			Area in ha[b] (rank)						
Androscoggin Lake	Wayne (6)		1699.00	(3)	9.21	(3)	6.33	(3)	11
Massachusetts Bog	Massachusetts Gore (4)		127.07	(3)	9.18	(3)	5.12	(3)	9
Lower Sabao Lake	T35 MD (5)		468.49	(3)	9.00	(3)	3.86	(3)	11
Round Pond	Waterboro (16)		143.66	(3)	8.80	(3)	8.80	(3)	9
Hobart Lake	Edmunds Twp (15)		153.50	(3)	8.56	(3)	8.56	(3)	12
Torsey Lake	Mount Vernon (6)		280.32	(3)	8.53	(3)	2.37	(2)	10
Clary Lake	Jefferson (8)		357.37	(3)	8.52	(3)	8.52	(3)	12
Long Pond	Long Pond Twp (13)		1443.53	(3)	8.46	(2)	5.26	(2)	11
Meadow Brook	Woodville (10)		108.43	(2)	7.98	(0)	2.77	(0)	8
Lower First Saint John Pond	T4 R17 WELS (13)		108.07	(2)	7.83	(2)	3.77	(2)	9
Rocky Lake	Whiting (15)		647.59	(3)	7.76	(3)	2.42	(2)	11
Silver Lake	Bucksport (5)		280.65	(3)	6.77	(3)	5.12	(3)	11
Mainstream Pond	Harmony (13)	1989-1993	184.09	(3)	6.41	(1)	4.78	(1)	9
Pleasant Lake	T6 R6 WELS (10)		294.81	(3)	6.28	(2)	5.06	(2)	12
Chesuncook Lake	T4 R12 WELS (11)		12919.39	(3)	6.24	(2)	2.49	(3)	10
Little Purgatory Pond	Litchfield (6)		211.19	(3)	6.23	(3)	4.09	(3)	11
Mooselookmeguntic Lake	Richardsontown Twp (9)		6700.11	(3)	5.74	(3)	1.84	(2)	10
Upper Pleasant Pond	Richmond (6)		129.64	(3)	5.59	(3)	2.25	(2)	8
Aziscohos Lake	Parkertown Twp (9)		2873.54	(3)	5.57	(3)	1.58	(2)	10
Mary L Pond	T12 R16 WELS (2)		115.15	(3)	5.00	(3)	2.17	(2)	11
Total Area < 105 ha, Total Semipermanent Area < 20 ha									
The Pool	Appleton (7)		84.23	(2)	19.32	(3)	19.32	(3)	8
Hothole Pond	Orland (5)		70.03	(2)	18.01	(3)	16.47	(3)	10
Massacre Pond	Scarborough (3)		28.95	(2)	16.65	(3)	16.65	(3)	8
Little Sabattus Pond	Greene (1)		55.65	(2)	14.14	(3)	14.14	(3)	9
Big Pond	Steuben (15)		70.71	(2)	13.39	(3)	13.39	(3)	8
Cross Pond	Morrill (14)		97.21	(2)	11.23	(2)	6.56	(2)	11
Bearce Lake	Baring (15)		29.34	(2)	10.98	(3)	3.90	(3)	11
Toddy Pond	Surry (5)		52.42	(2)	10.74	(3)	8.07	(3)	9
Culling Pond	Monticello (2)		25.61	(2)	10.70	(3)	5.68	(3)	9
Pettengill Stream	Union (7)		49.82	(2)	10.32	(3)	10.32	(3)	9

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
China Lake	China (6)		32.06	(2)	9.85	(3)	9.85	(3)	11
Great Pond	Cape Elizabeth (3)		72.33	(2)	9.52	(3)	3.80	(3)	9
Upper Pond	Bristol (8)		65.09	(2)	9.35	(3)	9.08	(3)	11
Carrie Bogan	Allagash (2)		58.14	(2)	8.79	(1)	8.79	(1)	8
Mary L Pond	T12 R16 WELS (2)		59.21	(2)	8.70	(3)	5.94	(3)	11
Rock Haven Lake	Newfield (16)		90.45	(2)	8.56	(3)	8.40	(3)	11
Harmon Beach Pond	Standish (3)		24.57	(2)	8.54	(3)	7.84	(3)	10
Olamon Stream	Greenbush (10)		90.14	(2)	7.96	(0)	3.52	(0)	11
Cascade Brook	Saco (16)		26.41	(2)	7.86	(3)	6.64	(3)	8
Magurrewock Brook	Calais (15)		27.44	(2)	7.83	(2)	3.06	(2)	10
Symmes Pond	Newfield (16)		28.14	(2)	7.79	(3)	7.79	(3)	9
Dead Stream	Old Town (10)		32.05	(2)	7.69	(2)	5.13	(2)	9
Weary Pond	Whitefield (8)		35.62	(2)	7.44	(3)	7.44	(3)	11
Ledge Pond	Baring (15)		23.63	(2)	7.09	(3)	6.74	(3)	9
Lemon Stream	Athens (13)		24.24	(2)	7.08	(1)	4.32	(1)	9
Cat Pond	Fryeburg (9)		29.47	(2)	6.79	(3)	6.79	(3)	8
Dilling Lake	Easton (2)		30.24	(2)	6.36	(3)	6.36	(3)	9
Stantial Brook	Knox (14)		21.14	(2)	6.24	(3)	4.86	(3)	8
Whites Pond	Palmyra (13)		92.80	(2)	6.02	(3)	5.17	(3)	8
Western Lake	Edmunds Twp (15)		35.34	(2)	5.88	(3)	5.88	(3)	11
Horseshoe Pond	West Gardiner (6)		35.81	(2)	5.73	(3)	3.31	(3)	9
Lazy Tom Stream	T1 R13 WELS (11)		94.37	(2)	5.72	(3)	3.97	(3)	8
Swan Pond	Hartford (9)		32.27	(2)	5.66	(3)	5.66	(3)	8
Pattee Brook	Fort Fairfield (2)		28.53	(2)	5.49	(3)	4.07	(3)	9
Grassy Pond	Rockport (7)		89.37	(2)	5.17	(3)	5.08	(3)	8
Maxy Brook	Maxfield (10)		39.38	(2)	5.05	(1)	5.05	(0)	9
Total Area < 20 ha, Total Semipermanent Area < 20 ha									
Berry Pond	Winthrop (6)		19.02	(1)	16.46	(3)	12.54	(3)	9
Carlton Bog	Troy (14)		16.95	(1)	14.08	(3)	14.08	(3)	8
Martin Stream	Dixmont (10)		10.76	(1)	9.75	(3)	9.75	(3)	9
Shaw Brook	Troy (14)		13.60	(1)	6.48	(3)	6.48	(3)	7

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Joys Pond	Pittston (6)		12.44	(1)	6.35	(3)	4.37	(3)	7
Pennaquan River	Pembroke (15)		46.81	(2)	9.53	(3)	6.83	(3)	8
Dolliff Pond	Morrill (14)		16.97	(1)	6.01	(3)	6.01	(3)	10
Worthley Pond	New Gloucester (1)		18.44	(1)	6.01	(3)	4.97	(3)	7
Bear Pond	Turner (9)		8.31	(1)	5.60	(3)	5.60	(3)	7
Crane Mill Brook	Edmunds Twp (15)		15.31	(1)	5.48	(3)	5.23	(3)	8
Ripple Pond	Mount Desert (5)		7.36	(1)	5.30	(3)	5.30	(3)	8
Snow Brook	Skowhegan (13)		18.71	(1)	5.21	(3)	3.44	(3)	8
Winslow Rd Marsh	Albion (6)		12.51	(1)	5.16	(2)	5.16	(2)	8
MPR Land Swamp	Norridgewock (13)		14.55	(1)	5.14	(3)	3.06	(3)	7
Total Area > 105 ha, Total Semipermanent Area < 5 ha									
Spectacle Pond	Augusta (6)		168.56	(3)	4.97	(3)	3.01	(2)	10
Caucomgomoc Lake	T7 R14 WELS (11)		2801.74	(3)	4.94	(1)	3.72	(1)	11
Nicatous Stream	T3 ND (5)		121.96	(3)	4.80	(3)	1.45	(2)	11
Rangeley Lake	Rangeley (4)		2613.99	(3)	4.60	(3)	2.33	(2)	10
Lower Patten Pond	Surry (5)		363.32	(3)	4.58	(3)	4.58	(3)	11
Frost Pond	Sedgwick (5)		120.07	(3)	4.46	(3)	4.46	(3)	9
Long Lake	Madawaska (2)		2998.23	(3)	4.31	(1)	2.97	(0)	10
Frost Pond Flowage	Dole Brook Twp (13)		374.62	(3)	4.20	(0)	1.76	(0)	11
Brownfield Bog WMA	Brownfield (9)		251.90	(3)	4.19	(3)	4.19	(3)	11
Porter Lake	Strong (4)		221.15	(3)	4.18	(3)	4.18	(3)	11
Estes Bog	Poland (1)		316.07	(3)	4.02	(3)	4.02	(3)	11
Jim Pond	Jim Pond Twp (4)		160.63	(3)	3.99	(3)	3.20	(3)	10
Megunticook Lake	Lincolnville (14)		638.59	(3)	3.97	(2)	3.97	(2)	10
Richardson Lake	Richardsontown Twp (9)		3210.60	(3)	3.95	(2)	2.64	(2)	9
Mud Pond	Winslow (6)		144.45	(3)	3.64	(2)	3.64	(3)	9
Pickerel Pond	Wayne (6)		355.10	(3)	3.59	(2)	1.36	(2)	9
Mud Pond	T6 R8 WELS (10)		155.55	(3)	3.56	(3)	3.56	(3)	11
Spectacle Pond	Osborn (5)		745.67	(3)	3.53	(2)	3.33	(3)	11
Maranacook Lake	Readfield (6)		764.47	(3)	3.52	(2)	2.04	(2)	9
Meddybemps Lake	Alexander (15)		3655.66	(3)	3.46	(2)	0.95	(1)	8

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Square Lake	T16 R5 WELS (2)		4393.02	(3)	3.41	(0)	2.05	(0)	9
Great Pond	Belgrade (6)		4853.35	(3)	3.40	(1)	1.67	(1)	9
Mosquito Pond	The Forks Plt (13)		918.30	(3)	3.33	(2)	1.94	(1)	9
Mud Pond	T6 R12 WELS (11)		596.60	(3)	3.29	(2)	3.16	(2)	10
Kanokolus Bog	Unity (14)		113.77	(3)	3.27	(2)	2.62	(1)	9
Little Pond	Rome (6)		1025.99	(3)	3.26	(3)	1.72	(3)	9
Sheepscot Pond	Palermo (14)		779.21	(3)	3.24	(1)	1.65	(1)	9
Sandy Pond	Freedom (14)		205.73	(3)	3.09	(3)	2.35	(3)	10
B Pond	TB R11 WELS (11)		285.59	(3)	3.08	(2)	0.77	(1)	8
Pierce Pond	Pierce Pond Twp (13)		635.49	(3)	2.91	(0)	1.49	(0)	9
Burnham Brook	Devereaux Twp (15)		134.80	(3)	2.88	(2)	1.88	(2)	8
Baskahegan Lake	Brookton Twp (15)		3079.11	(3)	2.84	(3)	1.86	(3)	9
Parmachenee Lake	Lynchtown Twp (9)		398.86	(3)	2.81	(2)	2.38	(2)	10
Wesserunsett Lake	Madison (13)		644.54	(3)	2.75	(2)	1.18	(1)	9
Orchard Bog	Caswell (2)		162.95	(3)	2.60	(2)	2.60	(2)	10
Moose Pond	Acton (16)		301.49	(3)	2.59	(2)	2.59	(2)	9
Sargent Bog	Lagrange (10)		1511.93	(3)	2.44	(1)	1.91	(1)	10
Webber Pond	Vassalboro (6)		509.55	(3)	2.43	(2)	1.76	(2)	9
Montegail Pond	T19 MD BPP (15)		215.29	(3)	2.31	(2)	1.70	(2)	8
Little SW Branch St. John's River	T9 R18 WELS (13)		108.17	(2)	2.27	(3)	1.03	(3)	5
Upper Sabao Lake	T41 MD (5)		209.55	(3)	2.20	(2)	2.20	(2)	9
Canaan Bog	Canaan (13)		465.54	(3)	2.16	(2)	2.16	(2)	9
Grass Pond	T24 MD BPP (15)		228.18	(3)	2.09	(2)	2.09	(2)	9
Pemaquid Pond	Bremen (8)		1156.31	(3)	1.95	(2)	1.95	(2)	9
Beddington Lake	Beddington (15)		222.05	(3)	1.93	(2)	1.36	(2)	9
Woodland Lake	Baileyville (15)		251.28	(3)	1.85	(2)	1.32	(3)	9
Nashs Lake	Calais (15)		351.86	(3)	1.85	(2)	0.98	(1)	9
Endless Lake	T3 R9 NWP (10)		629.05	(3)	1.84	(3)	1.22	(2)	9
Little Bog	T6 R17 WELS (13)		217.17	(3)	1.83	(3)	0.55	(3)	7
Pollard Brook	Edinburg (10)		152.97	(3)	1.78	(1)	1.20	(1)	10
Southern inlet Rocky Lake	East Machias (15)		162.03	(3)	1.77	(2)	1.77	(2)	10

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semipermanent		
Echo Lake	Fayette (6)		499.89	(3)	1.75	(2)	1.18	(2)	9
Long Pond	Chain of Ponds Twp (4)		319.10	(3)	1.70	(2)	0.75	(1)	8
Branns Mill Pond	Dover-Foxcroft (11)		170.19	(3)	1.66	(2)	1.66	(2)	9
Lower Kimball Pond	Fryeburg (9)		173.45	(3)	1.63	(2)	1.63	(2)	7
Androgscoggin River	Jay (4)		135.14	(3)	1.60	(2)	1.60	(2)	7
Hancock Pond	Embden (13)		139.31	(3)	1.57	(3)	1.57	(3)	7
Third Roach Pond	Shawtown Twp (11)		351.87	(3)	1.57	(2)	1.08	(1)	9
Tripp Pond	Poland (1)		301.03	(3)	1.56	(2)	0.88	(1)	8
Dexter Pond	Wayne (6)		377.52	(3)	1.50	(2)	1.04	(1)	8
Saponac Pond	Grand Falls Twp (10)		437.15	(3)	1.49	(1)	0.96	(1)	9
Narraguagus Lake	T16 MD (5)		346.51	(3)	1.49	(2)	1.49	(2)	10
Lovejoy Pond	Albion (6)		201.18	(3)	1.42	(2)	0.66	(1)	8
Trafton Pond	T10 R7 WELS (2)		280.11	(3)	1.37	(2)	1.13	(2)	10
Lower Range Pond	Poland (1)		120.41	(3)	1.35	(2)	1.35	(2)	7
Deer Meadow Pond	Jefferson (8)		1999.73	(3)	1.32	(2)	0.95	(1)	9
Mud Brook Flowage	T2 R8 WELS (10)		106.80	(2)	1.30	(1)	1.30	(1)	9
Pleasant Pond	Litchfield (6)		274.60	(3)	1.26	(1)	1.26	(2)	8
Keene Bog	Chester (10)		175.88	(3)	1.26	(1)	0.79	(2)	8
Big Heath	Centerville (15)		509.67	(3)	1.20	(1)	0.62	(1)	8
South Branch Lake	T2 R8 NWP (10)		871.30	(3)	1.16	(0)	1.16	(0)	9
Caribou Bog	Old Town (10)		255.94	(3)	1.15	(0)	1.15	(0)	8
Dean Brook Deadwater	Long A Twp (10)		108.33	(2)	1.15	(0)	0.53	(0)	6
Fifth Machias Lake	T36 MD BPP (15)		640.19	(3)	1.12	(1)	0.93	(1)	8
Crystal Lake	Hersey (2)		105.53	(2)	1.11	(1)	1.11	(2)	5
Lower Oxbrook Lake	T6 ND BPP (15)		141.95	(3)	1.07	(3)	0.55	(3)	7
Indian Pond	T7 R9 NWP (11)		243.29	(3)	1.04	(1)	1.04	(1)	5
Silver Lake	Lee (10)		253.77	(3)	1.01	(2)	0.53	(3)	7
Egg Pond	Lincoln (10)		354.26	(3)	0.98	(0)	0.55	(0)	7
Berry Heath	East Machias (15)		158.58	(3)	0.95	(1)	0.73	(1)	8
Lower Pistol Lake	T3 ND (5)		454.63	(3)	0.94	(1)	0.94	(1)	7
Campbell Brook	Sandy Bay Twp (13)		117.47	(3)	0.93	(1)	0.93	(1)	6

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semipermanent		
Portage Lake	Portage Lake (2)	1957-1959	1162.72	(3)	0.90	(0)	0.70	(0)	7
Fifteenmile stream	Benton (6)		174.16	(3)	0.89	(2)	0.89	(2)	8
Rush Pond	Herseytown Twp (10)		106.50	(2)	0.88	(2)	0.73	(2)	4
Lovewell Pond	Fryeburg (9)		441.71	(3)	0.83	(1)	0.60	(1)	7
Bald Mountain Pond	Bald Mountain Twp T2 R3 (13)		543.03	(3)	0.81	(2)	0.81	(1)	8
Lake Hebron	Monson (11)		267.19	(3)	0.81	(1)	0.64	(1)	7
Lake Onawa	Elliottsville Twp (11)		561.51	(3)	0.80	(1)	0.23	(0)	6
Main Stream	T39 MD (5)		275.26	(3)	0.80	(1)	0.35	(0)	6
Barrows Lake	Alexander (15)		131.91	(3)	0.79	(1)	0.79	(1)	7
Umbagog Lake	Magalloway Plt (9)		1014.93	(3)	0.74	(1)	0.43	(0)	6
Number Three Pond	T3 R1 NBPP (10)		329.50	(3)	0.74	(3)	0.74	(3)	7
Donnell Pond	T9 SD (5)		466.05	(3)	0.70	(1)	0.70	(1)	7
Duck Pond	T5 R12 WELS (11)		205.56	(3)	0.64	(0)	0.43	(1)	6
Haycock Pond	T35 MD (5)		184.22	(3)	0.63	(1)	0.63	(1)	8
Gassabias Lake	T41 MD (5)		400.36	(3)	0.60	(1)	0.32	(0)	6
Inlet St. John River	T12 R16 WELS (2)		160.39	(3)	0.59	(1)	0.59	(1)	8
Partridge Brook Flowage	TA R7 WELS (10)		792.49	(3)	0.59	(3)	0.43	(3)	7
Mooseleuk Lake	T10 R9 WELS (11)		542.85	(3)	0.59	(1)	0.46	(1)	7
Salmon Brook Lake	Perham (2)		124.92	(3)	0.59	(2)	0.59	(3)	5
Sebec Lake	Bowerbank (11)		2624.88	(3)	0.57	(1)	0.48	(1)	7
Little Pushaw Pond	Hudson (10)		548.02	(3)	0.57	(2)	0.52	(2)	7
Grand Lake	Weston (2)		3649.73	(3)	0.56	(1)	0.56	(1)	7
Pleasant Pond	Caratunk (13)		420.58	(3)	0.56	(2)	0.56	(2)	7
Chemo Bog	Bradley (10)		735.63	(3)	0.55	(3)	0.55	(3)	7
Umsaskis Lake	T11 R13 WELS (2)		1418.54	(3)	0.54	(1)	0.42	(0)	6
Dead River	T3 R4 BKP WKR (13)		303.11	(3)	0.53	(2)	0.53	(1)	7
Clifford Lake	T27 ED BPP (15)		690.59	(3)	0.52	(1)	0.52	(1)	7
Lobster Lake	Lobster Twp (11)		1742.00	(3)	0.51	(3)	0.28	(3)	6
Little Pond	Liberty (14)		451.33	(3)	0.50	(3)	0.50	(3)	7
Pleasant Lake	Otisfield (3)		609.40	(3)	0.49	(0)	0.49	(1)	6
Rock Dam Heath	T16 MD (5)		144.33	(3)	0.49	(0)	0.49	(1)	6

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Burnham Pond	Big Squaw Twp (11)		171.24	(3)	0.49	(0)	0.49	(1)	6
Northeast Pond	Lebanon (16)		167.62	(3)	0.46	(0)	0.46	(1)	4
Indian Pond	Chase Stream Twp (13)		1374.79	(3)	0.45	(0)	0.45	(0)	6
Hardy Pond	Lake View Plt (11)		119.52	(3)	0.45	(0)	0.27	(0)	6
Lower Togue Pond	T2 R9 WELS (11)		193.13	(3)	0.44	(1)	0.44	(1)	6
Bagley Brook Heath	Cutler (15)		130.18	(3)	0.41	(0)	0.41	(0)	6
Mountain View Pond	Big Squaw Twp (11)		225.11	(3)	0.38	(0)	0.38	(0)	3
Passadumkeag River	Summit Twp (10)		559.53	(3)	0.37	(2)	0.37	(1)	6
Mattawamkeag Lake	Island Falls (2)		1553.01	(3)	0.35	(0)	0.23	(0)	5
Long Pond	Dole Brook Twp (13)		359.52	(3)	0.34	(2)	0.34	(2)	6
Marston Meadow	Glenburn (10)		123.05	(3)	0.32	(0)	0.32	(0)	6
Spencer Pond	E. Middlesex Canal Grant Twp (11)		557.84	(3)	0.32	(0)	0.32	(0)	5
Eagle Pond	Drew Plt (10)		691.07	(3)	0.32	(0)	0.32	(0)	5
Salmon Stream	Medway (10)		440.60	(3)	0.28	(1)	0.28	(1)	6
Passamagamet Lake	T1 R9 WELS (11)		225.24	(3)	0.28	(0)	0.28	(0)	5
Seboomook Lake	Plymouth Twp (13)		2722.41	(3)	0.27	(1)	0.27	(1)	5
Chemquasabamticook Lake	T10 R15 WELS (11)		1233.26	(3)	0.25	(1)	0.25	(1)	5
Cranberry Pond	T8 R6 WELS (10)		111.53	(3)	0.24	(3)	0.24	(3)	3
Holeb Pond	Holeb Twp (13)		703.60	(3)	0.23	(1)	0.23	(1)	5
Spring River Lake	T10 SD (5)		326.36	(3)	0.22	(0)	0.22	(0)	5
Squa Pan Lake	Squapan Twp (2)		2125.91	(3)	0.22	(0)	0.22	(0)	5
East Pond	Smithfield (13)		867.46	(3)	0.22	(0)	0.22	(0)	5
Rainbow Lake	Rainbow Twp (11)		658.87	(3)	0.21	(1)	0.21	(1)	6
Sennebec Pond	Union (7)		229.46	(3)	0.20	(0)	0.20	(0)	6
Katahdin Lake	T3 R8 WELS (10)		276.90	(3)	0.20	(0)	0.20	(1)	6
Ephraim Brook	Argyle Twp (10)		164.15	(3)	0.19	(2)	0.19	(2)	6
Rockabema Lake	Moro Plt (2)		162.16	(3)	0.17	(0)	0.17	(0)	3
Coon Road Swamp	Otisfield (3)		1748.27	(3)	0.17	(0)	0.17	(0)	5
Lower Patten Pond	Surry (5)		144.04	(3)	0.16	(0)	0.09	(0)	5
C Pond	C Surplus (9)		176.00	(3)	0.15	(0)	0.15	(0)	3
Lake Cathance	No 14 Twp (15)		1329.94	(3)	0.14	(0)	0.14	(0)	5

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Upper Jo-Mary Lake	TA R10 WELS (11)		776.87	(3)	0.13	(0)	0.13	(0)	6
Machias River	Whitneyville (15)		218.85	(3)	0.12	(0)	0.12	(0)	6
Turner Deadwater	T4 R9 WELS (11)		139.33	(3)	0.12	(0)	0.12	(0)	4
East Branch Lake	T3 R9 NWP (10)		489.23	(3)	0.12	(0)	0.08	(0)	6
David Pond	Fayette (6)		124.28	(3)	0.12	(0)	0.12	(0)	5
Great Pond	Franklin (5)		146.82	(3)	0.11	(0)	0.11	(0)	6
Highland Lake	Bridgton (3)		549.65	(3)	0.11	(0)	0.11	(0)	5
Parlin Pond	Parlin Pond Twp (13)		260.96	(3)	0.11	(3)	0.11	(3)	3
Flanders Pond	Sullivan (5)		282.70	(3)	0.09	(0)	0.09	(0)	5
Georges Pond	Franklin (5)		146.39	(3)	0.08	(0)	0.08	(0)	5
Tomhegan Pond	West Middlesex Canal Grant (13)		143.08	(3)	0.08	(3)	0.08	(3)	3
Pleasant Lake	T4 R3 WELS (2)		735.67	(3)	0.08	(0)	0.08	(0)	5
Boyden Lake	Perry (15)		731.85	(3)	0.07	(0)	0.07	(0)	5
Falls Brook Lake	T18 R10 WELS (2)		120.05	(3)	0.04	(2)	0.04	(2)	4
Total Area < 105 ha, Total Semipermanent Area < 5 ha									
Northeast Pond	Hartford (9)		29.86	(2)	4.92	(3)	4.92	(3)	8
Curtis Bog	Sabattus (1)		68.48	(2)	4.75	(3)	3.30	(3)	8
Second Musquash Pond	T1 R11 WELS (11)		34.48	(2)	4.65	(3)	3.98	(3)	10
West Alna Road Pond	Alna (8)		21.84	(2)	4.58	(3)	4.58	(3)	8
Horn Pond	Jefferson (8)		43.45	(2)	4.55	(3)	4.55	(3)	10
Clays Pond	Fryeburg (9)		41.43	(2)	4.45	(3)	3.57	(3)	9
Bradley Pond	Topsham (12)		58.78	(2)	4.43	(3)	4.43	(3)	8
Martin Lake	Hamlin (2)		37.43	(2)	4.41	(0)	4.41	(1)	9
Schoodic Bog	Sullivan (5)		41.73	(2)	4.05	(3)	3.36	(3)	10
Bog Lake	T14 R5 WELS (2)		43.13	(2)	3.80	(0)	1.39	(0)	6
Contrary Brook Bog	Winn (10)		102.95	(2)	3.77	(1)	2.64	(1)	6
Mud Mills Pond	Monmouth (6)		21.80	(2)	3.53	(2)	3.53	(3)	7
Leadbetter Pond	T7 R12 WELS (11)		36.28	(2)	3.44	(1)	3.44	(1)	9
Beaver Brook Lake	Linneus (2)		54.24	(2)	3.42	(2)	1.89	(2)	6
Plymouth Bog	Plymouth (10)		44.19	(2)	3.35	(1)	3.35	(0)	8
Spring River	T16 MD (5)		29.15	(2)	3.33	(2)	1.40	(2)	9

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semipermanent		
Nevin Pond	Anson (13)		28.04	(2)	3.32	(2)	3.32	(3)	7
Bottle Pond	T2 R9 WELS (11)		29.21	(2)	3.26	(0)	2.84	(1)	8
Ninemile Deadwater	T14 R14 WELS (2)		32.22	(2)	3.26	(1)	3.26	(1)	8
Colson Branch	T16 MD (5)		24.34	(2)	3.25	(2)	1.84	(2)	9
Pollard Brook	Edinburg (10)		92.92	(2)	3.19	(2)	1.24	(2)	9
Mud Lake	Caswell (2)		25.89	(2)	2.98	(1)	2.15	(1)	7
Hardy Brook	Maxfield (10)		34.07	(2)	2.97	(3)	2.97	(3)	9
Beaver Pond	Phillips (4)		23.21	(2)	2.88	(2)	2.88	(2)	7
Center Pond	Phippsburg (12)		34.04	(2)	2.81	(2)	2.81	(2)	7
Cranberry Pond	Baring (15)		28.44	(2)	2.70	(2)	1.89	(2)	9
Madawaska River	Connor Twp (2)		28.02	(2)	2.65	(0)	1.87	(0)	6
Sanborn Pond	Brooks (14)		64.11	(2)	2.61	(1)	2.61	(2)	7
Chandler Stream	T9 R8 WELS (2)		44.02	(2)	2.58	(2)	1.68	(2)	8
Barnes Brook	Enfield (10)		27.79	(2)	2.55	(2)	2.55	(2)	9
Cut Pond	Dudley Twp (2)		76.54	(2)	2.41	(2)	2.41	(2)	6
Sargent Bog	Alton (10)		78.23	(2)	2.40	(3)	1.56	(3)	9
Halfmoon Pond	Saint Albans (13)		42.85	(2)	2.40	(2)	1.56	(2)	9
Ketch Pond	Limestone (2)		20.16	(2)	2.39	(0)	1.66	(0)	7
Otter Lake	T3 R4 WELS (2)		46.42	(2)	2.39	(2)	1.45	(2)	6
Upper McNally Pond	T11 R10 WELS (2)		81.13	(2)	2.37	(2)	2.07	(2)	7
Monson Pond	Fort Fairfield (2)		68.64	(2)	2.35	(2)	1.18	(2)	7
Weymouth Pond	Corinna (10)		48.60	(2)	2.34	(1)	1.48	(2)	9
Davidson Pond	Herseytown Twp (10)		37.00	(2)	2.32	(1)	1.92	(1)	6
Mopang First Lake	T30 MD BPP (15)		23.42	(2)	2.23	(2)	1.74	(2)	6
Pinkham Pond	Alna (8)		23.08	(2)	2.22	(2)	2.22	(2)	6
Maxy brook	Maxfield (10)		38.31	(2)	2.17	(3)	1.11	(3)	7
Little Purgatory Pond	Litchfield (6)		27.86	(2)	2.16	(2)	1.38	(2)	8
Adams Pond	Boothbay (8)		43.83	(2)	2.03	(2)	1.22	(2)	7
Saint Croix Lake	Webbertown Twp (2)		90.53	(2)	1.99	(2)	1.71	(2)	9
Violette Stream	Van Buren (2)		102.11	(2)	1.98	(0)	1.10	(0)	6
Depot Stream Pond	T12 R16 WELS (2)		57.69	(2)	1.88	(2)	1.12	(2)	7

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Total		Total semipermanent		Maximum semimpermanent		Total rank
						Area in ha[b] (rank)			
Little Falls Pond	Allagash (2)		46.97	(2)	1.88	(2)	1.88	(2)	7
Lily Pond	New Vineyard (4)		51.11	(2)	1.80	(2)	1.63	(2)	6
Brandy Pond	Webbertown Twp (2)		72.13	(2)	1.74	(2)	0.88	(1)	8
Second Lake	T18 ED BPP (15)		23.12	(2)	1.73	(2)	1.73	(2)	8
Bog Pond	T3 R9 NWP (10)		35.94	(2)	1.68	(2)	1.68	(2)	7
Barker Pond	Cornville (13)		57.51	(2)	1.68	(3)	0.97	(3)	6
South Branch Carry Brook	Plymouth Twp (13)		33.40	(2)	1.66	(2)	1.66	(1)	7
Meadow Brook	China (6)		31.90	(2)	1.65	(2)	1.65	(2)	8
Little Moxie Pond	East Moxie Twp (13)		31.96	(2)	1.65	(0)	0.94	(0)	6
Hawkins Brook	Bancroft (2)		40.37	(2)	1.61	(2)	1.17	(2)	6
Lowell Lake	Carroll Plt (10)		75.80	(2)	1.60	(1)	0.49	(2)	5
Hound Brook Lake	Dyer Twp (15)		37.17	(2)	1.58	(2)	0.86	(2)	6
Crocker Pond	Dennistown Plt (13)		27.06	(2)	1.57	(0)	1.57	(0)	7
Colby Pond	Liberty (14)		42.03	(2)	1.55	(1)	1.55	(1)	7
S. Branch Medunkeunk Stream	T2 R9 NWP (11)		98.31	(2)	1.54	(2)	1.46	(2)	9
Chandler River	Centerville (15)		23.24	(2)	1.52	(2)	1.52	(2)	9
Umberhind Marsh	Richmond (6)		27.56	(2)	1.49	(2)	1.49	(2)	7
Black River	T14 R15 WELS (2)		52.07	(2)	1.45	(0)	1.45	(0)	6
Lost Pond	T7 R13 WELS (11)		30.73	(2)	1.44	(2)	1.44	(3)	8
Corea Bog	Gouldsboro (5)		22.63	(2)	1.44	(2)	0.77	(1)	5
Felker Pond	King & Bartlett Twp (13)		26.91	(2)	1.43	(1)	0.53	(1)	6
Crane Mill Brook	Edmunds Twp (15)		30.61	(2)	1.42	(2)	0.91	(1)	6
Austin Stream	Mayfield Twp (13)		102.33	(2)	1.40	(3)	1.40	(3)	6
Gristmill Pond	Lowell (10)		74.90	(2)	1.39	(2)	1.39	(2)	8
Pocasset Lake	Wayne (6)		22.22	(2)	1.37	(2)	1.37	(2)	8
Schoodic Brook	Cherryfield (15)		26.03	(2)	1.36	(2)	1.36	(2)	7
Little Pond	Searsmont (14)		86.81	(2)	1.34	(1)	1.34	(1)	9
Cranberry Pond	Baring (15)		52.46	(2)	1.32	(2)	1.32	(2)	9
Tunk Stream Pond	Steuben (15)		60.49	(2)	1.29	(1)	1.29	(2)	5
Smith Pond	Swanville (14)		42.42	(2)	1.28	(2)	1.28	(2)	6
Gerard Pond	Caswell (2)		27.01	(2)	1.21	(1)	1.21	(1)	6

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Spring Brook Marsh	Cutler (15)		53.71	(2)	1.20	(1)	1.20	(2)	8
Pepperpot Pond	Adamstown Twp (9)		32.06	(2)	1.20	(1)	1.20	(2)	7
Shields Brook	T10 R6 WELS (2)		68.91	(2)	1.18	(1)	1.06	(1)	5
Stump Pond	Lincoln (10)		83.19	(2)	1.16	(1)	1.16	(1)	8
Lone Jack Pond	Johnson Mountain Twp (13)		21.45	(2)	1.16	(1)	1.16	(1)	6
Basin Pond	Pierce Pond Twp (13)		40.48	(2)	1.15	(1)	0.45	(1)	7
Mud Pond	Parkman (11)		36.61	(2)	1.13	(2)	1.13	(3)	6
Kelley Point Road Marsh	Jonesport (15)		47.47	(2)	1.11	(1)	1.11	(2)	5
Merrill Pond	Lee (10)		33.41	(2)	1.11	(1)	1.11	(1)	7
Southwest Pond	Beddington (15)		35.85	(2)	1.10	(1)	1.10	(2)	7
Hoyt Brook	Edinburg (10)		55.75	(2)	1.09	(2)	1.09	(2)	8
Seboeis Stream	Seboeis Plt (10)		96.05	(2)	1.09	(0)	1.09	(0)	8
Beech Island Pond	Surry (5)		30.84	(2)	1.09	(1)	1.09	(2)	5
Garland Pond	Garland (10)		56.08	(2)	1.08	(1)	1.08	(1)	6
Greers Bog	Morrill (14)		47.58	(2)	1.08	(2)	0.96	(3)	7
Cedar Swamp Pond	Clifton (10)		23.31	(2)	1.07	(2)	0.45	(3)	4
Mud Pond	Monmouth (6)		101.66	(2)	1.04	(1)	0.97	(1)	4
Schoodic Brook	Deblois (15)		21.92	(2)	0.98	(1)	0.98	(1)	7
Little Salmon Stream	Medway (10)		39.39	(2)	0.97	(1)	0.97	(1)	4
Bauds Pond	New Vineyard (4)		20.53	(2)	0.97	(1)	0.97	(1)	5
Little Moose Pond	T7 R10 WELS (11)		20.20	(2)	0.96	(3)	0.96	(3)	4
Logan Ponds	T2 R9 WELS (11)		62.96	(2)	0.96	(2)	0.75	(2)	7
Little Cobbosseecontee Lake	Winthrop (6)		58.74	(2)	0.95	(1)	0.95	(1)	6
Indian Lake	Crawford (15)		33.07	(2)	0.94	(1)	0.94	(1)	4
Hammond Brook Lake	Connor Twp (2)		64.98	(2)	0.93	(2)	0.93	(2)	5
South Branch Meduxnekeag River	Hodgdon (2)		86.09	(2)	0.93	(1)	0.57	(1)	5
Hammond Brook	Cyr Plt (2)		40.88	(2)	0.92	(3)	0.43	(3)	4
Lancaster Brook	Kenduskeag (10)		53.22	(2)	0.91	(3)	0.91	(3)	7
Moose Pond	Mount Vernon (6)		31.09	(2)	0.90	(1)	0.90	(1)	4
Beaver Brook	T9 R4 WELS (2)		30.93	(2)	0.88	(1)	0.88	(1)	5
Lawry Pond	Searsmont (14)		83.53	(2)	0.87	(2)	0.87	(2)	4

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semipermanent		
Jones Brook	Big Twenty Twp (2)		23.17	(2)	0.87	(0)	0.87	(0)	5
Inlet St. John River	T11 R16 WELS (2)		76.52	(2)	0.85	(1)	0.85	(1)	7
Mosquito Pond	The Forks Plt (13)		30.21	(2)	0.82	(3)	0.82	(3)	4
Marshall Pond	Oxford (9)		92.33	(2)	0.82	(1)	0.76	(1)	4
Northwest Branch St. John River	T11 R17 WELS (2)		45.47	(2)	0.81	(1)	0.81	(1)	7
Cut Pond	Dudley Twp (2)		84.83	(2)	0.81	(1)	0.81	(1)	7
Southwest Branch St. John River	T8 R19 WELS (13)		31.12	(2)	0.80	(3)	0.80	(3)	5
Willard Brook	Caswell (2)		38.75	(2)	0.75	(0)	0.57	(0)	5
Clarkson Pond	T9 R13 WELS (11)		24.82	(2)	0.66	(3)	0.66	(3)	4
Pollack Brook	Enfield (10)		46.74	(2)	0.66	(1)	0.37	(1)	4
Wing Pond	Lowelltown Twp (4)		27.95	(2)	0.65	(1)	0.65	(1)	7
East Branch Penobscot Inlet	T7 R10 WELS (11)		59.30	(2)	0.65	(3)	0.65	(3)	4
Lovejoy Pond	T39 MD (5)		29.18	(2)	0.64	(1)	0.38	(0)	6
Little Turner Pond	Forsyth Twp (13)		54.62	(2)	0.62	(0)	0.62	(0)	5
Porcupine Mtn Bog	Lubec (15)		29.51	(2)	0.61	(1)	0.61	(1)	5
North Branch Carry Brook	Seboomook Twp (13)		41.36	(2)	0.61	(3)	0.61	(3)	7
Square Pond	Acton (16)		23.51	(2)	0.60	(1)	0.60	(1)	4
Burntland Brook	T11 R16 WELS (2)		64.09	(2)	0.60	(1)	0.46	(1)	7
Seavey Lake	Wesley (15)		86.02	(2)	0.60	(1)	0.60	(1)	7
Long Bog	T1 R12 WELS (11)		40.33	(2)	0.59	(1)	0.59	(1)	7
Narraguagus River	Cherryfield (15)		26.10	(2)	0.57	(1)	0.57	(1)	7
Beech Pond	Palermo (14)		35.39	(2)	0.57	(2)	0.57	(2)	6
Rat Pond	T2 R9 WELS (11)		94.38	(2)	0.57	(0)	0.57	(0)	7
Little Round Pond	Eagle Lake Twp (11)		31.64	(2)	0.55	(1)	0.55	(1)	4
The Heath	Casco (3)		49.51	(2)	0.55	(1)	0.55	(1)	4
Bonny Pond	Leeds (1)		60.78	(2)	0.55	(1)	0.55	(1)	7
Hoyt Brook	Edinburg (10)		21.65	(2)	0.54	(0)	0.54	(0)	5
Williams Brook	Jackman (13)		24.23	(2)	0.54	(3)	0.54	(3)	4
Parlin Stream	Parlin Pond Twp (13)		60.23	(2)	0.54	(1)	0.54	(1)	5
Trout Pond	Lowell (10)		26.40	(2)	0.53	(3)	0.53	(3)	4
Bracey Pond	T35 MD (5)		89.44	(2)	0.53	(1)	0.53	(1)	7

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Total		Total semipermanent		Maximum semimpermanent		Total rank
					Area in ha[b] (rank)				
Henderson Pond	TA R11 WELS (11)		79.45	(2)	0.53	(1)	0.53	(1)	5
Spring Lake	T3 ND (5)		29.57	(2)	0.51	(1)	0.51	(1)	6
Ninemile Deadwater	T14 R15 WELS (2)		35.21	(2)	0.51	(2)	0.51	(2)	5
West Branch Narranguagus River	T16 MD (5)		21.84	(2)	0.50	(1)	0.50	(1)	7
Weed Pond	T4 R9 WELS (11)		99.18	(2)	0.49	(1)	0.25	(0)	3
Jones Pond	Wyman Twp (4)		23.22	(2)	0.48	(0)	0.48	(1)	4
Redington Pond	Redington Twp (4)		42.13	(2)	0.47	(0)	0.47	(1)	3
Beaver Brook	T9 R4 WELS (2)		34.16	(2)	0.46	(0)	0.26	(0)	3
Jones Pond	Bald Mountain Twp T4 R3 (13)		61.12	(2)	0.45	(0)	0.45	(0)	4
Mill Pond	Appleton (7)		26.36	(2)	0.45	(0)	0.45	(1)	4
Mud Pond	T2 R10 WELS (11)		21.08	(2)	0.44	(1)	0.44	(1)	6
Shed Pond	Manchester (6)		30.25	(2)	0.44	(0)	0.44	(0)	3
Lermond Pond	Hope (7)		71.91	(2)	0.43	(0)	0.43	(0)	2
Wassataquoik Lake	T4 R10 WELS (11)		71.48	(2)	0.43	(0)	0.35	(0)	3
Beaver Pond	Seven Ponds Twp (4)		41.73	(2)	0.41	(0)	0.41	(0)	3
Parker Bog Ponds	T3 R5 BKP WKR (13)		62.18	(2)	0.40	(1)	0.40	(1)	3
Squaw Pond	Beattie Twp (4)		28.73	(2)	0.40	(0)	0.34	(0)	5
Bartlett Pond	Waterboro (16)		81.81	(2)	0.39	(0)	0.39	(0)	5
McKeen Lake	T14 R10 WELS (2)		57.81	(2)	0.39	(1)	0.39	(1)	2
Upper Unknown Lake	T4 ND (5)		22.15	(2)	0.38	(0)	0.38	(0)	2
Middle Elbow Pond	T10 R10 WELS (11)		41.38	(2)	0.37	(0)	0.37	(0)	4
Sam Hill Lake	T31 MD BPP (15)		40.23	(2)	0.37	(0)	0.37	(0)	2
Dickey Pond	T17 R5 WELS (2)		88.63	(2)	0.35	(3)	0.35	(3)	2
Jewett Brook	Spencer Bay Twp (11)		21.64	(2)	0.35	(0)	0.35	(0)	3
Machias River	Garfield Plt (2)		27.21	(2)	0.34	(0)	0.34	(0)	2
Rober Pond	T4 R8 WELS (10)		37.22	(2)	0.33	(3)	0.33	(3)	3
Chisholm Brook	Big Twenty Twp (2)		42.33	(2)	0.33	(0)	0.33	(0)	2
Oran Pond	Mariaville (5)		37.71	(2)	0.32	(0)	0.32	(0)	3
Horseshoe Pond	Parlin Pond Twp (13)		53.03	(2)	0.31	(0)	0.31	(0)	5
Baker Flowage	Mayfield Twp (13)		33.67	(2)	0.31	(1)	0.31	(1)	3
Upper Mason Pond	Belfast (14)		25.32	(2)	0.31	(2)	0.31	(3)	5

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Jimmie Pond	Manchester (6)		43.02	(2)	0.29	(0)	0.29	(0)	5
Knights Pond	Squaretown Twp (13)		53.33	(2)	0.28	(0)	0.28	(0)	3
Molunkus Stream	Mattawamkeag (10)		44.90	(2)	0.28	(1)	0.28	(1)	3
Stetson Road Swamp	Levant (10)		55.10	(2)	0.27	(1)	0.27	(2)	2
Butterfield Brook	Caswell (2)		21.68	(2)	0.26	(2)	0.16	(2)	3
Little Burnt Pond	Otis (5)		30.31	(2)	0.25	(0)	0.25	(0)	4
Lower Hudson Pond	T10 R10 WELS (11)		38.58	(2)	0.25	(3)	0.25	(3)	2
Maces Pond	Rockport (7)		21.59	(2)	0.25	(0)	0.25	(0)	2
Bridgham Swamp	T18 MD BPP (15)		41.13	(2)	0.24	(0)	0.17	(0)	4
Munson Lake	T19 ED BPP (15)		59.92	(2)	0.24	(0)	0.24	(0)	4
Black Brook	Big Six Twp (13)		30.78	(2)	0.23	(3)	0.23	(3)	2
Spencer Pond	T3 ND (5)		23.21	(2)	0.23	(0)	0.23	(0)	4
Ayers Stream	T2 R8 NWP (10)		58.18	(2)	0.21	(2)	0.21	(2)	3
Wales Pond	Hollis (16)		52.37	(2)	0.21	(0)	0.21	(0)	3
Androscoggin River	Jay (4)		46.19	(2)	0.20	(0)	0.15	(0)	3
Branns Mill Pond	Dover-Foxcroft (11)		65.79	(2)	0.20	(0)	0.15	(0)	5
Cambolasse Pond	Lincoln (10)		94.97	(2)	0.18	(1)	0.18	(1)	4
Colcord Pond	Porter (9)		89.44	(2)	0.18	(0)	0.14	(0)	2
Myrick Pond	T10 SD (5)		38.78	(2)	0.18	(0)	0.18	(0)	5
St. John River	T13 R15 WELS (2)		32.08	(2)	0.17	(0)	0.17	(0)	5
Townline Brook	T7 R5 WELS (2)		22.12	(2)	0.16	(0)	0.16	(0)	3
Moores Bog	Caratunk (13)		22.32	(2)	0.15	(1)	0.15	(1)	3
Jordan Pond	Mount Desert (5)		76.61	(2)	0.15	(0)	0.15	(0)	2
Ironbound Pond	Alder Brook Twp (13)		20.27	(2)	0.13	(0)	0.13	(1)	3
Alder Stream	Corinna (10)		72.33	(2)	0.12	(2)	0.12	(2)	4
Round Pond	T14 R8 WELS (2)		39.26	(2)	0.11	(2)	0.11	(2)	4
Little Seavey Lake	Wesley (15)		50.27	(2)	0.11	(0)	0.11	(0)	2
Thurston Pond	Bucksport (5)		59.02	(2)	0.11	(0)	0.11	(0)	2
Chase Ponds	T14 R9 WELS (2)		77.27	(2)	0.11	(2)	0.11	(2)	3
Allen Pond	Greene (1)		78.10	(2)	0.10	(0)	0.10	(0)	3
McGowan Pond	T11 R8 WELS (2)		76.24	(2)	0.10	(0)	0.10	(0)	5

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)		Total semipermanent		Maximum semimpermanent		Total rank
			Total						
Cochrane Lake	New Limerick (2)		58.55	(2)	0.08	(0)	0.08	(0)	2
Bradbury Lake	New Limerick (2)		20.52	(2)	0.08	(0)	0.08	(0)	2
Supply Pond	Moose River (13)		40.14	(2)	0.06	(0)	0.06	(0)	3
Trafton lake	Limestone (2)		42.90	(2)	0.06	(0)	0.06	(0)	3
Blunder Pond	T6 R10 WELS (11)		32.41	(2)	0.04	(1)	0.04	(2)	2
Mount Blue Pond	Avon (4)		69.27	(2)	0.04	(0)	0.04	(0)	2
Total Area < 20 ha, Total Semipermanent Area < 5 ha									
Hilton Brook	Starks (13)		7.12	(1)	4.80	(3)	3.88	(3)	7
McLean Lake	Saint Francis (2)		6.82	(1)	4.73	(2)	4.42	(2)	7
Mud Pond	Oxford (9)		9.07	(1)	4.36	(3)	4.36	(3)	7
Cranberry Pond	Fayette (6)		10.52	(1)	4.30	(3)	4.30	(3)	10
West Pond	Parsonsfield (16)		19.66	(1)	4.08	(3)	2.45	(2)	6
Mud Pond	Turner (1)		16.89	(1)	3.92	(2)	3.92	(3)	6
Barlett Pond	Livermore (1)		12.51	(1)	3.85	(2)	3.85	(3)	6
Palermo Pond	Freedom (14)		7.92	(1)	3.76	(2)	3.76	(2)	6
Penknife Lakes	Charlotte (15)		16.68	(1)	3.60	(2)	3.60	(3)	9
Traffton Meadow	Georgetown (12)		14.50	(1)	3.46	(2)	2.27	(2)	6
Palmer Meadow	Medford (11)		12.86	(1)	3.38	(2)	2.39	(2)	6
Mud Pond	Montville (14)		18.39	(1)	3.32	(3)	3.32	(3)	6
Bean Brook	T11 R17 WELS (2)		19.16	(1)	3.31	(2)	2.77	(2)	6
Greenleaf Pond	Abbot (11)		6.20	(1)	3.26	(1)	3.26	(0)	6
Montville Marsh	Montville (14)		5.06	(1)	3.17	(0)	3.17	(0)	7
Sturtevant Pond stream	Magalloway Plt (9)		13.50	(1)	3.12	(2)	3.12	(3)	6
Grand Falls Flowage	Baileyville (15)		7.99	(1)	3.09	(1)	3.09	(1)	8
Vose Pond	Calais (15)		11.38	(1)	3.05	(2)	3.05	(2)	8
Alder Stream	Corinna (10)		10.22	(1)	3.03	(2)	3.03	(2)	5
Turner Hill Swamp	Milbridge (15)		16.72	(1)	2.91	(2)	2.91	(2)	5
Sebec River	Milo (11)		19.09	(1)	2.83	(2)	2.83	(2)	6
Herricks Bog	Northport (14)		10.46	(1)	2.77	(1)	2.77	(0)	7
Hare St. Marsh	Avon (4)		5.02	(1)	2.74	(2)	1.56	(2)	6
Olamon Stream	Greenfield Twp (10)		16.50	(1)	2.70	(1)	1.50	(2)	6

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semipermanent		
Chase Pond	Solon (13)		9.60	(1)	2.54	(0)	2.54	(0)	6
Beech Pond	Palermo (14)		6.41	(1)	2.52	(2)	2.52	(2)	7
Outlet Stream	Winslow (6)		18.64	(1)	2.46	(2)	2.46	(2)	6
Little Cobbosseecontee Lake	Winthrop (6)		16.71	(1)	2.44	(2)	1.51	(2)	7
Medomak Brook	Liberty (14)		10.66	(1)	2.43	(2)	2.24	(2)	6
Josiah Brook	Starks (13)		10.25	(1)	2.38	(2)	2.38	(2)	5
Lily Lake	East Machias (15)		19.14	(1)	2.36	(2)	1.23	(2)	8
Rowell Bog	Madison (13)		19.53	(1)	2.36	(3)	1.29	(3)	6
South Barters Island Pond	Boothbay (8)		14.97	(1)	2.30	(2)	1.89	(2)	5
Dead Lake	Fryeburg (9)		13.85	(1)	2.28	(2)	1.15	(2)	5
Josiah Brook Pond	Starks (13)		5.95	(1)	2.26	(2)	1.74	(2)	6
Little Mud Brook	T2 R8 WELS (10)		15.27	(1)	2.26	(2)	1.36	(2)	8
First Lake	Wallagrass (2)		5.58	(1)	2.26	(0)	2.26	(0)	6
Lower Elbow Pond	T10 R10 WELS (11)		16.08	(1)	2.24	(0)	1.53	(0)	7
Salmon Falls River	Acton (16)		11.98	(1)	2.24	(2)	1.61	(2)	5
Breakneck Ponds	Bar Harbor (5)		13.26	(1)	2.05	(2)	2.05	(2)	8
Rideout Lake	Monticello (2)		5.09	(1)	1.99	(2)	1.34	(2)	5
Alder Brook	Milo (11)		12.10	(1)	1.99	(2)	1.73	(2)	6
Federal Row Marsh	Industry (4)		8.55	(1)	1.95	(2)	1.41	(2)	7
Pushaw Road Marsh	Glenburn (10)		7.48	(1)	1.91	(0)	1.91	(0)	7
Parker Pond	Brooksville (5)		14.51	(1)	1.90	(2)	1.90	(2)	5
Pennington Brook Marsh	Winterville Plt (2)		11.45	(1)	1.89	(1)	1.89	(1)	6
Little Cathance Lake	No 14 Twp (15)		11.93	(1)	1.86	(2)	1.13	(2)	7
Mud Pond	Peru (9)		19.93	(1)	1.83	(2)	0.69	(1)	4
Rocky Pond	T2 R9 WELS (11)		5.43	(1)	1.82	(0)	1.82	(0)	8
Little Labrador Pond	Sumner (9)		17.74	(1)	1.81	(2)	1.81	(2)	5
Hoyt Brook	Winthrop (6)		7.95	(1)	1.72	(1)	1.72	(2)	7
Ballard Pond	Strong (4)		13.00	(1)	1.72	(2)	0.62	(1)	4
Marcum Pond	Fort Kent (2)		12.77	(1)	1.70	(1)	1.70	(0)	5
Mountain Pond	Forest Twp (15)		19.88	(1)	1.65	(3)	1.04	(2)	5
Ryan Lake	Baileyville (15)		17.09	(1)	1.64	(3)	1.64	(3)	6

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Total		Total semipermanent		Maximum semipermanent		Total rank
								Area in ha[b] (rank)	
Cargill Pond	Liberty (14)		6.64	(1)	1.57	(2)	1.57	(2)	7
Chandler River	Centerville (15)		7.28	(1)	1.57	(2)	0.60	(1)	5
Muddy Brook	Farmington (4)		5.43	(1)	1.54	(2)	1.54	(2)	5
West Branch Narraguagus River	Beddington (15)		12.33	(1)	1.54	(2)	1.54	(2)	6
Mud Pond	Kingsbury Plt (11)		18.74	(1)	1.47	(2)	0.76	(1)	5
Nutter Pond	Palermo (14)		18.02	(1)	1.46	(2)	1.46	(3)	5
Norse Pond	Cutler (15)		5.36	(1)	1.43	(2)	1.43	(2)	6
Tilton Pond	Fayette (6)		5.74	(1)	1.40	(2)	1.40	(2)	5
York Ponds	Monroe (14)		7.84	(1)	1.39	(1)	1.39	(1)	5
Farm Brook	Jackson (14)		5.52	(1)	1.38	(2)	0.76	(2)	4
Jesse Bog	Ellsworth (5)		11.04	(1)	1.32	(2)	0.97	(1)	6
Little Cobbosseecontee Lake	Winthrop (6)		6.77	(1)	1.30	(3)	1.21	(3)	6
Traffton Meadow	Georgetown (12)		9.84	(1)	1.29	(1)	1.29	(2)	5
Norse Pond	Cutler (15)		5.93	(1)	1.29	(1)	1.29	(2)	5
Salt Marsh Cove	Edgecomb (8)		5.44	(1)	1.20	(1)	0.62	(1)	3
Southwest Corner Swamp	T11 R14 WELS (2)		11.36	(1)	1.20	(1)	1.20	(2)	4
Lily Pond	Solon (13)		7.39	(1)	1.17	(3)	1.17	(3)	5
Warm Brook	Aurora (5)		16.67	(1)	1.13	(1)	1.13	(2)	4
Bartlett Pond	Lyman (16)		7.28	(1)	1.10	(1)	1.10	(2)	5
Campbell Pond	Phippsburg (12)		12.02	(1)	1.09	(1)	1.09	(2)	5
Meadow Brook	Auburn (1)		11.86	(1)	1.08	(1)	0.92	(1)	3
Hemlock Stream	Edinburg (10)		10.12	(1)	1.07	(1)	1.07	(1)	6
Heath Brook	Acton (16)		10.84	(1)	1.04	(1)	0.61	(1)	3
Houghton Pond	West Bath (12)		6.05	(1)	1.01	(1)	1.01	(1)	3
Wiggins Brook	Trescott Twp (15)		19.02	(1)	1.00	(1)	0.77	(1)	4
Nezinscott River	Turner (9)		6.92	(1)	0.94	(1)	0.94	(1)	6
Clay Brook	Jay (4)		12.49	(1)	0.93	(1)	0.86	(1)	4
Mill Pond	Readfield (6)		18.51	(1)	0.92	(1)	0.92	(1)	6
Dolby Pond	TA R7 WELS (10)		11.94	(1)	0.91	(3)	0.91	(3)	6
Brandy Brook	Webbertown Twp (2)		9.83	(1)	0.89	(1)	0.89	(1)	6
Prescott Hill Rd Marsh	Liberty (14)		10.63	(1)	0.86	(2)	0.38	(2)	2

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Youngs Lake	Westfield (2)		6.28	(1)	0.85	(1)	0.85	(1)	3
Aziscohos Pond	Magalloway Plt (9)		6.04	(1)	0.83	(1)	0.83	(1)	3
Fifteenth Stream	Cooper (15)		10.94	(1)	0.82	(1)	0.82	(1)	5
Boulder Pond	T5 R7 BKP WKR (13)		11.59	(1)	0.82	(0)	0.82	(1)	4
Penobscot River	Chester (10)		6.83	(1)	0.81	(3)	0.81	(3)	3
Loon Stream Deadwater	Saint John Twp (13)		9.02	(1)	0.81	(0)	0.81	(0)	4
Spaulding Ponds	Fort Kent (2)		9.17	(1)	0.79	(2)	0.79	(2)	3
McConnell Brook	T11 R7 WELS (2)		11.17	(1)	0.79	(1)	0.44	(0)	2
Toothaker Pond	Phillips (4)		14.07	(1)	0.77	(1)	0.77	(1)	3
Medomak Brook Marsh	Washington (7)		11.72	(1)	0.77	(1)	0.77	(1)	4
Cat Pond	Fryeburg (9)		5.44	(1)	0.76	(1)	0.76	(1)	5
Trout Pond	T3 R7 WELS (10)		7.79	(1)	0.75	(0)	0.75	(0)	4
Myrick Pond	T16 MD (5)		15.87	(1)	0.75	(1)	0.75	(1)	6
Daaquam River	T11 R17 WELS (2)		14.64	(1)	0.71	(1)	0.71	(1)	6
Ingalls Pond	Baldwin (3)		8.34	(1)	0.69	(1)	0.69	(1)	4
Wesserunsett Stream	Skowhegan (13)		10.42	(1)	0.69	(1)	0.69	(1)	4
Allen Pond	T35 MD (5)		8.67	(1)	0.68	(1)	0.68	(1)	6
Winthrop St. Marsh	Manchester (6)		10.25	(1)	0.68	(1)	0.68	(1)	3
Vose Pond	Calais (15)		13.33	(1)	0.66	(3)	0.36	(3)	5
Kezar Pond	Winthrop (6)		15.86	(1)	0.66	(1)	0.66	(1)	5
Big Pond	Ellsworth (5)		14.07	(1)	0.65	(1)	0.46	(1)	4
Pearl Ponds	Bowdoin College Grant W. Twp (11)		8.29	(1)	0.65	(1)	0.65	(1)	4
Burgoin Lake	Saint Agatha (2)		15.16	(1)	0.64	(3)	0.64	(2)	3
Moody Pond	Waterboro (16)		13.63	(1)	0.63	(1)	0.63	(1)	4
Middle Springy Pond	Clifton (10)		9.58	(1)	0.63	(3)	0.63	(3)	3
Lily Pond	Gouldsboro (5)		11.75	(1)	0.63	(1)	0.32	(0)	2
Blanchard Brook	Dead River Twp (13)		14.61	(1)	0.62	(1)	0.44	(1)	6
Wesserunsett Stream	Skowhegan (13)		15.76	(1)	0.61	(1)	0.28	(0)	3
Humpback Bog	T28 MD (5)		18.82	(1)	0.61	(1)	0.61	(1)	6
Ketchum Lake	TD R2 WELS (2)		8.24	(1)	0.60	(1)	0.60	(1)	3
Birch Stream	Lagrange (10)		7.29	(1)	0.59	(1)	0.59	(2)	4

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Martin Lake	Hamlin (2)		7.17	(1)	0.58	(3)	0.58	(3)	4
Douglas Pond	Kibby Twp (4)		8.65	(1)	0.58	(1)	0.58	(1)	4
Rowell Pond	Solon (13)		16.19	(1)	0.57	(0)	0.57	(1)	4
Mud Pond	Stetson (10)		16.75	(1)	0.57	(1)	0.39	(1)	5
East Stream	Trescott Twp (15)		10.47	(1)	0.57	(1)	0.57	(1)	4
Lily Pond	Monroe (14)		12.89	(1)	0.57	(3)	0.57	(3)	3
St. Francis River	Big Twenty Twp (2)		14.16	(1)	0.55	(1)	0.55	(1)	3
Culling Pond	Monticello (2)		5.22	(1)	0.55	(1)	0.55	(1)	3
East Branch Enchanted Stream	Upper Enchanted Twp (13)		17.31	(1)	0.55	(1)	0.55	(1)	4
Norse Pond	Cutler (15)		14.94	(1)	0.53	(1)	0.53	(1)	4
Mud Pond	Litchfield (6)		7.93	(1)	0.53	(1)	0.53	(1)	3
Mud Pond	T19 R11 WELS (2)		18.12	(1)	0.52	(1)	0.36	(1)	5
Pitman Pond	T2 R10 WELS (11)		6.87	(1)	0.52	(0)	0.52	(0)	5
East Side Rd Marsh	Steuben (15)		7.73	(1)	0.52	(1)	0.52	(1)	4
Skinner Bog	Dixmont (10)		19.64	(1)	0.52	(1)	0.52	(1)	3
Basil Pond	Fort Kent (2)		15.53	(1)	0.52	(1)	0.19	(1)	2
St. John River	T11 R16 WELS (2)		6.00	(1)	0.51	(1)	0.51	(1)	6
Hubbard Pond	Porter (9)		15.34	(1)	0.50	(1)	0.50	(1)	3
Clear Lake	T10 R11 WELS (11)		8.10	(1)	0.50	(0)	0.50	(0)	3
Hammond Brook	Cyr Plt (2)		5.94	(1)	0.49	(1)	0.49	(0)	3
Andrscoggin Branch swamp	Canton (9)		5.80	(1)	0.48	(0)	0.48	(1)	2
Millbridge inlet	Steuben (15)		8.34	(1)	0.48	(0)	0.48	(1)	3
Mountain Pond	T8 R14 WELS (11)		14.30	(1)	0.46	(3)	0.46	(3)	2
Rober Pond	T4 R8 WELS (10)		8.28	(1)	0.46	(0)	0.46	(0)	3
Oran Pond	Mariaville (5)		9.51	(1)	0.46	(0)	0.46	(1)	2
Lower Fowler Pond	Trout Brook Twp (11)		17.61	(1)	0.46	(0)	0.46	(0)	3
Bog Brook	Athens (13)		7.43	(1)	0.46	(2)	0.46	(2)	3
Vose Pond	Calais (15)		17.35	(1)	0.45	(0)	0.45	(1)	5
Lake Auburn	Auburn (1)		6.04	(1)	0.42	(0)	0.42	(0)	3
Appalachie Pond	Boothbay (8)		11.45	(1)	0.42	(0)	0.42	(0)	2
Fisher Lake	Fort Fairfield (2)		10.97	(1)	0.42	(0)	0.42	(0)	2

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank) Total		Total semipermanent		Maximum semipermanent		Total rank
Picard Brook	Cyr Plt (2)		7.79	(1)	0.42	(2)	0.42	(2)	2
Tory Hill Pond	Phillips (4)		6.33	(1)	0.41	(0)	0.41	(0)	1
Estes Bog	Poland (1)		17.79	(1)	0.41	(0)	0.34	(0)	3
Bear Pond	T28 MD (5)		11.45	(1)	0.41	(0)	0.41	(0)	2
Dubay Lake	Connor Twp (2)		12.99	(1)	0.40	(1)	0.40	(2)	1
Third Lake	T39 MD (5)		6.28	(1)	0.40	(0)	0.40	(0)	4
Cold Stream	Medford (11)		17.08	(1)	0.39	(0)	0.27	(0)	2
Moore Brook	Caribou (2)		10.08	(1)	0.39	(0)	0.22	(0)	1
Pine Lake	Calais (15)		18.77	(1)	0.38	(1)	0.38	(0)	4
Grassy Pond	T25 MD BPP (15)		13.56	(1)	0.38	(0)	0.38	(0)	2
Northwest Pond	T4 R9 NWP (11)		11.24	(1)	0.37	(0)	0.21	(0)	2
Chisholm stream	Big Twenty Twp (2)		16.16	(1)	0.37	(1)	0.37	(1)	1
Mud Lake	T19 ED BPP (15)		11.92	(1)	0.37	(0)	0.37	(0)	2
North Brook	Lily Bay Twp (11)		5.64	(1)	0.36	(0)	0.36	(0)	1
Supply Pond	Jackman (13)		8.27	(1)	0.36	(3)	0.36	(3)	4
Silver Lake	T15 R5 WELS (2)		5.81	(1)	0.36	(0)	0.36	(0)	1
Snows Pond	Dover-Foxcroft (11)		11.76	(1)	0.35	(0)	0.35	(0)	2
Caineron Bog	Hammond (2)		12.84	(1)	0.35	(0)	0.35	(0)	2
East Pond Bog	Smithfield (13)		6.21	(1)	0.32	(0)	0.32	(0)	3
Hurd Pond	Dedham (5)		17.27	(1)	0.31	(0)	0.31	(0)	3
Third Davis Pond	Willimantic (11)		11.86	(1)	0.31	(0)	0.31	(0)	4
The Tarn	Bar Harbor (5)		9.84	(1)	0.31	(0)	0.31	(0)	2
North Pond	Norway (9)		13.94	(1)	0.31	(0)	0.24	(0)	1
Big Berry Pond	Johnson Mountain Twp (13)		14.55	(1)	0.30	(0)	0.30	(0)	2
Middle Oxhead Pond	T40 MD (5)		18.74	(1)	0.29	(0)	0.29	(0)	1
Little Burnt Pond	Clifton (10)		8.42	(1)	0.29	(0)	0.29	(0)	3
Horseshoe Pond	Parlin Pond Twp (13)		9.09	(1)	0.29	(0)	0.29	(0)	4
Goose Pond	Swans Island (5)		6.53	(1)	0.29	(0)	0.29	(0)	1
Black Pond	Lebanon (16)		9.60	(1)	0.28	(0)	0.28	(0)	1
Footman Brook	Exeter (10)		11.00	(1)	0.28	(3)	0.28	(3)	1
Gelot Pond	New Sweden (2)		15.37	(1)	0.27	(2)	0.27	(2)	2

Table D.1. Continued.

Wetland name	Town (county)[a]	Years colonized	Area in ha[b] (rank)						Total rank
			Total		Total semipermanent		Maximum semimpermanent		
Hothole Pond	Orland (5)		5.67	(1)	0.27	(0)	0.13	(0)	1
Lucky Brook	Days Academy Grant Twp (11)		10.06	(1)	0.27	(0)	0.27	(0)	2
Abbie Pond	Bowmantown Twp (9)		6.15	(1)	0.26	(0)	0.26	(0)	1
Holmes Stream marsh	Whiting (15)		6.58	(1)	0.26	(0)	0.26	(0)	4
Round Pond	Squaretown Twp (13)		18.15	(1)	0.25	(1)	0.25	(2)	1
Upper Pond	Bristol (8)		14.72	(1)	0.24	(0)	0.24	(0)	4
Cranberry Pond	Edmunds Twp (15)		9.62	(1)	0.23	(0)	0.23	(0)	4
Timber Brook	Waltham (5)		17.27	(1)	0.22	(0)	0.22	(0)	2
No Name Pond	Bald Mountain Twp T4 R3 (13)		7.80	(1)	0.21	(0)	0.21	(0)	2
Grey Pond	T11 R13 WELS (2)		5.19	(1)	0.21	(0)	0.21	(0)	3
Salmon Stream	Lee (10)		11.43	(1)	0.20	(2)	0.20	(1)	3
Little Michael Stream	Highland Plt (13)		7.78	(1)	0.20	(0)	0.20	(0)	2
Adams Brook	New Vineyard (4)		5.89	(1)	0.19	(0)	0.19	(0)	2
Alerton Lake	Monticello (2)		9.56	(1)	0.19	(0)	0.19	(0)	2
Mud Pond	Bald Mountain Twp T4 R3 (13)		9.11	(1)	0.18	(1)	0.18	(1)	2
Mud Pond	Holeb Twp (13)		9.98	(1)	0.18	(0)	0.18	(0)	2
Cleaves Brook	Prentiss Twp (10)		8.50	(1)	0.17	(2)	0.17	(2)	1
Grassy Pond	T4 R13 WELS (11)		19.82	(1)	0.17	(3)	0.17	(3)	4
Holmes Stream	Machiasport (15)		9.93	(1)	0.15	(0)	0.15	(0)	2
Upper Hudson Pond	T11 R10 WELS (2)		14.47	(1)	0.14	(0)	0.14	(0)	2
Ross Lake	Littleton (2)		16.01	(1)	0.13	(0)	0.13	(0)	2
Hid Pond	Kingfield (4)		7.10	(1)	0.13	(0)	0.13	(0)	1
Little Androscoggin River	West Paris (9)		5.07	(1)	0.12	(0)	0.12	(0)	1
Hale Pond	Alder Brook Twp (13)		15.66	(1)	0.10	(0)	0.10	(0)	2
Lily Pond	New Gloucester (3)		14.99	(1)	0.10	(0)	0.10	(0)	1
NW Branch Inlet Pond	T11 R17 WELS (2)		6.39	(1)	0.10	(0)	0.10	(0)	1
Little Kennebec Inlet	Machias (15)		5.22	(1)	0.08	(0)	0.08	(0)	2
Clearwater Pond	Attean Twp (13)		18.24	(1)	0.05	(0)	0.05	(0)	4

[a] 1 = Androscoggin, 2 = Aroostook, 3 = Cumberland, 4 = Franklin, 5 = Hancock, 6 = Kennebec, 7 = Knox, 8 = Lincoln, 9 = Oxford, 10 = Penobscot, 11 = Piscataquis, 12 = Sagadahoc, 13 = Somerset, 14 = Waldo, 15 = Washington, 16 = York.
[b] Wetlands were sorted first by size of semipermanent wetland area and then total area.

Appendix E. Arc/Info AML programs used to determine potential Black Tern habitat.

NWISIMPLIFYME.AML – A program designed to simplify NWI classifications and produce Arc/Info coverages of wetlands complexes.

```
/* Written by Andrew Gilbert, Dept. of Wildlife Ecology, University of Maine, Orono
/* 2/18/00

&watch nwisimplmewat.wat &append &commands
tables
  sel maine-alt.pat
  resel attribute lk 'M1*'
  calc attribute = 'MSUB'
  asel
  resel attribute lk 'M2*'
  calc attribute = 'MSHORE'
  asel
  resel attribute lk 'E1*'
  calc attribute = 'ESUB'
  asel
  resel attribute lk 'E2*'
  calc attribute = 'EINTER'
  asel
  resel attribute lk 'R1*'
  calc attribute = 'RTIDAL'
  asel
  resel attribute lk 'R*' xor attribute = 'RTIDAL'
  calc attribute = 'RFRESH'
  asel
  resel attribute lk 'L2RS*' or attribute lk 'L2US*' ~
    or attribute lk 'L2EM*'
  calc attribute = 'LSHORE'
  asel
  resel attribute lk 'L*' xor attribute = 'LSHORE'
  calc attribute = 'LAKE'
  asel
  resel attribute cn 'FO' and attribute nc 'EM'
  calc attribute = 'PFO'
  asel
  resel attribute lk 'POW*' or attribute lk 'PUB*' ~
    or attribute lk 'PRB*' or attribute lk 'PAB*'
  calc attribute = 'POPEN'
  asel
  resel attribute cn 'SS' and attribute nc 'EM'
  calc attribute = 'PSS'
```

asel
resel attribute cn 'EM' and attribute cn 'H'
calc attribute = 'PPERM'
asel
resel attribute cn 'EM' and attribute cn 'K'
calc attribute = 'PPERM'
asel
resel attribute lk '*EM1E*' or attribute lk '*FO1E*' ~
    or attribute lk '*FO2E*' or attribute lk '*FO3E*' ~
    or attribute lk '*FO4E*' or attribute lk '*FO5E*' ~
    or attribute lk '*FO6E*' or attribute lk '*FO7E*'
nsel
resel attribute cn 'EM' and attribute cn 'F' and attribute nc 'B'
calc attribute = 'PSMI'
asel
resel attribute cn 'EM' and attribute cn 'G'
calc attribute = 'PSMI'
asel
resel attribute cn 'EM' and attribute cn 'Z'
calc attribute = 'PSMI'
asel
resel attribute cn 'EM' and attribute cn 'C'
calc attribute = 'PSEAS'
asel
resel attribute cn 'EM' and attribute cn 'D'
calc attribute = 'PSEAS'
asel
resel attribute lk '*EM*E*'
calc attribute = 'PSEAS'
asel
resel attribute cn 'EM' and attribute cn 'Y'
calc attribute = 'PSEAS'
asel
resel attribute cn 'EM' and attribute cn 'A'
calc attribute = 'PTMP'
asel
resel attribute cn 'PEM' and attribute cn 'B'
calc attribute = 'PTMP'
asel
resel attribute cn 'PEM' and attribute cn 'J'
calc attribute = 'PTMP'
asel
resel attribute cn 'PEM' and attribute cn 'W'
calc attribute = 'PTMP'
asel
resel attribute lk 'PML*' or attribute lk 'PUS*' or ~

```
      attribute cn 'PEM1/' or attribute cn 'PEM1S' or ~
      attribute cn 'PEM1R' or attribute cn 'PEM1T' or ~
      attribute cn 'PEM1V' or attribute cn 'PEM1U'
    calc attribute = 'POTHER'
    q
/* combine simplified wetland types if adjacent
dissolve maine-alt maine-red attribute
kill maine-alt
/* create wetland basins
copy maine-red maine-red2
tables
    sel maine-red2.pat
    resel attribute lk 'P*' or attribute lk 'L*' xor attribute = 'PFO' ~
      xor attribute = 'POTHER'
    calc attribute = 'WET'
    q
dissolve maine-red2 maine-wet attribute
kill maine-red2
&watch &off &return
```

CALCAREAME.AML – A program designed to calculate areas of wetland types within complexes and then classify a wetland according to the most permanent flooding regime.

```
/* Written by Andrew Gilbert, Dept. of Wildlife Ecology, University of Maine, Orono
/* 2/18/00

&watch calcareamewat.wat &append &commands
union maine-red maine-wet maine-rw
tables
  sel maine-rw.pat
  res attribute = 'PSMI'
  stat MAINE-WET-ID areasemi.dat
  sum area     /* calculate the total area of semiperm wet
  max area     /* calculates the largest contiguous semiperm wet
  end
  asel
  res attribute = 'PSEAS'
  stat MAINE-WET-ID areaseas.dat/* calc total area pseas
  n
  sum area
  end
  asel
  res attribute = 'PPERM'
  stat MAINE-WET-ID areaperm.dat/* calc total area pperm
  y
  asel
  res attribute = 'PTMP'
  stat MAINE-WET-ID areatmp.dat/* calc total area ptmp
  y
  asel
  res attribute = 'LAKE'
  stat MAINE-WET-ID arealake.dat/* calc total area lake
  y
  asel
  res attribute = 'POPEN'
  stat MAINE-WET-ID areapopen.dat/* calc total pal. openwater
  y
  q
/* add data to a new file by the id classified in maine-wet
joinitem maine-wet.pat areasemi.dat maine-wet.pat MAINE-WET-ID
tables
  sel maine-wet.pat
  alter sum-area asemi , , , , ,
  alter frequency fsemi , , , ,
  alter max-area max-semi , , , , ,
  q
```

```
joinitem maine-wet.pat areaseas.dat maine-wet.pat MAINE-WET-ID
tables
   sel maine-wet.pat
   alter sum-area aseas , , , , ,
   alter frequency fseas , , , ,
   q
joinitem maine-wet.pat areaperm.dat maine-wet.pat MAINE-WET-ID
tables
   sel maine-wet.pat
   alter sum-area aperm , , , , ,
   alter frequency fperm , , , ,
   q
joinitem maine-wet.pat areatmp.dat maine-wet.pat MAINE-WET-ID
tables
   sel maine-wet.pat
   alter sum-area atemp , , , , ,
   alter frequency ftemp , , , ,
   q
joinitem maine-wet.pat arealake.dat maine-wet.pat MAINE-WET-ID
tables
   sel maine-wet.pat
   alter sum-area alake , , , , ,
   alter frequency flake , , , ,
   q
joinitem maine-wet.pat areapopen.dat maine-wet.pat MAINE-WET-ID
tables
   sel maine-wet.pat
   alter sum-area apopen , , , , ,
   alter frequency fpopen , , , ,
   q
/* change attribute of wetland complex to reflect most permanent flooding regime
tables
   sel maine-wet.pat
   res attribute = 'WET' and FPERM >= 1
   calc attribute = 'PERMANENT'
   asel
   res attribute = 'WET' and FSEMI >= 1
   calc attribute = 'SEMIPERMANENT'
   asel
   res attribute = 'WET' and FSEAS >= 1
   calc attribute = 'SEASONAL'
   asel
   res attribute = 'WET' and FTEMP >= 1
   calc attribute = 'TEMPORARY'
   q
&watch &off &return
```

SUITABLEME.AML – This program selects suitable wetlands according to established criteria.

```
/* Written by Andrew Gilbert, Dept. of Wildlife Ecology, University of Maine, Orono
/* 2/18/00

&watch suitablemewat.wat &append &commands
/* select suitable wetlands and classify them as suitable
tables
   additem maine-wet.pat suitable 2 4 b
   sel maine-wet.pat
   res attribute = 'SEMIPERMANENT'
   res area >= 50000
   res alake >= 10000 or apopen >= 10000
   calc suitable = 1
   q
/* select suitable wetlands and output to a new coverage
reselect maine-wet maine-suit poly
   res suitable = 1
   ~
   n
   n
/* Run the aml to calculate area and frequency of semiperm and seasonal
/* wetlands in a 25 sq. km cell
&run afss25me.aml
/* unload the suitable set to a csv file for ranking
tables
   sel maine-suit.pat
   res suitable = 1
   unload mainesuitable.csv init
   q
&watch &off &return
```

AFSS25ME.AML – A program called by suitableme.aml to calculate the area and number of semipermanent and seasonal wetlands within 25 km^2 cells.

```
/* Written by Andrew Gilbert, Dept. of Wildlife Ecology, University of Maine, Orono
/* 2/18/00


&watch afss25mewat.wat &append &commands
/* generate the 25 square km grid based on the map extents
generate maine-gr25
   fishnet
   336587, 4756341   /* point of origin
   336587, 5256070   /* y-axis point
   5000, 5000        /* width, height
   0                 /* columns
   667214, 5256070   /* opposite corner
   q
build maine-gr25
/* create a coverage with semipermanent and seasonal wetlands
reselect maine-wet mesemiseas poly
   res attribute = 'SEMIPERMANENT' or attribute = 'SEASONAL'
   ~
   n
   n
/* create a coverage associating wetland parts with each grid
identity mesemiseas maine-gr25 mesemiseasgr poly
/* calculates frequencies of wetlands and areas of each in grids
frequency mesemiseasgr.pat afsemiseas.dat aftot-id
   maine-gr25-id
   mesemiseas-id
   end
   area
   end
/* sum each grid to yield the total area and the number in each grid
tables
   sel afsemiseas.dat
   res mesemiseas-id ne 0 and maine-gr25-id ne 0
   stat maine-gr25-id afsemiseastot.dat
   sum area
   end
   sel afsemiseastot.dat
   alter frequency numsemiseas , , , ,
   alter sum-area areasemiseas , , , , ,
   q
/* add number and area of semipermanent wetland data to each grid cell
joinitem maine-gr25.pat afsemiseastot.dat maine-gr25.pat MAINE-GR25-ID
```

```
   /* create a point coverage of the label points of the suitable semipermanent wetlands
/* the point is created at the centroid of the polygon
arcedit
   edit maine-suit
   ef label
   sel all
   put maine-pt
   q
build maine-pt point
/* intersect those points with the appropriate suitable wetland, then relates that to a cell
intersect maine-pt maine-suit meptsuit point
intersect meptsuit maine-gr25 meptsuitgr point
joinitem maine-suit.pat meptsuitgr.pat maine-suit.pat MAINE-SUIT-ID
build maine-suit
&watch &off &return
```

NAMEWETS.AML – A program to name suitable wetlands.

```
/* Written by Andrew Gilbert, Dept. of Wildlife Ecology, University of Maine, Orono
/* 2/22/00

&watch namewetwat.wat &append &commands
projectdefine cover maine-suit
   projection utm
   zone 19
   units meters
   datum nad27
   parameters
/* select al lakes, pond, swamp, stream and reservoir names from the wetland
/* names coverage
reselect wetnames lkpdnames point
   res type lk 'lake' or type lk 'pond' or type lk 'swamp' ~
     or type lk 'reservoir'
   ~
   n
   n
ae
   ec maine-suit              /* create a coverage of label points
   ef labels
   sel all
   put mesuitcent
   q
/* add the town these points fall into
intersect mesuitcent metownshp mecent point
/* find the label point from the lkpdnames coverage closest to the centroid of suitable
/* wetlands to name them according to the lake or pond name
near mecent lkpdnames point 2500 centnearname location
joinitem centnearname.pat lkpdnames.pat centnearname.pat LKPDNAMES#
/* select only those points which fall within suitable wetlands
intersect centnearname maine-suit mesuitnear point
joinitem maine-suit.pat mesuitnear.pat maine-suit.pat MAINE-SUIT-ID
&watch &off &return
```

BIOGRAPHY OF THE AUTHOR

Andrew T. Gilbert was born in Winchester, Massachusetts on January 22, 1973. He was raised in Holliston, Massachusetts and graduated from Holliston High School in 1991.

Andrew attended Bowdoin College in Brunswick, Maine and graduated in 1995, earning a Bachelor's degree with honors in Chemistry and Anthropology. He was awarded the Merck Prize in Chemistry for excellence in research in 1995 and was elected to the Phi Beta Kappa Honor Society in the same year. Following graduation, he worked at Bowdoin College conducting research in synthetic organic chemistry and taught Introductory and Organic Chemistry lab. He also worked at Bigelow Laboratory for Ocean Sciences in Boothbay Harbor, Maine as a research assistant where he assisted with oceanographic research in the Arctic Ocean.

Andrew began his graduate study at The University of Maine in the fall of 1998 in the Wildlife Ecology program as a graduate research assistant. He received the Mendall Migratory Bird Prize for excellence in bird research and was elected to the Phi Kappa Phi Honor Society in December 2000. Andrew is a candidate for the Master of Science degree in Wildlife Ecology from The University of Maine in May, 2001.