HABITAT SELECTION AND BREEDING SUCCESS OF BLACK TERNS (Chlidonias niger) IN IMPOUNDED WETLANDS IN NEW BRUNSWICK

by

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ABSTRACT

My objectives were to determine the environmental cues Black Terns (Chlidonias niger) use for habitat selection by relating physical and biological characteristics of impounded wetlands with use by this species. I also determined the quality of the habitat by relating reproductive success to impoundment characteristics. I examined habitat use and quality at two scales: the impoundment level and the nest site level. I also examined habitat selection using social attraction, tested by using decoys and calls, and I measured the degree of site fidelity. Size of impoundment, vegetation density considered concurrently with water depth, and abundance of odonate prey determined use at the impoundment level. Features important at the nest site level included density of vegetation, amount of open water, and amount of cover. Black Terns have weak social attraction and low site tenacity. One impoundment had higher breeding success, and hence higher quality habitat, than the others but there were no discernable differences in habitat variables at the impoundment level. Successful nests were initiated earlier, were on higher nesting substrate, and had more cover to protect against predators and the elements.
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Chapter 1

Introduction
1.1 INTRODUCTION

1.1.1 Habitat Selection

Habitat selection is the choice of a place to live that results in the distribution of animals among available habitats. Natural selection favours animals that choose habitats that maximize individual fitness, that is survival and reproductive success. Fitness, as measured by total reproductive success, is maximized by having a ready access to mates, nest sites and materials, and food (Schoener 1974) and by having low rates of mortality of young due to predation or inclement weather (Burger 1985).

The concept of habitat selection can be divided into ultimate and proximate causation. Ultimate causes of habitat selection are the evolutionary costs and benefits of using each habitat type; proximate causes are the cues used to select a habitat (Partridge 1978, Hutto 1985). Hutto (1985) states that habitat use is believed to reflect innate responses to some proximate environmental cues that are themselves well correlated with the presence of ultimately important needs.

As Cody (1985) points out, birds are one group that have great potential for habitat selection due to their mobile and wide ranging nature. They fly over a wide variety of habitats and select specific ones for breeding, foraging and wintering. The proximate cues birds use for selecting habitat may be some physical aspect of the landscape, the presence of appropriate foraging or
nesting habitat, or the presence of other species. These factors may work independently, hierarchically, or all together. The selection of breeding habitat is especially important because once a choice is made, adults are tied to that area until the young are hatched or fledged (Burger 1985).

MacArthur et al. (1962) suggested that vegetation structure might play an important role in habitat selection when they used the structure of forest vegetation to successfully predict bird species diversity. A brief survey of recent literature reveals an emphasis on vegetation structure or structural aspects of habitat to determine bird habitat use (e.g. Bollinger 1995, Murkin and Murkin 1997, Ozesmi and Mitsch 1997, Kopp et al. 1998, Lemay et al. 1998).

The presence of food could be a factor in a certain habitat being selected. Marzluff et al. (1997) discovered that Golden Eagles (Aquila chrysaetos) favoured shrub habitat where their principal prey was found. Cody (1981) suggests that the structure of the habitat is important in habitat selection because it is an index of possible foraging sites, or may even correlate directly with food supply.

Another cue that could be used to select habitat is the presence of members of the same species, or conspecifics. The presence of conspecifics in a habitat could serve as an indicator of high quality habitat. Settlers may also benefit from living near others by gaining predator protection, as with colonial seabirds, or attracting mates (Muller et al. 1997). Muller et al. (1997) found that both conspecific attraction and habitat quality affected habitat selection in House
Wrens (*Troglodytes aedon*).

It is important that density alone is not used as an indicator of habitat quality, as species may be present or abundant in unsuitable habitats. This situation could result from social interactions or recent declines in the quality of habitat to which the population has not yet responded (Van Horne 1983). Van Horne (1983) warns against using density alone, and recommends using density, survival, and offspring production as a comparison of habitat quality between one area and another. Most habitat studies try to describe habitat associations of a species (proximate cues) rather than identify features important for survival or reproduction (ultimate factors). Thus, if only population density is used to represent habitat quality, the correlations of habitat features to density could misrepresent the suitability of certain habitats (Martin 1992). This was observed in a study on Californian Towhees (*Pipilo crissalis*) that found a higher density of towhees in a habitat that yielded lower reproductive success than in a habitat with lower towhee density (Purcell and Verner 1998); therefore, survival and successful reproduction must be linked to habitat features in order to determine the ultimately important factors in a habitat.

Scale is another important aspect to consider when assessing habitat selection. Selection may require a hierarchal series of decisions in which first the geographic location, then a particular habitat, and finally the location within the habitat (microhabitat) is chosen. Each of these decisions is based on cues that probably differ from those used at the next level (Hutto 1985). Most habitat...
selection studies examine only one scale, which may cause researchers to miss important habitat associations that exist at other scales.

An exception is the study by Pribil and Picman (1997) who examined female Red-winged Blackbird (*Agelaius phoeniceus*) habitat selection at the broad scale (choice of nesting area using 1 - 5 m plots) and at the narrow scale (choice of a nest site using 20 cm plots). They found that at the narrow scale, females had a strong preference for placing their nests in dense cattails that were surrounded by sparse cattails. This preference was not seen at the broader scale because the dense vegetation at the nest was combined with the sparse vegetation around it, resulting in an average density of cattails similar to the rest of the marsh. Similarly, Orians and Wittenberger (1991) found that female Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*) use the production of insects to select a marsh in which to settle, but use vegetation density to select a nest site within a marsh.

Discovering the proximate and ultimate causation of habitat selection of a species is especially important when developing habitat management plans. Determining the factors of habitat selection of a species, such as the Black Tern (*Chlidonias niger*), which has declined in numbers throughout its range, is of the utmost importance.
1.1.2 Black Tern Biology

The Black Tern is a marsh nesting bird which prefers semi-permanent wetlands greater than 20 ha in size, or greater than 11 ha if in a complex of wetlands (Kantrud and Stewart 1984, Brown and Dinsmore 1986). They use wetlands with 30% to 70% of the surface covered with emergent vegetation (Weller and Splatcher 1965, Chapman Mosher 1986), usually cattails (*Typha* spp.), bulrush (*Scirpus* spp.), or burreed (*Sparganium* spp.) although they are not restricted to wetlands with these types of vegetation (Provost 1947, Cuthbert 1954, Bailey 1977, Dunn 1979, Chapman Mosher 1986).

Much floating dead vegetation is usually present in wetlands used by Black Terns. Black Terns build their nests on dead cattail or bulrush mats, as well as on floating cattail rootstocks, floating grass/sedge mats, abandoned muskrat houses and feeding platforms, and on wooden boards or logs (Weller and Splatcher 1965, Bergman et al. 1970, Bailey 1977, Dunn 1979, Einsweiler 1988, Delehanty and Svedarsky 1993, Hickey 1997). Water depth of the wetlands used by Black Terns in most studies vary between 0.4 and 1.2 m (Provost 1947, Cuthbert 1954, Dunn 1979, Knutson 1991, Hickey 1997) although it can be less (Einsweiler 1988, Novak 1990).

It appears as though density of emergent vegetation (sparse to moderately dense) and availability of nest substrate are more important than plant type or water depth in selecting a habitat (Hickey 1997). As well, the
interspersion of water and vegetation is important in providing nest sites (Weller and Splatcher 1965, Hickey 1997) as Black Terns nest away from shore (Bailey 1977) and next to open water (Bailey 1977, Dunn 1979).

Open water is important for feeding. Black Terns feed mainly on insects such as dragonflies, damselflies and dipterans, and on fish. The percent of their diet composed of fish ranges from 5% to 41% (Cuthbert 1954, Goodwin 1960, Dunn 1979, Chapman Mosher 1986). It is probable that the frequency of a particular item in their diet depends on availability (Goodwin 1960). They feed by hawking insects out of the air, or by picking them off vegetation or from just under the water. They do not usually plunge dive into the water as seen with sea terns (Goodwin 1960).

Dunn and Agro’s (1995) literature review revealed that Black Terns begin to breed in mid-May to early June depending on latitude, and that their clutch size can be one to four eggs, although the average is 2.6. Most clutches are three eggs, with one and two egg clutches presumably resulting from eggs lost before the nest is discovered, or from young birds, which lay fewer eggs. After three weeks of incubation the eggs hatch and a semi-precocial chick emerges that can swim a day after hatching (Goodwin 1960). It takes 18 to 25 days before the young fledge, with most fledging around 19 to 21 days (Cuthbert 1954, Goodwin 1960, Bailey 1977, Dunn 1979).

Black Tern reproductive success is highly variable depending on the region, marsh and year. Nest success, defined as the number of nests to hatch
at least one young, ranges from 27% (Dunn 1979) to 96% (Chapman Mosher 1986). Less commonly used measures of success are hatching and fledging success, due to the difficulty in finding all the chicks. Hatching success is the proportion of eggs that hatch, and ranges from 23% (Mazzocchi and Muller 1993) to 90% (Chapman Mosher 1986). Fledging success is the proportion of chicks hatched that fledge, and ranges from 15-20% (Bailey 1977) to 65% (Einsweiler 1988). Overall, there is probably less than one chick raised to fledging per nest in most cases (Dunn and Agro 1995).

Black Terns nest semi-colonially and exhibit mobbing behaviour to drive off potential predators (Cuthbert 1954, Chapman Mosher 1986). Predators of Black Tern eggs and chicks include Great Horned Owl (Bubo virginianus; Bailey 1977, Einsweiler 1988), Black-crowned Night Heron (Nycticorax nycticorax; Bailey 1977), Great Blue Heron (Ardea herodias; Chapman and Forbes 1984), and mink (Mustela vison; Dunn 1979, Irene Mazzocchi, wildlife biologist, New York State Department of Environmental Conservation, pers. comm.). Black Terns also show alarm to the presence of raptors, bitterns, gulls, crows, blackbirds, and turtles (Goodwin 1960, Siglin and Weller 1963, Chapman Mosher 1986, Rabenold 1988). Adult Black Terns have been reported to have been attacked by a Common Raven (Corvus corax; Chapman Mosher 1986) and a Northern Harrier (Circus cyaneus; Maxson 1989).

A major source of Black Tern egg loss is due to inclement weather, effects of wind and waves, or changing water levels which cause the eggs to be washed
out of nests or nests to be destroyed (Bergman et al. 1970, Chapman Mosher 1986). Chick mortality is often from predation and sometimes starvation (Chapman Mosher 1986). Although predation is often proposed as a reason for the low fledging success (Dunn 1979, Delehanty and Svedarsky 1993), the actual mortality factor usually cannot be determined. This difficulty in determining the cause of mortality is also seen with Forster’s and Common Terns (Cuthbert and Louis 1993, Kirsch 1996). Chapman Mosher (1986) found a much higher egg and fledging success than in other Black Tern studies, which she attributes either to the fact that her study was in a managed area where the water levels were controlled, or because she used inconspicuous tape to mark nest sites instead of poles that previous researchers used that might have attracted predators.

Breeding success often depends on habitat type. Many studies have been done on the characteristics of Black Tern nest sites but very few relate them to breeding success. Bergman et al. (1970) and Dunn (1979) compared nest success to the nest substrate, but found no correlation. Chapman Mosher (1986) did a more detailed study and found that the highest hatching and fledging success was in nests in dense vegetation which protects the eggs from wind and wave action, and possibly protects the chicks from visually oriented predators; however a study by Hickey (1997) found no correlation between nest success and the density of the vegetation. Hickey (1997) did find that successful nests were closer to the marsh edge and to a dominant cover change.
(which might provide nest concealment), and further from large open water, than failed nests.

1.1.3 Black Tern Distribution and Status

There are two subspecies of Black Terns in the world - the old world subspecies (*Chlidonias niger niger*), which breeds in parts of Europe and Russia and winters along the coast of Africa (Cramp 1985), and the new world subspecies (*Chlidonias niger surinamensis*). North American Black Terns winter along the coasts of Central America and northern South America. In summer, the terns migrate to their breeding grounds in the northern United States and central Canada (Dunn and Agro 1995) (see Figure 1.1). The highest numbers of Black Terns occur on the northern Great Plains, where there are many productive wetlands in which to nest (Peterjohn and Sauer 1997) (see Figure 1.2). There are scattered populations in the northeast, and a recent report from the Northwest Territories discusses a colony as far north as 65°06' latitude (Barrett and Kay 1997).

The Black Tern is a recent arrival to the Maritimes, where it was first reported breeding in 1937 (Peters 1939, Peters 1941), although a Black Tern in juvenile plumage was collected on Sable Island off Nova Scotia in 1902 (Dwight 1903). From limited surveys done in this area, it appears that the terns prefer to breed in impounded wetlands which were built by Ducks Unlimited in the 1980's.
This is probably due to the stable water levels provided by the water control structures in the impoundments. Prior to the presence of impounded wetlands, Black Tern colonies were found on the periphery of lakes and in natural marshes on islands in the Saint John River, in New Brunswick (Hall 1971). The Black Tern is found in small numbers in New Brunswick; a 1997 survey found approximately 112 pairs in the entire province (Richards 1997). The New Brunswick population represents the eastern most portion of the Black Tern’s range, and is discontinuous from the main habitat area in the central U.S. and Canada.

The status of the North American Black Tern population has been a subject of some concern. The Breeding Bird Survey (BBS) data indicate that there has been a decrease in Black Tern numbers survey-wide, between 1966 and 1996; however, the rate of decline started to slow after 1980 (Peterjohn and Sauer 1997) (see Figure 1.3). Dunn and Agro (1995) estimate that there are a third as many terns in the 1990s as in the late 1960s. This decrease has been attributed to a loss of wetlands appropriate for breeding, due to draining for agricultural and developmental purposes (Gerson 1988). The strong correlation between changes in counts of Black Terns and Mallards (Anas platyrhynchos) along BBS routes supports the idea that changes in the amount of suitable habitat is causing the declines (Peterjohn and Sauer 1997).

The conterminous United States has lost an estimated 53% of its wetlands in the last 200 years (Dahl 1990), and Canada has lost 15% of its
wetlands (Lynch-Stewart 1993). The largest losses in Canada have been in the southern areas, such as southwestern Ontario where 68% of the wetlands are gone, and in the Prairies where half of the pothole wetlands have been lost (Lynch-Stewart 1993).

Two recent reports to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended that the Black Tern be classified as "Vulnerable" (Gerson 1988, Alvo and Dunn 1995); however, these recommendations were rejected as COSEWIC considers the Black Tern to be widespread and abundant. The Black Tern was on the Blue List in American Birds from 1978 to 1986; this is a list of birds whose populations are declining, based on the opinions of the continent's most active birders (Gerson, 1988). Although Black Tern censuses are not taken regularly in Canada and the United States, the general consensus is that populations have declined, and are still declining in the east (Gerson 1988), with six states listing the species as Threatened or Endangered, and 18 other states and provinces considering it of conservation concern (Shuford 1997). As Erskine (1992) points out, having a small population and few breeding sites makes the Black Tern's status precarious in the Maritimes.

It is important to determine the breeding habitat requirements of Black Terns in order to prevent their further decline and to bring their numbers up to previous levels. Their nesting requirements are quite specific as shown by their disinterest in apparently suitable habitat (Dunn, 1987), and abandonment of
previously used sites that appear unchanged to the human eye (Delehanty and Svedarsky 1993).

1.2 OBJECTIVES AND HYPOTHESES

Objective 1

To discover impoundment characteristics selected by Black Terns (proximate cues).

Hypothesis 1

Black Terns are selecting impoundments to nest in; settling is not a random event.

Overall Prediction

The features of impoundments used by Black Terns differ significantly from the features of impoundments not used.

Specific Predictions

1. Impoundments larger than 20 ha will be used out of proportion to their availability.

2. Impoundments with 30 to 70% open water will be used out of proportion to their availability.

3. The type and distribution of vegetation between used and unused impoundments will differ significantly.

4. The abundance of prey will be greater in used impoundments.
Objective 2
To discover impoundment and nest site features correlated with increased breeding success (ultimate factors).

Hypothesis 2a
Habitat quality varies between impoundments in the study area.

Prediction
Breeding success, as a measure of habitat quality, varies between impoundments in the study area.

Hypothesis 2b
The amount of cover at nest sites affects breeding success.

Prediction
There will be more cover at successful nests than at unsuccessful nests.

Objective 3
If there proves to be no observable difference between the characteristics of impoundments used and not used for nesting, a third objective is to explore the social aspect of habitat selection.

Hypothesis 3
Black Terns select an impoundment based on the presence of conspecifics.
**Prediction**

Black Terns can be attracted to nest at a previously unused impoundment using Black Tern decoys and calls.

1.3 PROJECT BACKGROUND AND DESIGN

Some wetlands in New Brunswick are being secured, enhanced, and restored by the Eastern Habitat Joint Venture (EHJV) which was launched in 1989 as part of the North American Waterfowl Management Plan (NAWMP). The purpose of the EHJV is to secure the waterfowl resources of eastern Canada and to enhance the abundance and quality of wetlands. Although the primary species of interest are waterfowl, the EHJV is also interested in maximizing the benefits to all species (NAWMP n.d.). The EHJV are interested in what effect impounding wetlands for stable water conditions (to enhance waterfowl brood habitat condition) will have on other non-target species, such as the Black Tern.

In cooperation with the New Brunswick Department of Natural Resources and Energy (NBDNRE), the Canadian Wildlife Service and Ducks Unlimited Canada, the EHJV is supporting a study of species use of both managed (impounded) and unmanaged wetlands on the Saint John River floodplain. Surveying was conducted for waterfowl, breeding songbirds and other avian species, amphibians, furbearers (muskrats), fish and insects, as well as
vegetation structure. I contributed to this larger study by examining the habitat requirements of the Black Tern, which was found in only one unmanaged wetland, and is apparently benefiting from the enhancement of wetlands for waterfowl.

My study was designed to evaluate Black Tern habitat selection at two spatial scales - the impoundment and the nest site level. The features selected for at the impoundment level may differ from those selected for at the nest site level. I compared used impoundments to unused impoundments, and nest sites to random sites within the impoundment. If used impoundments alone or nest sites alone are examined, then only habitat use can be characterized. Other Black Tern habitat studies have only investigated wetlands being used. Habitat selection will be explored in Chapter 2 of my thesis.

Scale is also a variable when considering the ultimate factors involved in habitat selection. I determined nesting success in three impoundments in 1997 and five impoundments in 1998, to see if there was a difference in habitat quality at the impoundment level. I also determined what features were important to breeding success within each impoundment at the nest site level. Using breeding success in more than one wetland to measure habitat quality is also unique to this research. This topic constitutes Chapter 3 of my thesis.
1.4 STUDY AREA

The study area was a 35 km section along the Saint John River floodplain between Fredericton and Saint John in New Brunswick (70 km from Saint John) (see Figure 1.4). The Saint John River originates in northwest Maine and flows 670 km to empty into the Bay of Fundy near the city of Saint John (Keachie and Cote 1973). The lower section of the river (Mactaquac Dam to Saint John) is affected by tidal action but high salinities are rarely seen further than 50 km from the mouth of the river (Keachie and Cote 1973). Stream flow is highest in April or May due to winter meltwaters combined with spring rains, and another peak occurs in the fall. Water levels usually fluctuate 3.7 m from the spring peak to the summer low and at times can fluctuate up to 6 m (Choate and Bowden 1973).

Spring runoff fills the floodplain wetlands annually. To enhance conditions for waterfowl broods, wetlands have been modified with dykes and water control structures (impounded) to maintain a stable water level throughout the summer after the river water level has dropped. Unimpounded wetlands tend to have more variable water levels and become dry meadows by the end of the summer. Stable water conditions probably cause the terns to prefer impounded wetlands over the unimpounded, or natural, wetlands (Chapman Mosher 1986).

There were 22 impounded wetlands in my study area (see Figure 1.5).
These impoundments were built in the 1980s and 1990s by Ducks Unlimited Canada as waterfowl brood marshes. The impoundments ranged in size from 8 to 128 ha, and cover a range of dominant vegetation types from shrub willow (Salix sp.) to cattails (Typha latifolia) to buckbean (Menyanthes trifoliata) and sedge (Carex sp.).
Figure 1.1 Distribution of the Black Tern in North, Central and South America.
(Dunn and Agro 1995)
Figure 1.2 Relative abundance of Black Terns along Breeding Bird Survey routes in the United States and southern Canada.
(Sauer et al. 1997)
Figure 1.3 Breeding Bird Survey annual indices for Black Tern populations in Canada (Sauer et al. 1997).
Figure 1.4 Study site location (in boxed area)
Figure 1.5 Study site (enlargement of boxed area from Fig. 1.4). Used impoundments as follows: 1. Duffies II, 2. Round Pond, 3. Lower Babbits, 4. Jemseg Flats, 5. McAllister Marsh, 6. Boyd's Marsh.
Chapter 2

Black Tern impoundment and nest site selection, food availability, social attraction, and site fidelity
2.1 INTRODUCTION

2.1.1 Nesting Habitat Associations

There are few studies that have quantitatively measured the features that Black Terns use to select a place to nest. Chapman Mosher (1986), Knutson (1991) and Hickey (1997) are the only researchers to have shown selection by comparing features at the nest site to random points within a marsh. My study examined selection at the nest site level as well, but also the impoundment level. The availability of food as a selection factor has not yet been studied for Black Terns, so a measure of food abundance was included in my study.

2.1.2 Social attraction

Twenty-five to thirty percent of Black Terns nest solitarily, while the remaining aggregate in groups of 11 to 50 nests, so Black Terns are considered to be a semi-colonial bird (Cuthbert 1954, Bailey 1977, Dunn 1979, Chapman Mosher 1986). Therefore, another factor the Black Terns may be using to select a place to nest is the presence of other Black Terns.

Wittenberger and Hunt (1985) state that nesting near conspecifics can provide protection from predators. Nesting near others of the same species, or even other species, can provide mutual vigilance, so that an individual does not have to spend as much time searching for predators, and could result in a
predator being detected faster. Mobbing is an effective method of deterring predators, and by nesting in a colony recruiting neighbours to help mob is much easier.

Nesting near conspecifics may also be an advantage if they serve as an indicator of high quality habitat. Brown and Rannala (1995) developed a model which suggests that a small number of birds choose sites based on the resources available and the rest (usually less experienced) are attracted to sites by the presence of other birds. Birds that choose sites by the number of other birds present probably spend less time and energy searching for suitable sites. Thus, a Black Tern could search for the presence of conspecifics instead of specific habitat features in order to decide where to nest.

2.1.3 Site tenacity

Another explanation for the distribution of Black Terns among available habitats is site tenacity, that is, returning to the same sites year after year. McNicholl (1975) suggests that site tenacity has a selective advantage by allowing the bird to become familiar with its surroundings and returning to a successful nest site.

In habitats of intermediate stability, such as marshes, that fluctuate over a short period, there is probably limited nest site tenacity. However, low tenacity is combined with group adherence, and this leads to the rapid recolonization of
temporarily unsuitable sites once they again become useable (McNicholl 1975). Delahanty and Svedarsky (1993) found that Black Terns recolonized a wetland in Minnesota a year after restoration, and continued to use it for two more years; however, there was no nesting there during the fourth year despite the fact that conditions appeared to be unchanged.

2.1.4 Objectives

My main question is why are only some impounded wetlands used by Black Terns for nesting? Since all impoundments provide stable water levels, what specific habitat features are necessary for a Black Tern nesting impoundment?

The main objective of this study is to determine the characteristics of impoundments the Black Terns are selecting. Vegetation features and food availability are two characteristics examined. Black Terns are presumably selecting impoundment features at two spatial scales, the impoundment level and the nest site level; therefore, I will examine features at each level.

Another objective is to assess how social interactions affect attraction of conspecifics to impoundments. A third objective is to determine the strength of Black Tern site tenacity to evaluate to what degree Black Terns move between impoundments between years.
2.2 METHODS

2.2.1 Impoundment selection

The study took place between late May and mid-August in 1997 and 1998. Six impoundments were used for nesting by Black Terns in 1997 and eight were used in 1998. There were a total of 22 impoundments present in the study area.

The impoundments that were "used" (i.e., those having at least one pair of Black Terns nesting) were compared to the 22 impoundments available in the study area, in 1997 and 1998. Impoundment size and percent vegetation were examined. Information on the size of impoundments was provided by Ducks Unlimited Canada (DUC). I estimated percent vegetation from aerial photographs taken in 1993 and 1997.

All six used impoundments in the study area were sampled, as well as seven unused impoundments for comparison, between July 23 and August 21, 1997. Unused impoundments were selected because they were similar to the used impoundments in size and percent vegetation. An additional unused impoundment was sampled on August 5 1998 in order to increase the sample size. The sampling unit was a circular plot with a radius of five metres centred at a random point. A transect line beginning at a random point along the dyke, ran a random direction into the impoundment. Random points were determined by moving a random distance along this transect line. All random numbers were
generated using the random button on a scientific calculator. There were 20 random points sampled in each impoundment, except for the impoundment sampled in 1998 which had only 12 points. If a random point occurred in open water (which would be useless to compare to a nest site), it was skipped and the next point was used instead. Percent area of the variables were determined by visual estimates. The sampling methods were modified from Hickey (1997).

The variables measured in the five metre plot included:

1. Percent of each plant species in the plot, then converted into physiognomic categories:
   
   Percent narrow-leaved (NLemerge) such as horsetail (*Equisetum* sp.) or sedge (*Carex* sp.), percent broad-leaved (BLEmerge) such as buckbean (*Menyanthes trifoliata*), percent robust (Robust) such as cattails (*Typha latifolia*) and pickeralweed (*Pontedaria cordata*), percent shrub (Shrub) such as willow (*Salix* sp.), meadowsweet (*Spiraea latifolia*) or sweet gale (*Myrica gale*).

2. Percent open water with no emergent vegetation (Water(%)).

3. Number of snags in the plot suitable for perching (Snag).

4. Number of potential nest sites in the plot; either mud mounds, open mats of dead or living vegetation, or fallen over dead vegetation (Potnest).

5. Average height class of the vegetation in each plot (Heightclass) (Hickey 1997):

   Height of the tallest dominant vegetation measured against a coverboard.
divided into black and white sections, 25 cm wide (Hays et al. 1981). Measurements were taken along transects 5 metres from the plot centre at the four cardinal points, with the coverboard at the plot centre. Heights were categorized as: 1 = <25 cm, 2 = 25-49 cm, 3 = 50-74 cm, 4 = 75-99 cm, 5 = 100-124 cm, 6 = 125-149 cm, 7 = >150 cm. The average value for a plot was calculated from the sum of the four readings and recategorized as: 1 = ≤ 50 cm (sum 0 - 9), 2 = 51 - 75 (sum 10 - 13), 3 = 76 - 100 (sum 14 - 17), 4 = >100 (sum ≥18).

6. Average horizontal cover at 25 cm (Cover25):

The visual measure of percent of horizontal cover from just above the water level to 25 cm. Measurements were taken using the black and white coverboard (Hays et al. 1981) at the plot centre, read from five metres at the four cardinal directions, to the nearest 20% of the amount of the board covered by vegetation at that level. The cover was categorized as: 0 = no cover, 1 = 20%, 2 = 40%, 3 = 60%, 4 = 80%, 5 = 100%. The average value for cover at each plot was calculated from the sum of readings from the four cardinal directions and re-categorized as: 1 = ≤ 20% (sum 0-5), 2 = 21-50% (sum 6-10), 3 = 51-79% (sum 11-15), 4 ≥ 80% (sum ≥ 16).

7. Average horizontal cover at 50 cm (Cover50):

The same procedure as with Cover25, but the measurements were taken between 25 cm and 50 cm above water level.
8. Average horizontal cover at 75 cm (Cover75):

Measurements were taken between 50 cm and 75 cm above the water level.

9. Average horizontal cover at 100 cm (Cover100):

Measurements were taken between 75 cm and 100 cm.

10. Average density (Density):

Density was measured along a transect at four cardinal points, classified as 1 = sparse (vegetation widely scattered and much water visible), 2 = moderate (some water visible through vegetation), 3 = dense (cannot see water through vegetation). The average value for plot was calculated from the sum of the four readings and categorized as: 1 = sparse (sum 4-6), 2 = moderate (sum 7-9), 3 = dense (sum 10-12).

11. Water depth: Divided into water depth to the bottom of the impoundment (Bottomdepth), and water depth on the vegetation mat (Matdepth). If the cardinal point fell on a mat, the depth of water over the mat of roots was measured, and if it fell in open water, depth to the bottom was measured, to the nearest centimetre.

2.2.2 Food availability

2.2.2.1 Odonate sampling

Odonate abundance was measured in eight "used" and four "unused"
impoundments between June 24 and August 4 1998. A low effort technique was used, which required checking for odonates only once a week. An exuvial census (Trottier 1966) was used in which a cheesecloth “fence” was placed in the water, to allow odonate nymphs to crawl up from the bottom of the impoundment, and subsequently emerge into adults and fly away, leaving the nymph exuviae behind on the cheesecloth. Five 1.5 x 1 metre rectangular fences were placed in each impoundment between June 24 and July 6. The fences had cheesecloth which extended from the bottom of the impoundment to at least 50 cm above water, and were placed in vegetation representative of the impoundment (Paul Brunelle, Odonatist, pers. comm.). These were checked for exuviae once a week; exuviae were removed as they were counted. Exuvial census is a standard technique for estimating the abundance of many aquatic insects (Southwood 1978).

Numbers of exuviae collected each week in each trap were converted into number of damselflies and dragonflies per day. Because the majority of the odonates counted were damselflies, and dragonflies did not reach peak emergence until after the Black Tern chicks had fledged, and because the majority of the food items captured within the impoundments were damselflies, I considered only the damselfly abundance. Average hatch date for Black Tern chicks in 1998 was June 26 and average fledge date was July 15. I summed the number of damselflies per day (by trap) that emerged in the impoundments between June 28 and July 15 to indicate food available to parents during the
chick rearing period. I selected June 28 rather than June 26 as young chicks a few days old eat mainly small insects and may not start eating odonates until they are a few days old. Wiggins and Morris (1987) showed that one to two day old Common Tern (Sterna hirundo) chicks were fed smaller food items and less often than older chicks.

2.2.2.2 Feeding studies

To confirm that odonates do make up a large portion of a chick's diet in my study area, eight nests were watched over five days for a total of 11 hours and 32 minutes. The nests contained chicks aged three to nine days old. Nests were encircled with a one metre diameter hardware cloth fence to keep the parents from moving the chicks to another site. The fence had a 10 cm strip of burlap around the bottom to prevent the chicks from getting their beaks caught in the fence. I watched from floating blinds or from tower blinds using 10 x 50 binoculars. The number of each type of food that the parent brought to the chicks was counted and the time noted. The impoundment the parent caught the food item from (within the nesting impoundment or from another nearby impoundment) was also noted, if possible.
2.2.3 Nest site selection

Habitat features at nest sites were measured from July 24 to August 4 in 1997 and June 12 to July 1 in 1998. Nest level habitat data were collected at 40 nests and 60 random points (the same used for the impoundment level analysis) in three impoundments in 1997 and at 56 nests and 57 random plots in five impoundments in 1998. The sampling unit was a five metre radius plot, centred around the nest/random point. An additional one metre radius sub-plot was centred around the nest and at the random plots to compare nest site feature versus random site features at a smaller scale.

The features measured in the five metre plot were the same as measured for the impoundment level analysis. Variables measured in the one metre plot included:

1. Percent water (Water).
2. Percent each vegetation species again broken into physiognomic categories:
   (NLer, BLer, Robust, Shrub, Deadshrub)
3. Percent open mat available on which to nest (Openmat).
4. Number of directions around the plot centre that contained vegetation within one metre (Dirveg). This is a measure of how much vegetation surrounds the nest and random plot, and can range from 0 directions (completely open) to 8 directions (completely enclosed). Directions used were N, NE, E, SE, S, SW, W, NW.
5. Area of nest substrate (Subsize): Length times width of vegetation mat on which the nest was built.

6. Height of nest above water (Subheight): Measured from the base of the nest to the surface of the water.

Also measured from the plot centre were:

1. Distance to nearest small water pool (between three and 15 metres in diameter, and shallow) (Distwaters).

2. Distance to nearest large water pool (Distwaterl). Pool has to be suitable for fishing by being larger than 15 metres in diameter if shallow, or by being deep (such as the deep channels around the inside of the dyke or around the constructed islands in the impoundments).

3. Distance to nearest cover change (Distchange). Distance from plot center to a major change in standing vegetation composition, visually estimated.

4. Distance to impoundment edge (Distedge). Distance from plot centre to impoundment edge, visually estimated.

2.2.4 Social attraction

Black Tern decoys were placed in an impoundment not previously used by Black Terns for nesting (Upper Babbits), and in an unused area of a used impoundment (Lower Babbits), to attract Black Terns to nest. Four decoys were
placed in each impoundment, two of which were carved out of wood with the wings raised, and two moulded from clay and in a sitting position. In each impoundment, two tape players wired to 12 volt batteries were placed in the impoundment next to the decoys. Each player was inside a plastic tub with a lid, with a mesh window, sitting on a floating platform. The players played Black Tern calls (obtained from the Borror Laboratory of Bioacoustics) during daylight hours and were turned off at night by a light sensitive switch. Decoys and sound recordings have been shown to attract Arctic and Common Terns to re-colonize abandoned sites (Kress 1983). The players and decoys were placed in the impoundments on May 15, 1998, at the time the first Black Tern was seen in the area, and the players were removed June 4 when most Black Terns had already started to nest.

In addition to calls and decoys, floating nest platforms were also placed nearby to ensure that the Black Terns had adequate nesting sites. Using a modified design of the platforms constructed by Mazzocchi (1996), eight 61 x 61 cm (two feet by two feet) platforms were placed 20 metres apart in a circle around the decoys and sound recordings in each impoundment. The distance of 20 metres was chosen because this was the average distance between nearest nests in 1997. The platforms were made of 0.5 cm hardware cloth stapled to a wooden frame which had Styrofoam floats nailed to the bottom. A rope with a brick on the end was attached to each platform to prevent it from floating away. A mixture of mud and dead vegetation was placed on the platforms as nesting
substrate and this caused the platforms to float so the mesh and bottom of the vegetation were just in the water. This kept the vegetation/mud mixture adequately moist to keep it from drying up and blowing off the platforms. This type of nesting platform has been used by Black Terns for nesting in many other studies (Chapman Mosher 1986, Faber 1992, Mazzocchi 1996, Alvo et al. 1998).

Eight additional platforms without sound or decoys were placed in another section of the unused impoundment to test if the Black Terns would select to nest there because of available nest sites alone.

2.2.5 Site tenacity

Black Terns were captured and banded in three impoundments in 1997 and 1998. The Black Terns in 1997 were captured on the nest using a simple trap patterned after Mazzocchi and Muller (1993) (see Figure 2.1). Trapping took place in late incubation and if the parent did not enter the trap after 20 minutes the trap was removed and another nest was tried. A standard U.S. Fish and Wildlife Service (USFWS) aluminum band was placed on one leg and a colour band that corresponded to the impoundment in which they were caught was placed on the other leg.

In 1998 a different trap design of my own was tried in an attempt to capture more terns (see Figure 2.2). This design reduced visual obstruction of the nest and used a rope to close the spring-loaded lid. Black Terns were
captured in the same three impoundments and the number of recaptures were noted. Captured unbanded Black Terns were banded with aluminum bands.

2.2.6 Statistical analysis

At the impoundment level of analysis, I used a non-parametric test (Mann-Whitney) to compare sizes and percent vegetation of used and unused impoundments. I took the mean of each variable for each impoundment to obtain one value for each impoundment and thus avoid pseudoreplication. I used either parametric or non-parametric univariate statistics to compare between used and unused impoundments. A non-parametric test was used when the data were skewed and contained a large number of zeros. Discriminant analysis was used to see if any interaction of variables could explain why an impoundment was used by Black Terns.

For odonate sampling, a Student’s t-test was used to compare mean damselfly abundance between used and unused impoundments. A linear regression was used to regress damselfly abundance against number of Black Tern pairs nesting in the used impoundments.

At the nest site level, I used a methodology similar to that used by Brennan et al. (1986) to apply logistic regression to use of nest site habitat. Univariate statistics were used to compare continuous variables between nest sites and random sites. I used chi-square analysis to test between nest and
random sites for categorical variables. Because I had some variables that were correlated and this could lead to problems in analysis, correlations were checked and if a pair of variables were correlated ($r > 0.8$), the one with the lower P-value from the univariate analysis was retained. Principal component analysis (PCA) was used when more than two variables were correlated. However PCA was needed only for the four horizontal cover variables (Cover25, Cover50, Cover75, Cover100), and the factor loadings for all four variables were very similar, so I averaged the values instead (new variable Cover), which made it easier to interpret. Subsequently, the variables were put in a stepwise logistic regression model with an alpha level of 0.05 to find which variables were useful in predicting the presence of a nest site.

The five metre and one metre radius plots were analysed separately because they represented two different scales of selection and some variables such as types of vegetation were measured in both and, therefore, correlated. Data from each year were analysed separately because data were collected at different times during the summer, and the vegetation was taller and thicker later in the summer.

2.3 RESULTS

2.3.1 Impoundment selection

Six impoundments in the study area were used by Black Terns for nesting
in 1997 and an additional two were used in 1998. Figure 2.3 illustrates that no impoundments less than 20 ha in area were used even though they comprised 36% (8 out of 22) of impoundments available. Median areas of the used impoundments were two times as large as the unused impoundments in both 1997 and 1998 (Mann-Whitney; \( P=0.032 \) and \( P=0.029 \) respectively); however, other than the 20 ha threshold, there was no apparent relationship between number of Black Tern pairs nesting in an impoundment and size of the impoundment (see figure 2.4 and 2.5).

There was no statistically significant difference between those impoundments used and those available in 1997 and 1998 in terms of percent of the impoundments covered in vegetation (Mann-Whitney; \( P=0.267 \) and \( P=0.370 \), respectively, see Fig. 2.6). Percent vegetation in used impoundments ranged from 45 to 75% and from 25 to 85% in all impoundments available. The 30 to 70% vegetation class was not selected for in either 1997 or 1998 (Fisher’s exact test; \( P=0.607 \) and \( P=1.000 \), respectively). There was no relationship between number of tern pairs in an impoundment and percent vegetation in 1997 or 1998 (Linear regression; \( P=0.961 \) and \( P=0.434 \), respectively).

There were two additional impoundments used by Black Terns in 1998 that were not used in 1997. I decided to omit these impoundments from the analysis because in one year they contributed to characterizing unused impoundments and the next year the same information was used to characterize used impoundments.
No habitat variables were statistically significantly different (at P=0.05) between used and unused impoundments; however, impoundment depth in 1998 and density of vegetation were the closest to being significant (Student’s t-test; P=0.114 and P=0.136, respectively) and when these two variables were put into a discriminant analysis, they correctly discriminated between used and unused impoundments 100% of the time. Figure 2.7 shows that terns prefer impoundments that are comparatively shallower and denser than unused impoundments (‘1’ was classed as sparse and ‘3’ as dense). Depths of impoundments in 1997 and density of vegetation did not discriminate as well (75% correctly classified) but the discriminant line is similar to the line for 1998 (see Figure 2.8).

2.3.2 Food availability

2.3.2.1 Odonate sampling

There was an average of three times as many damselflies that emerged in impoundments used by Black Terns for nesting than in impoundments not used (Student’s t-test, P=0.015). When a regression was performed on number of damselflies versus number of Black Tern pairs in an impoundment, a positive trend was observed (see Figure 2.9).
2.3.2.2 Feeding study

To check the importance of odonates in the diet of Black Terns in my study area, a feeding study was conducted at each of three impoundments, McAllister Marsh, Jemseg Flats, and Round Pond. Of the 239 items fed to chicks, 16% were dragonflies, 22% were damselflies and 45% were other insects, which probably included damselflies that could not be positively identified. Small fish, probably minnows and pickerel, constituted 14% (by numbers) of the chick diet, and the remaining 3% of the diet was composed of caterpillars or unidentified items.

Three of the nests watched had one parent which had been colour marked for another purpose in the study. This colour marking allowed for differentiation between parents so I could tell which parent was bringing which foods to the chicks. This revealed that these pairs of Black Terns tended to specialize, with one parent bringing back only fish and the occasional odonate (usually a dragonfly) and the other bringing back only odonates (usually damselflies) and small insects. Damselflies take a shorter amount of time to hunt and capture (an average of 3.1 minutes between feedings, n=37, SD=2.9) and are generally caught near the nest, whereas fish take longer to hunt and capture (an average of 26.4 minutes between feedings, n=8, SD=24.7) and are caught further away in open water.

At two other nests observed in Round Pond, Black Terns frequently flew
to an adjacent impoundment (Lower Babbits) and food types brought back were noted. Overall, 75% of the fish were caught in Lower Babbits (where there was much more open water), and half the damselflies, and most of the dragonflies were caught in a nearby section of emergent vegetation in Lower Babbits. Almost all of the small insects were caught in Round Pond, near the nest.

The distance to a nearby feeding impoundment for the three impoundments studied ranged from 400 to 3000 metres. In Jernseg Flats and Round Pond, the Black Terns could be seen regularly flying over to an adjacent impoundment 400 to 1000 metres from the nesting area to hunt. Black Terns carrying fish were noted in an unused impoundment flying in the direction of McAllisters Marsh (3 km away).

Additional impoundments were used for feeding once chicks had fledged and could fly to feeding impoundments with their parents. Feeding impoundments can be characterized as having large sections of open, unvegetated water in which Black Terns can fish. Adults with juveniles were seen fishing at the marshy edges of lakes or in shallow lakes with thin rushes dispersed throughout (see Table 2.1). Often juveniles would perch on whatever was available, such as fishing weir poles and plastic containers used as buoys.

2.3.3 Nest site selection

Forty-one nest sites in three impoundments were assessed in 1997 and
56 nest sites in five impoundments were assessed in 1998. Nesting areas moved in the three impoundments measured both years. For example, in Round Pond most nests (89%) were in cattails in the eastern part of the impoundment in 1997 and then were predominantly in horsetails (76%) in the western part of the impoundment in 1998 (see Figure 2.10). At Jemseg Flats, the Black Terns nested in the northern section of the impoundment in 1997 and moved to the southern section in 1998 (see Figure 2.11), and movement was also seen in McAllister Marsh (see Figure 2.12).

There was a difference in dominant vegetation composition between nest sites and random sites in 1997 (Chi-square; \( \chi^2=11.809, \text{ d.f.}=4, P=0.019 \)) with more shrubs present at the nest sites and fewer horsetail and grasses. However, there was no statistically significant difference in dominant vegetation in 1998 (Chi-square; \( \chi^2=8.250, \text{ d.f.}=4, P=0.083 \)) and the trend was towards fewer shrubs and more horsetail at the nest sites, which illustrates the shift of nesting areas between years. A chi-square test comparing dominant vegetation between nest and random sites, with data from 1997 and 1998 combined, reveals that no particular plant species was selected within an impoundment (Chi-square; \( \chi^2=6.299, \text{ d.f.}=5, P=0.278 \)) (see Figure 2.13).

The type of substrate on which nests were built differed between years, reflecting movement within impoundments between years (see Figure 2.14). Overall, unvegetated floating mats of vegetation, consisting of a wet mixture of roots, rotting vegetation and mud, was the favoured substrate (42%). Other
substrates included vegetated floating mats which included openings in cattail and buckbean mats (20%), platforms formed from dead vegetation caught up on dead wood or on shrubs and usually quite high and dry (22%), and dead or live vegetation such as grass or horsetails that has fallen over and formed a nesting substrate (16%). I saw only one instance of a Black Tern nesting near a muskrat feeding platform and the nest had been placed behind the platform rather than on it.

The mean height of nest substrate above water was 10.7 cm, although it was significantly different between years (Student’s t-test, P=0.001). In 1997, mean substrate height was 14.3 cm and mean height was 8.1 cm in 1998. Mean substrate area for both years combined was 0.714 m², and it was significantly different between years (Student’s t-test; P<0.001). In 1997, mean substrate area was 1.154 m², and in 1998, mean substrate area was 0.391 m².

In the one metre radius plot, the only variables statistically significantly different between nest and random plots in both years were amount of open mat and number of directions around the plot centre with vegetation within one metre. Amount of open mat is obviously important as there was some open mat at every nest site (for Black Terns to build their nests on) and there were no open mats in any of the random points in 1997 and only two random points had open mats in 1998. Nest sites were less surrounded by vegetation than the random sites in both years (Chi-square; $\chi^2=19.688$, d.f.=3, P<0.001, and $\chi^2=26.808$, d.f.=4, P<0.001, respectively). There were fewer nest sites
completely surrounded (all eight sides with vegetation) and more with zero to seven sides surrounded than at the random sites (see Figure 2.15).

Other statistically different variables (at P=0.05) in the one metre plot in 1998, were percent water and percent dead shrub, which each had a higher percent in nest plots (see Table 2.3). Percent narrow-leaved vegetation was significantly less in the nest plots in 1997 (see Table 2.2). Percent water was correlated to directions surrounded by vegetation, so I used directions surrounded by vegetation in the analysis as it had a smaller P-value in univariate tests. Stepwise logistic regressions performed on the significant variables from each year, revealed that only percent open mat was kept in the model in 1997 and percent open mat and directions surrounded by vegetation were kept in the model in 1998 (see Table 2.4). These two variables correctly classified 70% of the data used to build the model in 1998 and 100% of the data in 1997.

In five metre radius plots, only height classes of the dominant vegetation were significantly different between nest and random sites in both years; however, the distributions are considerably different between years (see Figure 2.16), probably as a result of the later sampling date in 1997. In general, vegetation is shorter (less than 75 cm) at nest plots.

There were significantly fewer narrow-leaved emergents at nest sites than random sites in 1997, and nests were significantly closer to the edge of the impoundment (see Table 2.5). In 1998, there were significantly fewer submersgents, and more snags at nest sites, and mat depths were deeper than at
random sites. There was less average cover at 50 cm and at 1 metre above water level at the nests (see Figure 2.17 and Figure 2.18). Average density was moderate at nest sites (see Figure 2.19), as was percent water (25-50%) (see Figure 2.20). Another significant variable was cover, which is an average of all four cover values at the four heights above water, and which was less at nest sites (see Table 2.7).

Percent open water, divided into categories, was put into the regression in place of percent water in both 1997 and 1998. In 1998, percent dead wood was highly correlated with percent snag so snag was selected to enter the regression.

Stepwise logistic regression was performed on the variables from each year, and percent narrow-leaved emergents, distance to large water pool and distance to edge were kept in the model in 1997 (see Table 2.6). These three variables correctly classified 63% of the data used to build the model. Amount of cover, percent water (categorical), mat depth, and number of snags were kept in the model in 1998, and these variables correctly classified 66% of the data used to build the model (see Table 2.8). Combining the 1998 one metre and the five metre plot variables resulted in the six variables correctly classifying 83.1% of the data used to build the model.
2.3.4 Social attraction

Two Black Terns nested near the decoys in Lower Babbits. One nest was on a platform I placed and was initiated on June 23, and the other was on a vegetation mat and was initiated on June 15. The nest on the vegetation mat failed, presumably when the water level in the impoundment rose, whereas the platform-nest hatched two chicks. There were at least four other nests in another section of the impoundment that had been used for nesting in previous years.

No Black Terns nested in Upper Babbits, an impoundment not previously used for nesting. Black Terns were seen fishing in the area around the decoys, sound recordings, and platforms but did not nest there. The platforms alone that had been placed in another section of Upper Babbits were also not used by the Black Terns, although from the presence of droppings, muskrats and ducks used them as resting areas.

2.3.5 Site tenacity

Twenty-one adult Black Terns were captured and banded in three impoundments in 1997. Of the 32 adults caught in 1998, only two had been banded previously. Therefore, the proportion of banded birds that returned to the impoundments to nest was only 9.5% (2/21). Both recaptures were from the
same impoundment in which they had been banded the previous year, and they had both hatched chicks the previous year (although the chicks could not be found five days later). Unfortunately, the adults had to be captured to check the bands as it was impossible to see the impoundment-specific colour bands when the terns were flying or standing on the nest. The aluminum USFWS band was more visible than the colour band, and that was visible only at close range.

2.4 DISCUSSION
2.4.1 Impoundment selection

The Black Terns in my study did not nest in impoundments smaller than 20 ha. Brown and Dinsmore (1986) found that Black Terns did not nest in marshes smaller than 20 ha if the marsh was isolated, but they would nest in smaller marshes (5 - 11 ha) if the marshes were in a complex. Two of the impoundments in the study area were less than 20 ha and in a complex, but they were not used. The Black Tern could be called a size dependent species in that impoundments have to be a minimum size before they will nest in them, although there is no preference for larger sizes beyond this threshold. The requirement of larger impoundments to nest in may reflect the need of Black Terns to have large foraging areas (discussed later).

Although there was no statistically significant difference in percent vegetation between used and unused impoundments, it does appear that Black
Terns were avoiding the extremes of too much or too little vegetation. They used impoundments with between 45 and 75% vegetation, which is somewhat close to the 50:50 hemi-marsh conditions that Weller and Splatcher (1965) cite as being ideal. Linz et al.'s (1994) study of cattail management found that numbers of Black Terns were positively related to percent water and dead emergents.

Two factors acting in tandem that affected where Black Terns nested were density of vegetation and impoundment depth. It appears that terns prefer moderately dense vegetation in a shallow impoundment, but will use an impoundment that has denser vegetation if it also has deeper water. Again the extremes, of sparse vegetation, and dense vegetation in very deep water, were apparently avoided in my study.

2.4.2 Food availability

One factor that could be influencing whether an impoundment is used, and how many terns are present, is abundance of odonate prey within the impoundment. A positive relationship was seen between number of pairs of Black Terns nesting in an impoundment and damselfly abundance, and there were more damselflies emerging in used than unused impoundments.

Orians and Wittenberger (1991) also found a relationship between food availability and number of birds attracted to settle there. They found that there
was a higher density of Yellow-headed Blackbird females in marshes with higher emergence rates of odonates. They suggested that females assess the production of odonates at the time they settle, possibly indirectly from features of the habitat, and use that to select habitat.

Odonates constituted at least 38% of food items fed to the chicks in my study area, and therefore are an important part of the diet. Chapman Mosher (1986) and Welham and Ydenberg (1993) observed that Black Terns often lose at least one chick to starvation, so the presence of plentiful odonates in a nesting marsh would be important to chick survival.

Another factor influencing habitat selection may be the presence of a nearby feeding site with open water where the Black Terns can fish. While fish constituted only 14% of the items in the chick diet in New Brunswick, the proportion of calories and protein provided by each fish is higher than provided by the odonates, and therefore fishes are an important component of their diet. Dunn (1979) suggests that fish provide at least one-third of the protein required for growing chicks. Calculations from Welham and Ydenberg (1993) reveal that the average fish a Black Tern would consume provides approximately 1000 joules of energy, whereas an odonate would provide approximately 481 joules.

All of the impoundments used in my study were next to a marsh with open water or had sufficiently large areas of open water within the impoundment. I observed Black Terns regularly foraging 0.4 to 1.0 km away from nest sites, and sometimes further. Hickey (1997) also found that they foraged up to 0.8 km
much of the time, and Chapman Mosher (1986) found 60% of the terns travelled distances greater than 0.5 km to hunt for food. Delehanty and Svedarsky (1993) suggested that one reason a restored wetland was recolonized was the presence of a water storage reservoir with large areas of open water in which terns fished.

The specialization of parents on certain food items seen in this study was also noted by Dunn (1979), who found one parent brought fish to the nest and the other brought small insects. Goodwin (1960) found that it was the male parent that brought 94% of the fish to the nest. He also found that the amount of time between feedings depended on the food item, with chicks being fed 46 damselflies in an hour compared to three fish in an hour. I obtained similar results in my study.

I also found that if a Black Tern parent traveled outside the impoundment to hunt for food, it was more likely to bring back larger items such as fish or dragonflies. If the parent was foraging around the nest site, it usually caught small insects or damselflies. This is consistent with the concept of optimal foraging; that is, if the parent has to expend more energy to get to a feeding area, that feeding area should provide larger or higher energy food (Schoener 1979). Chapman Mosher (1986) also noted that if the Black Terns travelled long distances (an average of 2.4 km), the areas to which they travelled had more open water than the nesting impoundment, and therefore more opportunities to catch fish.
Mossman (1989) cited having extensive feeding areas nearby as an important habitat requirement for Forster's Terns, another marsh-breeding tern. He suggested that Forster's Terns use of only large wetland complexes reflects a need for large feeding areas. The same logic could be applied to Black Terns.

In addition to having feeding marshes to forage for fish to feed chicks, it seems important to have what Hickey (1997) calls day-use areas. These are areas to which adult Black Terns bring their fledglings so they can start feeding themselves. These areas have large amounts of open water and perches for juveniles. I found that tern families used shallow marshy lakes and marshy edges of deeper lakes, as well as actual marshes.

2.4.3 Nest site selection

The typical nest site has a moderate density of vegetation, providing a moderate amount of cover (50 - 80% horizontal cover at 50 cm above water level), interspersed with a moderate (25-50%) amount of open water. There have to be suitable nest substrates such as floating mats of vegetation that are not completely surrounded by vegetation. There should be snags near the nest site for perch sites for juveniles and adults. The type of vegetation in the impoundment is not important as seen by the Black Tern's use of different types of vegetation within the same impoundment in different years.

The preference for moderate amounts of cover has been noted
qualitatively in other studies (Cuthbert 1954, Dunn 1979) and quantitatively by Hickey (1997) who found 85% of nest plots were in sparse to moderately dense vegetation. Hickey (1997) also found a moderate (40 - 60%) interspersion of cover and water at nest sites was favoured by Black Terns. Burger (1985) found that, for water level-nesting marsh birds, nesting near open water was an important anti-predator strategy. She found terns killed by mink because they could not fly from dense cattails and were trying to swim instead. Thus, a moderate amount of cover interspersed with water and a site with at least one side of the nest clear of vegetation should be advantageous because Black Terns can see predators coming and quickly fly up from the nest. The presence of some vegetation is necessary for chicks to hide and to reduce the impact of any waves that might swamp the nest (Bergman et al. 1970, Chapman Mosher 1986, Hickey 1997).

The presence of open mats on which Black Terns can build nests is obviously an important factor in nest site selection. In predicting whether a site is a potential nest site, the logistic regression analysis showed the presence of an open mat to be very important. However, this analysis tends to overemphasize the importance of the presence of a mat for differentiating between a nest and random site, as very few random plots fell on an obvious open mat (none in 1997 and two in 1998). The substrates that Black Terns could use to nest is not always easy to recognize. It may be as obscure as a small clump of grass that has fallen over. I have seen Black Terns build nests
on small pieces of mat barely above the water, the same size as the nest built on it, or on some floating dead grass or horsetail that is easy to overlook. Black Terns do not necessarily choose to nest on well-defined, sturdy mats if they are available but will often select low, wet mats.

Other studies indicate the importance of the presence of muskrats in creating suitable nesting habitat for Black Terns (Cuthbert 1954, Weller and Splatcher 1965, Bergman et al. 1970); however, most of these studies took place in cattail marshes where muskrats ate cattails, thereby providing open water and muskrat feeding platforms that Black Terns used for nesting. There was only one cattail impoundment in my study area, and Black Terns did not use feeding platforms on which to build nests as there were other vegetation mats available. Black Terns in New Brunswick nest in impounded wetlands that are managed by Ducks Unlimited for waterfowl brood production. Periodically, Ducks Unlimited cuts channels and pools through the vegetation, and this helps produce clumps of dead vegetation and rootstocks on which terns nest.

In general, the logistic regression models were not very good at predicting which sites were random and which were nest sites. Separately, the 1998 one metre plot variables and five metre plot variables correctly classified only 70% and 66% of the data used to build the model, however the one and five metre plot variables together correctly classified 83% of the data. The 1997 five metre plot variables correctly classified only 61% of the data. The 1997 one metre plot variables correctly classified 100% of the data but I feel this to be misleading
and arises because all nest sites had some open mat present and none of the random sites had any open mat.

The logistic regression found different variables to be significant predictors for each year, which could be due to the different times at which the vegetation was sampled. In terms of amount of cover, density of vegetation and percent water in the plot, I believe that the 1998 data provided a better picture of what Black Terns are selecting in a nest site. This is due to the fact that the 1998 data were collected in June when the chicks were still present. The 1997 data were not collected until after the Black Terns had left the impoundments in late July and early August and the vegetation had grown considerably from when chicks were present. This could cause any differences between nest and random sites to become obscured.

That different variables were found to be significant between years could also be attributed to the different nest sites within the impoundments between years or the effects of different weather between years (see Chapter 3).

Hickey (1997) also used logistic regression to build a model for predicting Black Tern nest sites. She found that vegetation density, horizontal cover 50 cm above water level and vegetation cover to water ratio were significant variables. These correctly classified 77% of the data used to build the model. When she tested the model the next year, it correctly classified 88% of the nest sites in the same area, but only 64% of the nest sites outside the study area. There are many reasons why models based solely on habitat elements may not be good
predictors of species responses. The habitat descriptors may not account for intracommunity relationships, weather may be a factor, and factors controlling populations may vary between years and types of environments (O'Neal and Carey 1986).

2.4.4 Social attraction

Black Terns did not nest in a previously unused impoundment that had tern decoys, sound recordings and platforms present. However, two late-nesting Black Terns nested next to the decoys in a previously unused section of a nesting impoundment, which indicates that there maybe weak social attraction among Black Terns. That this attraction is weak is illustrated by the fact that one of the impoundments in 1998 had only two pairs of Black Terns nesting in it, and that in another impoundment a pair of terns nested 160 metres away from their nearest neighbour.

Kress (1983) re-established a Common and Arctic Tern colony using decoys and sound recordings; however, even though terns were attracted to the site, no terns bred there in the first two years. It was only after four years of using the decoys and sound recordings that peak numbers of nesting terns were achieved. I put out the decoys and sound recordings for one summer and the recordings were taken in after peak initiation in early June. It may take longer to attract Black Terns to a new site, as it did for the Arctic and Common Terns;
however, marsh terns have to be much more flexible than marine terns as their habitats change from year to year (McNicholl 1975).

Attracting Black Terns with decoys and sound recordings to nest in areas they have not used previously has been tried without success by other researchers. At the Montezuma National Wildlife Refuge in New York and around Lake Ontario sound recordings and decoys were used for one season but no Black Terns were attracted to nest (Tracey Gingrech, wildlife biologist, Montezuma National Wildlife Refuge, personal communication, Richardson 1996).

In my study, the two pairs of Black Terns that were attracted to nest near one set of decoys were late-nesters, which could indicate that they were first-time breeders (Harrington 1974, Massey and Atwood 1981). Inexperienced breeders would be more likely to rely on the presence of conspecifics to cue them where to nest as more experienced breeders already have first-hand knowledge about habitat quality (Muller et al. 1997). The presence of a large (20 pair) colony of Black Terns in the adjacent impoundment may have also helped in attracting the late-nesters to the area.

In general, it is probably a combination of factors that attract Black Terns to a certain impoundment or section of a impoundment to nest in. There have to be the appropriate amounts of cover, water, and food within the impoundment, but there may also be an attraction to conspecifics. That all the Black Terns nested in a different section of the impoundment at Jemseg and Round Marsh
between years indicates some degree of social attraction among terns.

2.4.5 Site tenacity

The new trap design used in 1998 was very useful in trapping adults that had built their nests on very small platforms. The legs of the new trap allowed it to be placed around any small substrate, whereas the older trap design had to rest on the platform and, therefore, could not be used with a small substrate. The new trap may have facilitated the capture of Black Terns due to the reduced visual obstruction over the nest. However, there appear to be Black Terns that tend to settle back onto the nest no matter what trap is over top of it. Conversely, there are some Black Terns that will mob anything around the nest that is foreign and will not settle back on the nest until it is gone. Perhaps an even less noticeable trap design would have greater success.

Site tenacity for Black Terns appears to be quite low. A study on site tenacity in Black Terns by Stern (1987) found only 15% of the 506 banded Black Terns returned in subsequent years. However, 71% of the recaptures nested in the same nesting area, even though only 38% nested in the same colony site. He estimated an annual survival rate of 0.70 to 0.75 is necessary to maintain a stable population, therefore, the low rate of return was due to weak site tenacity not low annual survival. If the assumption is made that 75% (16/21) of banded adult Black Terns survived to the next year, and only 2 were recaptured, then
site tenacity would be 12.5%.

Bailey (1977) observed seven of the 35 Black Terns which he had banded in the previous year and recaptured only four, for a return rate of 20%. The nest sites within the marsh of the four he recaptured moved 500 to 4000 metres away from where they had nested the previous year. The Black Terns returned to the same general area but selected nest sites based on the current conditions. In contrast, Dunn (1979) found that the five banded Black Terns she recaptured moved no more than 100 metres from the banding site. The two Black Terns I recaptured nested 213 and 255 metres from their nests the previous year, although the whole colony also moved the same distance (see Figure 2.12).

Therefore, the theory that birds nesting in unstable habitats will have low site tenacity is supported (McNicholl 1975). Black Terns may return to the same geographic area but appear to choose the nest site based on conditions present in the marsh, which vary from year to year. The two recaptured adults came back to the same impoundment in which they were banded. This may indicate that, if conditions remain the same, a Black Tern will return to the marsh in which it nested previously. It is generally accepted that individuals will return to a nesting area if they were successful in raising young the previous year (Switzer 1997). However, a recent study by Renkin and Smith (1995) on Least Terns found they were as likely to use another colony in a subsequent year even when they had nested successfully at the original colony. They also found that,
although the terns had fairly low colony tenacity, they did not move far from the banding site. They suggest that the Least Terns are loyal to a section of the river and use a number of colony sites among years. The same may apply to Black Terns.

2.5 SUMMARY

There are several important features at the impoundment level that Black Terns are selecting in New Brunswick. Impoundments have to be at least 20 ha in size. They may require a combination of moderately dense vegetation and a shallow impoundment or dense vegetation and a deeper impoundment, with water depth ranging from 50 to 90 cm. There is a positive relationship between number of Black Terns nesting in an impoundment and number of odonates emerging during the chick-rearing period. Having open water in which to fish nearby may also be an important impoundment selection factor. Features selected at the nest level include moderate density of vegetation, moderate amounts of cover, and 25 - 50% water. A floating mat of vegetation that is not surrounded by vegetation on all sides is essential. Black Terns may have only a weak social attraction, at least to decoys, and have a low site tenacity.
Table 2.1 Locations and descriptions of where Black Tern adults and juveniles were seen feeding in 1997 and 1998.

<table>
<thead>
<tr>
<th>Feeding area</th>
<th>No. of tems seen in 1997 (date seen)</th>
<th>No. of tems seen in 1998 (date seen)</th>
<th>Description of Feeding area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Timber Lake</td>
<td>7 ad., 6 juv. (Aug. 2)</td>
<td>11 ad., 5 juv. (July 30)</td>
<td>Next to Grand Lake Meadows, 53 ha, &lt;25% vegetation (rushes, pickeralweed, and watershield), &gt;1m deep, poles to perch on.</td>
</tr>
<tr>
<td>Coys Lake/ Harts Lake</td>
<td></td>
<td>11 ad./juv. (Aug. 2)</td>
<td>&gt;70 ha, grasses at edges and open water in middle.</td>
</tr>
<tr>
<td>Coys Gut (GLM)</td>
<td></td>
<td>4 ad., 6 juv. (July 30)</td>
<td>Opening in the vegetation (buckbean and willow) at the edge of Grand Lake, lots of perches provided by weirs.</td>
</tr>
<tr>
<td>Foshay (Lake, Imp 1, Imp 2)</td>
<td>6 ad., 9 juv., 7 ad./juv. (Aug. 9)</td>
<td>6 ad., 5 juv. (July 23)</td>
<td>Foshay Lake - large and deep with marshy edges, buoys and weirs to perch on. Foshay 1 - 61 ha, &lt;50% vegetation (water shield and sedges). Foshay 2 - 36 ha, 25% vegetation (buckbean and cordgrass), mats to land on.</td>
</tr>
</tbody>
</table>
Table 2.2 Results of univariate tests on habitat variables in one metre radius plot, comparing Black Tern nests and random plots, in 1997.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1997 nest plots</th>
<th>1997 random plots</th>
<th>Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean/SE (median)</td>
<td>n</td>
<td>mean/SE (median)</td>
</tr>
<tr>
<td>Water</td>
<td>41</td>
<td>20.0/3.1</td>
<td>60</td>
<td>19.1/3.5</td>
</tr>
<tr>
<td>NLemerge</td>
<td>41</td>
<td>14.8/3.7</td>
<td>60</td>
<td>36.0/3.7</td>
</tr>
<tr>
<td>BLemerge</td>
<td>41</td>
<td>12.4/4.3</td>
<td>60</td>
<td>18.4/3.6</td>
</tr>
<tr>
<td>Robust</td>
<td>41</td>
<td>28.6/5.9</td>
<td>60</td>
<td>17.1/4.2</td>
</tr>
<tr>
<td>Shrub</td>
<td>41</td>
<td>13.8/3.8</td>
<td>60</td>
<td>8.6/2.0</td>
</tr>
<tr>
<td>Deadshrub</td>
<td>41</td>
<td>(0.0)</td>
<td>60</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Openmat</td>
<td>41</td>
<td>(22.3)</td>
<td>60</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Dirveg</td>
<td>41</td>
<td>-</td>
<td>56</td>
<td>-</td>
</tr>
</tbody>
</table>

* Values given in parentheses are medians

b Mann-Whitney non-parametric two sample test

Table 2.3 Results of univariate tests on habitat variables in one metre radius plot, comparing Black Tern nests and random plots, in 1998.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1998 nest plots</th>
<th>1998 random plots</th>
<th>Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean/SE</td>
<td>n</td>
<td>mean/SE</td>
</tr>
<tr>
<td>Water</td>
<td>56</td>
<td>33.2/3.3</td>
<td>57</td>
<td>24.0/3.3</td>
</tr>
<tr>
<td>NLemerge</td>
<td>56</td>
<td>27.9/2.7</td>
<td>57</td>
<td>33.2/3.6</td>
</tr>
<tr>
<td>BLemerge</td>
<td>56</td>
<td>17.0/3.0</td>
<td>57</td>
<td>24.0/4.2</td>
</tr>
<tr>
<td>Robust</td>
<td>56</td>
<td>3.7/1.7</td>
<td>57</td>
<td>11.6/3.8</td>
</tr>
<tr>
<td>Shrub</td>
<td>56</td>
<td>2.2/0.8</td>
<td>57</td>
<td>5.7/1.6</td>
</tr>
<tr>
<td>Deadshrub</td>
<td>56</td>
<td>1.6/0.6</td>
<td>57</td>
<td>0.1/0.1</td>
</tr>
<tr>
<td>Openmat</td>
<td>56</td>
<td>11.7/2.8</td>
<td>57</td>
<td>1.2/0.9</td>
</tr>
<tr>
<td>Dirveg</td>
<td>56</td>
<td>-</td>
<td>57</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2.4 Results of logistic regression on habitat variables from one metre radius plot in 1997 and 1998.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1997 Coefficient</th>
<th>P-value</th>
<th>Odds ratio</th>
<th>95% C.I.</th>
<th>1998 Coefficient</th>
<th>P-value</th>
<th>Odds ratio</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-25.01</td>
<td>0.999</td>
<td>-</td>
<td>-</td>
<td>0.391</td>
<td>0.547</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Openmat</td>
<td>64.36</td>
<td>0.999</td>
<td>8.9x10^27</td>
<td>( . , 0)</td>
<td>0.208</td>
<td>0.001</td>
<td>1.231</td>
<td>(1.087, 1.395)</td>
</tr>
<tr>
<td>Dirveg</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-1.97</td>
<td>0.035</td>
<td>0.821</td>
<td>(0.684, 0.986)</td>
</tr>
</tbody>
</table>
Table 2.5 Results of univariate test on habitat variables in five metre radius plot, comparing Black Tern nest to random plots, in 1997.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1997 nest plots</th>
<th>1997 random plots</th>
<th>Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean</td>
<td>SE</td>
<td>n</td>
</tr>
<tr>
<td>Water (%)</td>
<td>41</td>
<td>32.0</td>
<td>3.0</td>
<td>60</td>
</tr>
<tr>
<td>Water (cat.)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>41</td>
<td>-</td>
<td>-</td>
<td>60</td>
</tr>
<tr>
<td>NLemerge</td>
<td>41</td>
<td>16.3</td>
<td>2.9</td>
<td>60</td>
</tr>
<tr>
<td>Blemerge</td>
<td>41</td>
<td>11.4</td>
<td>2.9</td>
<td>60</td>
</tr>
<tr>
<td>Robust</td>
<td>41</td>
<td>31.5</td>
<td>4.9</td>
<td>60</td>
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<tr>
<td>Shrub</td>
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<td>19.4</td>
<td>3.0</td>
<td>60</td>
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<td>Deadwood</td>
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<td>0.3</td>
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<td>Snag</td>
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<td>2.7</td>
<td>0.7</td>
<td>60</td>
</tr>
<tr>
<td>Snagdist</td>
<td>15</td>
<td>1.8</td>
<td>0.4</td>
<td>14</td>
</tr>
<tr>
<td>Distwaters</td>
<td>29</td>
<td>3.6</td>
<td>0.9</td>
<td>33</td>
</tr>
<tr>
<td>Distwaterl</td>
<td>41</td>
<td>42.9</td>
<td>6.8</td>
<td>60</td>
</tr>
<tr>
<td>Distedge</td>
<td>41</td>
<td>78.3</td>
<td>7.4</td>
<td>60</td>
</tr>
<tr>
<td>Distchange</td>
<td>17</td>
<td>32.1</td>
<td>6.5</td>
<td>8</td>
</tr>
<tr>
<td>Matdepth</td>
<td>39</td>
<td>19.6</td>
<td>1.8</td>
<td>58</td>
</tr>
<tr>
<td>Bottomdepth</td>
<td>24</td>
<td>62.2</td>
<td>2.2</td>
<td>36</td>
</tr>
<tr>
<td>Cover</td>
<td>41</td>
<td>3.2</td>
<td>0.1</td>
<td>60</td>
</tr>
<tr>
<td>Heightclass</td>
<td>41</td>
<td>-</td>
<td>-</td>
<td>58</td>
</tr>
<tr>
<td>Cover25</td>
<td>41</td>
<td>-</td>
<td>-</td>
<td>60</td>
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<td>Cover50</td>
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<td>-</td>
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<tr>
<td>Cover100</td>
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<td>60</td>
</tr>
<tr>
<td>Density</td>
<td>41</td>
<td>-</td>
<td>-</td>
<td>60</td>
</tr>
</tbody>
</table>

<sup>c</sup> Percent water divided into categories (<25%, 25-50%, and >50%)

Table 2.6 Results of stepwise logistic regression on Black Tern nest and random plot habitat variables from five metre plot in 1997.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>SE</th>
<th>P-value</th>
<th>Odds ratio</th>
<th>95% C.I.</th>
</tr>
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<td>Constant</td>
<td>1.417</td>
<td>0.597</td>
<td>0.018</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NLemerge</td>
<td>-0.043</td>
<td>0.013</td>
<td>0.001</td>
<td>0.958</td>
<td>(0.934,0.981)</td>
</tr>
<tr>
<td>Distedge</td>
<td>-0.015</td>
<td>0.006</td>
<td>0.008</td>
<td>0.985</td>
<td>(0.974,0.996)</td>
</tr>
<tr>
<td>Distwaterl</td>
<td>0.015</td>
<td>0.006</td>
<td>0.020</td>
<td>1.015</td>
<td>(1.002,1.027)</td>
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</tbody>
</table>
Table 2.7 Results of univariate test on habitat variables in five metre radius plot, comparing Black Tern nests to random plots, in 1998.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1998 nest plots</th>
<th>1998 random plots</th>
<th>Test</th>
<th>P-value</th>
</tr>
</thead>
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<tr>
<td></td>
<td>n</td>
<td>mean/ (median)</td>
<td>SE</td>
<td>n</td>
</tr>
<tr>
<td>Water (%)</td>
<td>56</td>
<td>32.6</td>
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<td>57</td>
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<tr>
<td>Water (cat.)</td>
<td>56</td>
<td>-</td>
<td>-</td>
<td>57</td>
</tr>
<tr>
<td>Submergent</td>
<td>53</td>
<td>27.5</td>
<td>4.6</td>
<td>50</td>
</tr>
<tr>
<td>NLemerge</td>
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<td>33.3</td>
<td>2.1</td>
<td>57</td>
</tr>
<tr>
<td>BLemerge</td>
<td>56</td>
<td>22.2</td>
<td>3.3</td>
<td>57</td>
</tr>
<tr>
<td>Robust</td>
<td>56</td>
<td>3.9</td>
<td>1.4</td>
<td>57</td>
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<td>Shrub</td>
<td>56</td>
<td>4.0</td>
<td>1.2</td>
<td>57</td>
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<td>Deadwood</td>
<td>56</td>
<td>(0.0)</td>
<td>-</td>
<td>57</td>
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<td>Snag</td>
<td>56</td>
<td>5.2</td>
<td>1.3</td>
<td>57</td>
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<td>Snagdist</td>
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<td>Distwaters</td>
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<td>0.6</td>
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<td>47</td>
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<td>Matdepth</td>
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<td>1.3</td>
<td>53</td>
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<td>57</td>
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<td>-</td>
<td>57</td>
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<td>-</td>
<td>57</td>
</tr>
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<td>57</td>
</tr>
<tr>
<td>Density</td>
<td>56</td>
<td>-</td>
<td>-</td>
<td>57</td>
</tr>
</tbody>
</table>

Table 2.8 Results of stepwise logistic regression on Black Tern nest and random plot habitat variables in five metre plots in 1998.

<table>
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<tr>
<th>Coefficient</th>
<th>SE</th>
<th>P-value</th>
<th>Odds ratio</th>
<th>95% C.I.</th>
</tr>
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<td>1.409</td>
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</tr>
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<td>Cover</td>
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<td>0.500</td>
<td>0.008</td>
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<tr>
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<td>0.385</td>
<td>0.440</td>
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</tr>
<tr>
<td>Water_2</td>
<td>0.976</td>
<td>0.371</td>
<td>0.008</td>
<td>2.654</td>
</tr>
<tr>
<td>Matdepth</td>
<td>0.058</td>
<td>0.026</td>
<td>0.024</td>
<td>1.060</td>
</tr>
<tr>
<td>Snag</td>
<td>0.083</td>
<td>0.044</td>
<td>0.059</td>
<td>1.087</td>
</tr>
</tbody>
</table>
Figure 2.1 Nest trap used in 1997 (designed by Mazzocchi and Muller 1993)

Figure 2.2 Nest trap design used in 1998
Figure 2.3 Percent impoundments used in 1997 (n=6) and 1998 (n=8) vs. percent available (n=22) in each size class.

Figure 2.4 Regression of number of Black Tern pairs per impoundment vs. impoundment size in 1997 (P=0.662, \( r^2 = 0.053 \)).
Figure 2.5 Regression of number of Black Terns per impoundment vs. impoundment size in 1998 (P=0.808, r²=0.011).

Figure 2.6 Percent impoundments used in 1997 (n=6) and in 1998 (n=8) vs. percent available (n=16) by vegetation class.
Figure 2.7 Scatterplot showing discriminant analysis between used (n=6) and unused (n=6) impoundments, using density of vegetation and depth of impoundment in 1998. "1" represents sparse vegetation and "3" represents dense vegetation.

Figure 2.8 Scatterplot showing discriminant analysis between used (n=6) and unused (n=6) impoundments, using density of vegetation and depth of marsh in 1997. "1" represents sparse vegetation and "3" represents dense vegetation.
Figure 2.9  Regression of number of Black Tern pairs per marsh vs. damselfly abundance.  (Linear regression, $P=0.020$, $r^2 = 0.138$).
Figure 2.10 Map of Round Pond impoundment showing the location of Black Tern nests in 1997 and 1998.
Figure 2.11 Map of Jemseg Flats impoundment showing the location of Black Tern nests in 1997 and 1998.
Figure 2.12 Map of McAllister Marsh impoundment showing the location of Black Tern nests in 1997 and 1998.
Figure 2.13 Dominant vegetation in Black Tern nest plots (n=97) and random plots (n=117), 1997/1998 combined.
Figure 2.14 Black Tern nest substrate use: A) 1997, B) 1998, C) 1997/1998 combined.
Figure 2.15 Directions containing vegetation within one metre of the plot centre at Black Tern nest plots (n=56) and random plots (n=56) in 1998. (Chi-square; $\chi^2=26.8$, d.f.=4, $P<0.001$)
Figure 2.16 Height of dominant vegetation at Black Tern plots and random plots: 
A) 1997 (Chi-square; $\chi^2=6.85$, d.f.=2, $P=0.033$), B) 1998 (Chi-square; $\chi^2=12.14$, d.f.=3, $P=0.007$).
Figure 2.17  Mean horizontal cover 50 cm above water in Black Tern nest plots (n=56) and random plots (n=57) in 1998. (Chi-square; $\chi^2=10.77$, d.f.=3, P=0.013)

Figure 2.18  Mean horizontal cover one metre above water in Black Tern nest plots (n=56) and random plots (n=57) in 1998. (Chi-square; $\chi^2=10.65$, d.f.=3, P=0.014)
Figure 2.19 Density of vegetation at Black Tern nest plots (n=56) and random plots (n=57) in 1998. (Chi-square; $\chi^2=6.35$, d.f.=2, $P=0.042$)

Figure 2.20 Percent water in 5 metre plot at Black Tern nest plots (n=56) and random plots (n=57) in 1998. (Chi-square; $\chi^2=8.92$, d.f.=2, $P=0.012$).
Chapter 3

Black Tern breeding success
3.1 INTRODUCTION

Survival and successful reproduction must be linked to habitat features in order to determine the ultimately important factors in a habitat. Density alone may not be a reliable indicator of habitat quality as a species may be present or abundant in unsuitable habitats. This situation could occur due to social interactions or recent declines in quality of habitat to which the population has not yet responded (Van Home 1983). I will be using Black Tern reproductive success to indicate which impoundments have high quality habitat and which features at the nest site are linked to reproductive success.

Three impounded marshes were used to study reproductive success in 1997 and an additional two impoundments were monitored in 1998. The impoundments ranged in size from 30 to 80 ha, and contained vegetation such as horsetail (*Equisetum fluviatile*), buckbean (*Menyanthes trifoliata*), cattails (*Typha latifolia*), sedge (*Carex sp.*) and willow shrubs (*Salix sp.*).

3.2 METHODS

Water levels were monitored in two of the impoundments in 1997 and 1998. The fluctuations in water levels were measured relative to the boards on the water control structures throughout the season and converted into impoundment water depths. Numbers of potential avian and mammalian
predators in the impoundment were recorded each time an impoundment was entered. These were converted into number of predators seen per observer-hour.

Blinds on top of five metre high towers were built on dykes or on islands within the impoundments. Progress of the Black Terns was monitored from these blinds to assess the general area of the nests and to conduct feeding studies (see Chapter 2). In 1998, a floating blind was used to move about Round Pond impoundment. This impoundment had many channels cut through it allowing me to get close to nests without disturbing the adults.

Nest searches by foot and canoe were begun once the colony was into its second and third week of incubation to avoid the risk of adults abandoning their eggs. Nests were located by observing the behaviour of the Black Terns. When I approached a nest, the terns would mob aggressively. Nest locations were marked with a wire flag placed 10 metres to the north of the nest. Eggs were floated in a container of marsh water to determine stage of incubation (Hays and LeCroy 1971). My own observations, among others (Jeanne Hickey, Cornell University, personal communication) aided in determining stage of incubation (see Table 3.1).

Before the eggs hatched, as many parents as possible in the three impoundments were trapped on nests using traps described in Chapter 2. They were banded with standard USFWS aluminum leg bands. In 1998, the parents were also colour marked with a two colour combination of oil paints on the
cheeks and white under-tail coverts. This identified parents to individual nests and was used to determine which parents were still present in the impoundment and feeding young.

Eggs were checked every four to eight days and around the hatch date (extrapolated from the stage of incubation assuming a 21 day incubation period) to determine the number of chicks that hatched. Chicks were monitored once a week where possible. Once chicks are a few days old they are able to swim away from the nest and hide in vegetation and can be almost impossible to find; therefore the behaviour of the parent was also noted to determine if the chicks were still alive. At least one chick was assumed to be alive if the parents mobbed near the nest site or were seen bringing food.

Nests that had eggs missing before the hatch date and where the parents were no longer mobbing were assumed to have been depredated or destroyed and considered unsuccessful. A nest was also considered unsuccessful if it was past the expected hatch date and the eggs failed to hatch.

The impoundments were observed from the dyke and canoe on the expected fledging dates of the chicks. The identity of the parents still present in the impoundment (as indicated by the colour marking) and the number of fledglings flying around the impoundment with the parents was noted.

Nest success in this study is defined as the number of nests that hatched at least one egg divided by the number of nests found with eggs (Mazzocchi and Muller 1993, Hickey 1997). Hatching success is the number of eggs hatched.
divided by the total number of eggs laid (Mazzocchi and Muller 1993). Fledging success is the number of terms fledged (were seen flying) divided by the number of chicks hatched (Chapman Mosher 1986, Hickey 1997). Overall success is the number of fledglings divided by the number of eggs laid. Fledglings per pair is the number of fledglings divided by the number of nests in which an egg was laid.

As the chicks were difficult to locate after they had hatched, the midpoint between the ranges of values for hatching, fledging and overall success was used for comparison between years and impoundments. The minimum values represent the number of young actually observed, which is undoubtably lower than the number of chicks that actually hatched. The maximum value represents the largest number that could have hatched/fledged given the number of eggs/chicks found at last check. The maximum value for the number of chicks fledged is probably closer to reality as most chick mortality occurs in the first four to eight days after hatching (Einsweiler 1988), and most nests could be monitored until this point.

The Mayfield method (Mayfield 1975, Johnson and Shaffer 1990) was used to estimate nest success in order to account for the nests that were initiated and failed before I found them. It compensates for the fact that the shorter the time span of observation for each nest, the less the observed losses. Linear regression was used to relate breeding success to habitat variables among impoundments. Nest features were compared to nest fates using a Chi-
square test (if categorical data), or a Student’s t-test (if continuous data). The habitat variables used to relate to breeding success were the same ones measured in Chapter 2. See Chapter 2 for a description of the methods of habitat assessment.

3.3 RESULTS

3.3.1 Nest initiation

Thirty-seven nests were monitored for breeding success in three impoundments in 1997 and 38 were monitored in 1998. Sixteen nests in two additional impoundments were monitored in 1998. In 1997, Jemseg Flats average nest initiation date was a week later than the other two impoundments (ANOVA, P=0.001, Bonferonni post hoc test, P=0.002). The nests in 1998 were initiated significantly earlier than in 1997 (t-test, P<0.001), with an average date of 10 June (range of 3 June - 3 July) in 1997, and 3 June (range of 24 May - 18 June) in 1998. The later initiation in 1997 could be due to the wetter spring and delayed ice melt that caused the Saint John River water levels to remain high until June. Water levels in the impoundments remained correspondingly high (see Figure 3.1). The spring of 1998 was warm and dry, with an average temperature in May of 14.0°C, compared to the 30-year average of 10.8°C, while the average temperature in May of 1997 was close to the 30-year average (see
Figure 3.2). There was also less rainfall in May of 1998 than in 1997, although June was wetter (see Figure 3.3).

There appears to be an inverse relationship between number of Black Terns in an impoundment and nest initiation dates (see Figure 3.4); terns in larger colonies tended to nest earlier.

Average clutch size was smaller in 1997 than 1998 (t-test, P<0.001), with an average of 2.4 eggs per nest in 1997 and 2.9 eggs per nest in 1998 (see Tables 3.2 and 3.3). Nests were located, on average, around the tenth day of incubation in both years so the larger clutch size in 1998 cannot be a result of finding the nests earlier in the incubation stage (i.e., before an egg was lost). There was one four-egg clutch found in 1998, but it was suspected to have been laid by two female Black Terns because there were three adults flying around the nest and one egg was laid later than the other three. Two of the eggs hatched chicks, of which one disappeared and the other was found drowned near the nest. The other two eggs were found cracked open with half formed chicks inside.

Density of nests was 0.27/ha in McAllister Marsh, 0.42/ha in Jemseg Flats, and 0.67/ha in Round Pond, for an average density of 0.41/ha. The nearest neighbour distances, however, were considerably closer than indicated by these densities, with a median of 26 metres.
3.3.2 Breeding success

Table 3.2 and 3.3 presents the breeding success data for 1997 and 1998 respectively, for the impoundments monitored.

The Mayfield estimates of nest success were fairly close to the actual nest success observed, except in the case of Round Pond in 1997, and in Jemseg Flats in 1998, where the Mayfield estimate was considerably lower. There was no significant difference in nest success between years (Chi-square, d.f.=1, \( \chi^2 = 0.253, P=0.615 \)), and no significant difference in hatching success (Chi-square, d.f.=1, \( \chi^2 =0.398, P=0.528 \)). Although fledging and overall success seemed higher in 1998, the difference was not significant (Chi-square, d.f.=1, \( \chi^2 =2.541, P=0.111; \chi^2 =2.048, P=0.152 \) for fledging and overall success, respectively).

The use of colour marking on adults worked well in identifying individuals. The oil paint lasted well into the breeding season, until the young fledged. Paint placed on the cheeks was not visible except at close range, while the paint on the white under-tail coverts showed up well, especially when terns was hovering. Green and blue were the most visible colours, yellow, orange and pink less so.

Nest success for the impoundments observed over the two years combined was 76%, hatching success was 57%, fledging success was 53% and overall success was 30%. There was approximately 0.7 fledglings produced per
pair in the three impoundments in 1997 and approximately 1.0 fledgling per pair in 1998, for an average of 0.8 fledglings per pair per year.

3.3.3 Predation index and causes of nest failure

Number of predators seen per observer hour was fairly consistent between years for the three impoundments (see Table 3.4). Jemseg appears to have consistently more predators present, probably due to the presence of fishing weirs in the adjacent marsh which attracts a large number of gulls. Over 40 gulls were observed in the adjacent marsh at one time in 1998.

Gulls and Northern Harriers were mobbed by Black Terns if they flew over the impoundment, but Black Terns also mobbed Great Blue Herons, ducks, frogs, and neighbouring Black Tern fledglings if they got too near the nests. Black Terns and Red-winged Blackbirds (*Agelaius phoeniceus*) were observed chasing each other. There was a pair of Short-eared Owls (*Asio flammeus*) nesting at the edge of Round Pond both years, but the adults were never observed in the impoundment while an observer was present. Only when a fledgling owl sat in the impoundment was it mobbed by Black Terns.

Predation did not appear to be a large source of nest failure, although there were some failures that were unaccounted for (see Table 3.5). Destruction of nests by ducks or muskrats that climbed onto nest platforms was a major cause of nest failure in 1997, as assumed by the presence of feathers and
faeces on the platform. One nest platform was found with the nest and eggs gone, and the platform of vegetation with small 1.5 cm diameter holes drilled into it, as though something had been probing it. The platform had orange faeces containing buckbean seeds on it.

In 1998, two dead adult terns were found on their nest platforms in two different impoundments. There was no sign of predation, however, the bodies were fairly decomposed. Both nests with dead adults were abandoned by the other parent and thus failed to hatch. There were also three nests abandoned by both parents in 1998. Abandonment was the cause of the highest proportion of failed nests in 1998. Inviable eggs also composed a portion of failed nests in 1997 and 1998. Only two chicks were found dead over the two years of my study, one of which apparently drowned when its head got stuck under a buckbean stem. Most chicks simply disappeared without leaving an indication as to the cause.

3.3.4 Impoundment breeding success

The overall success of McAllisters Marsh was twice that of either Jemseg Flats or Round Pond in 1997 (Chi-square, d.f.=2, \( \chi^2=6.546, P=0.038 \)). While there was no significant difference in overall success between impoundments in 1998 (Chi-square, d.f.=2, \( \chi^2=2.074, P=0.355 \)), the same trend was observed as in 1997. When the data from the two years were pooled, McAllister was found to
have a much higher overall success and Jemseg a lower success rate (Chi-square, d.f.=2, $\chi^2=7.786$, $P=0.021$) than Round Pond.

The only habitat variable that was significantly related to nest success in the five impoundments examined was amount of cover 25 cm above water level (Linear regression, $r^2 = 0.826$, $P=0.033$); however, amount of cover was very similar between those impoundments with low nest success and those with high nest success (see Figure 3.5).

There was also a strong positive relationship between number of pairs of Black Terns nesting in an impoundment and hatching success of the impoundment (Linear regression, $r^2=0.927$, $P=0.009$) (see Figure 3.6), as well as between number of pairs of Black Terns and the nest success (Linear regression, $r^2=0.862$, $P=0.023$). Average date nests were initiated in each impoundment was inversely related to hatching success (Linear regression, $r^2=0.855$, $P=0.025$) (see Figure 3.7) and nesting success (Linear regression, $r^2=0.772$, $P=0.050$) of each impoundment.

3.3.5 Nest level breeding success

The only variable consistently related to nest success both years was the date that the nest was initiated. Successful nests (that had hatched at least one egg) were initiated, on average, five days earlier than failed nests in both years (Student’s t-test, $P=0.006$ in 1997, $P=0.029$ in 1998).
The nest substrate may also play a role in nest success. Substrates used for nesting included unvegetated floating mats, consisting of a wet mixture of roots, rotting vegetation and mud, vegetated floating mats which included openings in cattail and buckbean mats, platforms formed from dead vegetation caught up on dead wood or on shrubs and usually quite high and dry, and dead vegetation such as grass or horsetails that had fallen over and formed a nesting substrate. The lowest nest success was found on nests built on fallen-over dead vegetation (see Table 3.6). Of the nests that successfully hatched a least one chick, 46% were on unvegetated mats, and only 9% were on dead vegetation. There was a significant difference between nest success based on substrate type (Chi-square, $\chi^2=8.941$, $P=0.030$).

Data from 1998 probably provided a better picture of what the impoundment was like when the nest was being used, as the data were collected earlier in the summer when chicks were still present in the impoundment. Data in 1997 were collected after the Black Terns had left the nesting impoundments, when the vegetation had grown in more. Thus I will concentrate mainly on the 1998 data.

In 1998, height of nest substrate was significantly higher at nests that were successful in hatching at least one egg (Student’s t-test, $P=0.011$). Average height at successful nests was 9.1 cm, and average height at unsuccessful nests was 5.7 cm. Amount of cover was also significantly different between successful and unsuccessful nests, with successful nests having more
horizontal cover between water level and one metre (Student's t-test, P=0.045). Also significantly different was amount of cover between 25 cm and 50 cm above water, with successful nests having greater than 79% horizontal cover (see Figure 3.8) (Fisher Exact test, $\chi^2=7.704, P=0.012$).

In 1998, nests with chicks that produced fledglings had a larger substrate area (0.409 m²) than nests with chicks that failed to produce fledglings (0.173 m²) (Student's t-test, P=0.033). Nests that fledged young also had significantly less narrow-leaved emergents in the one metre radius plot around the nest than the nests that failed to fledge young (Student's t-test, P=0.005). Successful nests probably had less narrow-leaved emergents in the one metre radius plots because more of the plot was covered by the nesting substrate and open water than in the plots with the failed nests.

3.4 DISCUSSION

3.4.1 Nest initiation

Average nest initiation dates in my study were 3 June in 1998 and 10 June in 1997. Other studies have found peak nest initiation to be within the first week of June in Iowa (Provost 1947, Bergman et al. 1970), Michigan (Cuthbert 1954), Oregon (Stern 1987), and British Columbia (Chapman Mosher 1986), while some have found initiation to be a week or two earlier in Wisconsin (Bailey 1977) and New York (Hickey 1997). Average clutch size over the two years
studied was 2.7 which is similar to the average of 2.6 Dunn and Agro (1995) found from many studies.

Black Terns could be selecting to nest in higher quality sites first, which is why the nest initiation dates were earlier in impoundments with a larger number of terns nesting. Orians and Wittenberger (1991) found that territories that attracted female Yellow-headed Blackbirds early, attracted the highest number of females, and Fretwell and Lucas (1970) theorize that there is a hierarchy of habitat preferences with the best habitat being used first.

3.4.2 Breeding success

There was an average nest success rate of 76% for this study. This is similar to the nest success rate found by Chapman Mosher (1986) in British Columbia, and Laurent (1993) in Wisconsin, but much higher than the approximately 30% nest success found in many other studies (Bergman et al. 1970, Bailey 1977, Dunn 1979, Mazzocchi and Muller 1993).

The average hatching success rate of 57% is in the middle of the range cited by other studies. Mazzocchi and Muller (1993) and Hickey (1997) found a hatch success rate of 23% and 39% in New York, while Chapman Mosher (1986) found a hatch success rate of 73% in British Columbia.

The average fledging success rate of 53% is similar to the 54% found in Hickey’s (1997) study, and the 61% found in Chapman Mosher’s (1986) study.
In areas with high predation pressure, the fledging success was much lower, as seen in Bailey's (1977) study where only 15% - 20% of chicks fledged.

The overall success rate (number of fledglings per eggs laid) of 30% for this study is reflected in other studies (Rabenold 1988, Novak 1990, Hickey 1997). The average number of fledglings per pair of Black Terns was 0.8 in this study. An average of 0.6 fledglings per pair was found in a New York study (Hickey 1997), and a summary of studies for a Northeast Black Tern Regional meeting (Anonymous 1994) concluded that rates vary among years, but 0.7 fledglings per pair is probably average. From this I can conclude that Black Terns nesting in my study area are reproducing as successfully or better than other populations in North America. This will be discussed further.

3.4.3 Nest and chick fates

The greatest cause of nest failure in 1997 was attributed to ducks and muskrats disturbing the Black Tern's nesting substrate, although ducks and muskrats could have started using the substrates after the terns had left for other reasons such as predation of eggs or abandonment. A proportion of failed nests were unsuccessful due to inviable eggs or eggs that had been cracked and gone bad. A large number of nest fates were unknown because eggs simply disappeared. In 1998, abandonment of nests was the cause of the highest proportion of failed nests. The death of one member of a pair of adults at two
nests also caused additional nest abandonment. There appeared to be less destruction by ducks and muskrats in 1998 than in 1997.

These results were somewhat different than those found by others studying Black Tern nesting success. Most losses in other studies were attributed to weather or predation. Heavy rain events caused significant nest losses when nests were swamped by water and waves (Bergman et al. 1970, Bailey 1977, Chapman Mosher 1986, Mazzocchi and Muller 1993, Hickey 1997). If water levels were controlled such as in a managed area, the number of nests washed out was much lower (Chapman Mosher 1986). I had no problem with washouts, since all of my nests were in impounded wetlands that had consistent water levels due to water control structures.

Predation was also mentioned as another source of nest loss in some studies, although in most cases it was merely assumed to be predation, since most eggs simply disappear (Faber 1992, Mazzocchi and Muller 1993). Hickey (1997) found predation accounted for the most nest loss in a relatively warm and dry year, whereas the weather was the more important factor in a cool, wet year. Chapman Mosher (1986) found loss of eggs due to predation was as high as 8.7% but that 22% of the predation loss was caused by muskrats climbing onto nesting platforms and knocking the eggs off platforms.

The number of potential predators seen in the impoundments was low in this study. The highest number seen was in the Jemseg Flats impoundment in 1998 and only 12 were seen in 42 hours of observing. Frogs were not
considered predators, however, Black Terns were observed to mob them on two separate occasions when they were near the nest. The species of the frog being mobbed could not be determined, but there were numerous Green Frogs (*Rana clamitans*), Northern Leopard Frogs (*Rana pipiens*) and Bullfrogs (*Rana catesbeiana*) in all the impoundments (personal observation). Bullfrogs are known to eat any animal they can swallow, including small birds, mammals, and other frogs (Gilhen 1984).

Chick fates were not determined in this study as chicks were very hard to find after they were a few days old. Bailey (1977) used pens around 26 chicks, of which 16 (62%) were depredated, however, he states that there were high predation levels in that marsh. Chapman Mosher (1986) found chick losses to predation varied between 1% and 6.5%. She attributed this low level of predation to either a low number of predators in the area, or the inconspicuous way she marked nests compared with other researchers.

Others have found starvation to account for 20% of chick deaths (Chapman Mosher 1986, Welham and Ydenberg 1993). Chapman Mosher (1986) found that Black Terns were less successful in raising young in cooler years due to lower availability of food. Fewer odonates emerge in cool weather (Orians 1980), and if it was cool for four days in a row, the smallest chick usually died.

Fledging success was lower in 1997 than in 1998, however, the average temperature and rainfall during the chick-rearing period was similar in both
years. May of 1998 was warmer than average, and in 1997 the water levels in the impoundments remained high into June. This may have lead to a decreased odonate emergence in 1997 and an increased one in 1998 leading to a difference in fledging success.

3.4.4 Impoundment breeding success

Overall breeding success (number of fledglings divided by number of eggs laid) was significantly higher at McAllister Marsh, and was somewhat lower at Jemseg Flats, than at Round Pond. This indicates there was a difference in habitat quality between the impoundments in this study.

Hatching and nesting success were found to be positively related to the number of pairs of Black Terns nesting in the impoundment in 1998, and inversely related to the average nest initiation date. It could be that having more Black Terns in an impoundment provided better protection against intruders by having more individuals to help mob, and by increasing vigilance (Wittenberger and Hunt 1985). Or, having more Black Terns in a impoundment could simply indicate that the impoundment is of higher quality and, therefore, it is selected first and more terns choose to nest there (as discussed earlier). However, Rabenold (1988) found that although one marsh had 68% of nests laid in the area, it produced only 20% of the fledglings. This indicates that numbers of Black Terns using a marsh do not always indicate habitat quality.
While the only other statistically significant relationship with nest success was average amount of horizontal cover at 0 to 25 cm above the water level in each impoundment, I do not believe this to be a biologically significant relationship. The range of amount of cover over which nest success was affected is very narrow. If this relationship were true, then a impoundment with an average horizontal cover at 25 cm of 74% would have a 20% nest success rate while a impoundment with a value of 79% would have 100% nest success. This range of 5% cover is within the amount possible from sampling error, and is unlikely to account for differences in nest success.

The range of number of fledglings produced per pair was 0.4 to 1.5 depending on impoundment and year. On average, however, there was 0.8 fledgling produced per pair within the study. Hickey (1997) modeled Black Tern population dynamics and suggested that 1.24 fledglings per pair were required to achieve population growth, assuming an average annual adult survival rate of 0.7, and Stern (1987) estimated that one Black Tern fledgling per pair would maintain a stable population. Although no periodic censuses have been done on Black Terns in New Brunswick, their numbers have increased since 1971 (Hall 1971), probably as a result of the construction of impounded wetlands along the Saint John River floodplain, and the assumption is that the numbers have remained stable since then (Pat Kehoe, Biologist, formerly with wetlands division of Fish and Wildlife, NBDNRE, pers. comm.). Therefore, either the production of 0.8 fledgling per pair is adequate in New Brunswick for maintaining
a stable population of Black Terns, or there is immigration that offsets the inadequate breeding success. Two years of data may not be enough to accurately assess average breeding success for the area.

3.4.5 Nest level breeding success

Nests initiated earlier in both years were found to have higher nest success. This is found in other studies and could be due partly to the fact that older, more experienced terns nest earlier and generally have higher breeding success than younger terns (Massey and Atwood 1981, Nisbet et al. 1984, Fowler 1995, Burger et al. 1996). It is hypothesized that younger birds have lower reproductive success because they lack necessary skills to raise young, and are not physiologically mature (Fowler 1995).

The nesting substrate of nests that successfully hatched at least one egg in 1998 was higher above the water than the nesting substrate of unsuccessful nests. The higher nest substrate may have prevented eggs from being knocked off the substrate into the water. One egg is often lost during incubation, to weather or damage (Bailey 1977). There was no difference in nest substrate height between successful and unsuccessful nests in 1997, but the nesting substrate was significantly higher in 1997 than in 1998, so there was no low substrate to compare with. This could be due to the fact that nest site features
were not measured until later in the season in 1997, after the water levels had dropped somewhat.

Nest success was also positively influenced by having more horizontal cover, especially between 25 and 50 cm above water level. This could be important in providing protection from visually-oriented predators and from wind and wave action. Chapman Mosher (1986) found that hatching success was significantly influenced by wind and wave action. She attributed the high hatching success to the fact that most nests were surrounded by vegetation or at least protected from the prevailing wind, which protected eggs from being washed out of nests. Hickey (1997), however, found that there was no difference in the amount of horizontal cover between nests that were successful at hatching eggs and those that failed. She did find that successful nests were closer to a change in dominant cover and to the permanent marsh edge.

The type of nesting substrate could also have affected nest success. It appears that nests built on smaller, less stable, dead vegetation had a lower success rate than those built on floating mats of vegetation or on platforms of vegetation. Hickey (1997) found that nests built on artificial nesting platforms had the highest nesting success, while those on muskrat feeding platforms and houses had lower success even though they were the most used substrates. Dunn (1979) and Bergman et al. (1970) found no correlation between nest success and nest site characteristics.
Nests that fledged chicks had a larger substrate and more open water around the nest site than nests that failed to fledge chicks. Having open water nearby could be important to chick survival by providing an escape route through which chicks can swim. Chapman Mosher (1986) found fledging success to be significantly correlated with nesting in horsetail, which provided short, dense cover.

3.5 SUMMARY

The overall breeding success in this study was generally better than that seen in other studies. The New Brunswick Black Tern population appears to be stable with an average of 0.8 fledglings produced per pair per year. Nest failures in this study were attributed to nest disturbance by ducks and muskrats, inviable eggs, abandonment, and a number of failures with an unknown cause that could be attributed to predation.

The impoundments studied were found to have significant differences in overall breeding success which indicates there is a difference in habitat quality. It was found that hatching and nest success were positively related to number of pairs of Black Terns nesting in the impoundment. No other variables regressed significantly against impoundment level features.

Nests that successfully hatched at least one egg were initiated earlier than unsuccessful nests. Successful nests also had a higher nesting substrate,
and more horizontal cover, especially between 25 and 50 cm above water, which could protect against predators and wind and wave action. Those nests built on dead vegetation were less successful. Nests that successfully fledged at least one chick had a larger nesting substrate and more water near the nest than failed nests.
Table 3.1 Determining Black Tern incubation stage by floating eggs

<table>
<thead>
<tr>
<th>Description of egg(s)</th>
<th>No. of days after laying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg sinks to bottom of container and lays flat *</td>
<td>1 to 2 days</td>
</tr>
<tr>
<td>Egg at bottom of container sits at an angle *</td>
<td>3 to 5 days</td>
</tr>
<tr>
<td>All eggs sink, but stand vertically with large end up b</td>
<td>6 to 7 days</td>
</tr>
<tr>
<td>1 to 2 eggs begin to float while the third sinks vertically b</td>
<td>8 to 9 days</td>
</tr>
<tr>
<td>Individual egg barely floats or with only 0.5 cm diameter of shell above water if looking down on the egg c</td>
<td>8 to 9 days</td>
</tr>
<tr>
<td>All three eggs float b</td>
<td>10 to 11 days</td>
</tr>
<tr>
<td>Egg floats with 0.75 cm diameter of the shell above water c</td>
<td>10 to 12 days</td>
</tr>
<tr>
<td>Egg floats with 1.0 to 1.25 cm diameter of the shell above water c</td>
<td>13 to 15 days</td>
</tr>
<tr>
<td>Egg floats with 1.5 to 1.75 cm diameter of the shell above water c</td>
<td>16 to 18 days</td>
</tr>
<tr>
<td>Eggs pip d</td>
<td>19 to 20 days</td>
</tr>
<tr>
<td>Eggs hatch d</td>
<td>21 to 22 days</td>
</tr>
</tbody>
</table>

* Hays and LeCroy 1971
* Jeanne Hickey, personal communication
* This study
* Dunn 1979

Table 3.2 Black Tern breeding success statistics in 1997.

<table>
<thead>
<tr>
<th></th>
<th>McAllister Marsh</th>
<th>Jemseg Flats</th>
<th>Round Pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of nests (a)</td>
<td>9</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Ave. nest initiation date (SD)</td>
<td>June 7 (2 days)</td>
<td>June 13 (4 days)</td>
<td>June 8 (4 days)</td>
</tr>
<tr>
<td>No. eggs laid (b)</td>
<td>21</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>Average clutch size (SD)</td>
<td>2.33 (0.50)</td>
<td>2.69 (0.48)</td>
<td>2.40 (0.65)</td>
</tr>
<tr>
<td>Nest success</td>
<td>0.89</td>
<td>0.77</td>
<td>0.71</td>
</tr>
<tr>
<td>Mayfield nest success</td>
<td>0.81</td>
<td>0.73</td>
<td>0.35</td>
</tr>
<tr>
<td>No. eggs hatched (c)</td>
<td>15 - 16</td>
<td>17 - 19</td>
<td>16 - 22</td>
</tr>
<tr>
<td>Hatching success (c/b)</td>
<td>0.71 - 0.76</td>
<td>0.49 - 0.54</td>
<td>0.44 - 0.61</td>
</tr>
<tr>
<td>No. fledglings (d)</td>
<td>9 - 11</td>
<td>7</td>
<td>6 - 8</td>
</tr>
<tr>
<td>Fledging success (d/c)</td>
<td>0.60 - 0.69</td>
<td>0.37 - 0.41</td>
<td>0.37</td>
</tr>
<tr>
<td>Overall success (d/b)</td>
<td>0.43 - 0.52</td>
<td>0.20</td>
<td>0.17 - 0.22</td>
</tr>
<tr>
<td>No. fledglings / pair (d/a)</td>
<td>1.0 - 1.2</td>
<td>0.54</td>
<td>0.40 - 0.53</td>
</tr>
<tr>
<td>Median nearest neighbour distance (m)</td>
<td>22.0</td>
<td>26.0</td>
<td>31.5</td>
</tr>
</tbody>
</table>
### Table 3.3 Black Tern breeding success statistics in 1998.

<table>
<thead>
<tr>
<th></th>
<th>McAllister Marsh</th>
<th>Jemseg Flats</th>
<th>Round Pond</th>
<th>Duffies 2 Marsh</th>
<th>Boyds Marsh</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of nests (a)</strong></td>
<td>13</td>
<td>10</td>
<td>15</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td><strong>Ave. nest initiation date (SD)</strong></td>
<td>June 1 (5 days)</td>
<td>June 2 (5 days)</td>
<td>June 4 (6 days)</td>
<td>June 10 (6 days)</td>
<td>June 5 (6 days)</td>
</tr>
<tr>
<td><strong>No. eggs laid (b)</strong></td>
<td>39</td>
<td>29</td>
<td>43</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td><strong>Average clutch size (SD)</strong></td>
<td>3.00 (0.41)</td>
<td>2.90 (0.32)</td>
<td>2.87 (0.35)</td>
<td>2.75 (0.50)</td>
<td>2.67 (0.71)</td>
</tr>
<tr>
<td><strong>Nest success</strong></td>
<td>1.00</td>
<td>0.70</td>
<td>0.73</td>
<td>0.25</td>
<td>0.67</td>
</tr>
<tr>
<td><strong>Mayfield nest success</strong></td>
<td>1.00</td>
<td>0.52</td>
<td>0.77</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>No. eggs hatched (c)</strong></td>
<td>23 - 30</td>
<td>13 - 17</td>
<td>25 - 28</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Hatching success (c/b)</strong></td>
<td>0.59 - 0.77</td>
<td>0.45 - 0.59</td>
<td>0.58 - 0.65</td>
<td>0.18</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>No. fledglings (d)</strong></td>
<td>14 - 20</td>
<td>8</td>
<td>12 - 17</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td><strong>Fledging success (d/c)</strong></td>
<td>0.61 - 0.67</td>
<td>0.62</td>
<td>0.48 - 0.61</td>
<td>1.00</td>
<td>-</td>
</tr>
<tr>
<td><strong>Overall success (d/b)</strong></td>
<td>0.36 - 0.51</td>
<td>0.28</td>
<td>0.28 - 0.40</td>
<td>0.18</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>No. fledglings / pair (d/a)</strong></td>
<td>1.1 - 1.5</td>
<td>0.8</td>
<td>0.7 - 1.1</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Median nearest neighbour distance (m)</strong></td>
<td>37.0</td>
<td>15.0</td>
<td>24.0</td>
<td>33.5</td>
<td>66.5</td>
</tr>
</tbody>
</table>
Table 3.4 Predator index for three impoundments used by Black Terns 1997 and 1998

<table>
<thead>
<tr>
<th></th>
<th>1997</th>
<th>1998</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. predator</td>
<td>Observer hours</td>
</tr>
<tr>
<td>McAllister Marsh</td>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>Jemseg Flats</td>
<td>15</td>
<td>53.5</td>
</tr>
<tr>
<td>Round Pond</td>
<td>7</td>
<td>56</td>
</tr>
</tbody>
</table>

Table 3.5 Causes of Black Tern nest and egg loss in 1997 and 1998.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Duck / muskrat damage</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Inviable eggs</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Abandoned</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Dead adult</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
<td>-</td>
<td>11</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3.6 Black Tern nest success by substrate type in 1997 and 1998 combined.

<table>
<thead>
<tr>
<th>Substrate Type</th>
<th>Failed nests</th>
<th>Successful nests</th>
<th>Total</th>
<th>Nest success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead Vegetation</td>
<td>8 (33%)</td>
<td>6 (9%)</td>
<td>14 (15%)</td>
<td>0.43</td>
</tr>
<tr>
<td>Unvegetated floating mat</td>
<td>7 (29%)</td>
<td>32 (46%)</td>
<td>39 (42%)</td>
<td>0.82</td>
</tr>
<tr>
<td>Vegetated floating mat</td>
<td>5 (21%)</td>
<td>14 (20%)</td>
<td>19 (20%)</td>
<td>0.74</td>
</tr>
<tr>
<td>Platform</td>
<td>4 (17%)</td>
<td>17 (25%)</td>
<td>21 (23%)</td>
<td>0.81</td>
</tr>
</tbody>
</table>
Figure 3.1 Water depths at McAllister Marsh over the summer in 1997 and 1998.

Figure 3.2 Monthly mean temperature for the summer of 1997 and 1998, and the 30-year average measured at Gagetown, New Brunswick.
Figure 3.3 Cumulative weekly rainfall over the summer in 1997 and 1998 measured at Gagetown, New Brunswick.

Figure 3.4 Regression of individual Black Tern nest initiation dates vs. number of Black Tern pairs in the impoundment in 1998 (r²=0.297, P<0.001).
Figure 3.5 Regression of Black Tern nest success per impoundment vs. horizontal cover 0 to 25 cm above water level in 1998 ($r^2=0.826$, $P=0.033$).

Figure 3.6 Regression of hatching success per impoundment vs. the number of Black Terns per impoundment in 1998 ($r^2=0.927$, $P=0.009$).
Figure 3.7 Regression of Black Tern hatching success per impoundment vs. the average nest initiation date per impoundment in 1998 ($r^2=0.855$, $P=0.025$).

Figure 3.8 Mean horizontal cover 50 cm above water in successful Black Tern nest plots ($n=39$) and unsuccessful plots ($n=13$) in 1998.
Chapter 4

General discussion and conclusions
4.1 DISCUSSION

4.1.1 Impoundment and nest site selection

I found that Black Terns nested in impoundments larger than 20 ha out of proportion to their availability (Chapter 2), as I predicted. This supports my hypothesis that Black Terns are not settling randomly into impoundments but are selecting an impoundment to nest in. Larger impoundments may be used because they provide sufficiently large feeding areas for terns (Mossman 1989). The presence of open water areas near the nesting impoundment appear to be important as well, as fishing areas. As predicted, abundance of odonate prey may also be a selection factor, as it was higher in used impoundments and was related to the numbers of Black Terns present in the impoundments.

At the impoundment level, Black Terns appear to be selecting impoundments that either have moderately dense vegetation and relatively shallow water, or impoundments with dense vegetation and relatively deeper water. My prediction was that the type and distribution of vegetation would differ between used and unused impoundments. Although the physiognomic categories of type of vegetation did not differ consistently between used and unused impoundments, it appears that density of vegetation, when considered concurrently with depth of impoundment, does allow for discrimination between used and unused impoundments. Contrary to my prediction, impoundments between 30% and 70% open water were not used out of proportion to their
availability. However, it does appear that impoundments with a medium amount of open water were selected, as used impoundments had 25% to 55% open water, whereas the available impoundments ranged from 15% to 75% open water.

Black Terns nested on vegetation mats surrounded by moderately dense vegetation that was open on at least one side of the nest. Nests had 25% to 50% water around, and there were snags for the adults and juveniles to perch on.

There is a weak social attraction among Black Terns as seen with low numbers of pairs nesting in some of the impoundments, and the fact that no Black Terns nested in a previously unused impoundment that had decoys and sound recordings present, and only two pairs nested around decoys in a previously unused section of a used impoundment. However, the Black Tern colony within each impoundment did seem to stay together as it moved location between years. Therefore, my hypothesis that Black Terns select an impoundment based on the presence of conspecifics is supported, however weakly.

Black Terns have low site tenacity, as demonstrated by the fact that I recaptured only two Black Terns of the 21 I had banded the previous year. Other studies have concluded that although Black Terns may not come back to the same marsh each year to nest, that they probably come back to the same area (Stern 1987, Renkin and Smith 1995).
4.1.2 Breeding success

Breeding success of the Black Tern population in my study area appears to be similar to or higher than most other Black Tern studies (Bailey 1977, Chapman Mosher 1986, Rabenold 1988, Novak 1990, Mazzocchi and Muller 1993, Hickey 1997). Average nest success was 76%, hatching success was 57%, fledging success was 53%, and overall success was 30%, with an average of 0.8 fledgling per pair. In New Brunswick, Black Terns appear to have a stable nesting population of about 112 pairs.

There was a significant difference in overall success in the three impoundments where I monitored breeding success, as I had predicted. McAllister Marsh had an overall success rate of 45%, Round Pond Marsh 28% and Jemseg Flats 23%. This supports my hypothesis that habitat quality varies between impoundments, because breeding success is a measure of habitat quality. However, none of the variables measured could explain the difference in habitat quality.

There were very few predators sighted in the impoundments and this probably explains why predation was not a major cause of nest failure, although there was a large percentage of nest failures unaccounted for. The causes of nest failure included muskrats and ducks climbing on nesting platforms and damaging eggs, egg inviability, and nest abandonment.
Hatching and nesting success were found to be related to number of terns in the impoundment and inversely related to date initiated. Having more Black Terns in an impoundment may help in predator defense and vigilance, and an earlier nest initiation date usually indicates a more experienced and older bird which would be more likely to succeed in hatching young (Fowler 1995). It could also be that more Black Terns nest in higher quality habitat first.

I found nest success to be related also to height of nesting substrate, the type of nesting substrate, and amount of cover, especially at 25 to 50 cm above water level. Therefore, there was more cover at successful nests than at unsuccessful nests, as I had predicted. This supports my hypothesis that amount of cover at nest sites affects breeding success. Cover could be important to reduce damage by wind and waves and to hide from visually-oriented predators. Nests that fledged young were on a larger nesting substrate and had more open water than nests that did not fledge young.

4.2 RECOMMENDATIONS

There are several reports and theses on Black Tern conservation that give specific recommendations on management plans that should be implemented (Chapman Mosher 1986, Novak 1992, Hickey 1997, Shuford 1997). These recommend that marshes should be maintained in a “hemi-marsh” stage, where the water to vegetation ratio is 50:50. This can be achieved by
periodic drawdowns and flooding of the marshes, also by reducing vegetation by cutting or herbicides. Day use and roost sites containing open water and perches should be maintained within 2 km of the nesting marsh (Hickey 1997). In impoundments, water levels should be maintained around 40 - 100 cm deep and water levels should be kept constant.

The best way to reverse the trend in Black Tern population decline is to continue to preserve wetlands. In 1992 the Canadian government released the Federal Policy on Wetland Conservation under Canada's Green Plan, with the objective to promote conservation of wetlands. In addition there are numerous provincial initiatives and international agreements, such as the North American Waterfowl Plan, which were initiated in the late 1980's and 1990's to conserve and protect wetlands (Lynch-Stewart et al. 1993). The management practices of wetlands for waterfowl appear to be fully compatible with the needs of Black Terns by providing stable water levels throughout the breeding season and by providing open water areas for feeding, and vegetation mats for nest sites.

I would recommend, however, that further research by performed on the intra-community interactions, such as competition between Black Terns for nest sites and ducks and muskrats for roost sites. The role that frogs, turtles, ducks and muskrats play in nest failure and the extent of their effect should be investigated. There should be further investigations into the relationship between food availability (insect and fish abundance) and Black Tern numbers in
a nesting impoundment, as well factors that drive insect and fish abundance and distribution in impoundments.

4.3 CONCLUSION

My main question was why are only six of the 22 impoundments in my study area used consistently for nesting by the Black Terns? My study indicates that eight of the impoundments were less than 20 ha and therefore too small, and the remaining eight did not have the required mixture of vegetation density and water depth and/or did not produce enough odonate prey.

Another possibility is that the Black Tern population in New Brunswick, and specifically in my study area, is too small to fill all suitable habitats. Some impoundments may have been adequate as a Black Tern nesting marsh, as some of them seemed to be from visual inspection, however, the population is so small, the terns may not be numerous enough to occupy all the highest quality habitats.

It is important to continue Black Tern research and monitoring over their entire range in North America. Although the Breeding Bird Survey indicates that the decline in Black Tern populations has levelled off since 1980, there is some concern as to the precision of a method that monitors marsh birds from a roadside route, especially birds that are known to fluctuate in habitat use between years, such as Black Terns (Peterjohn and Sauer 1997, Shuford 1997). Regular
marsh monitoring is needed across the continent to get a true representation of the status of the Black Tern in North America, and further research is needed to prevent this decline from ever occurring again.
LITERATURE CITED


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