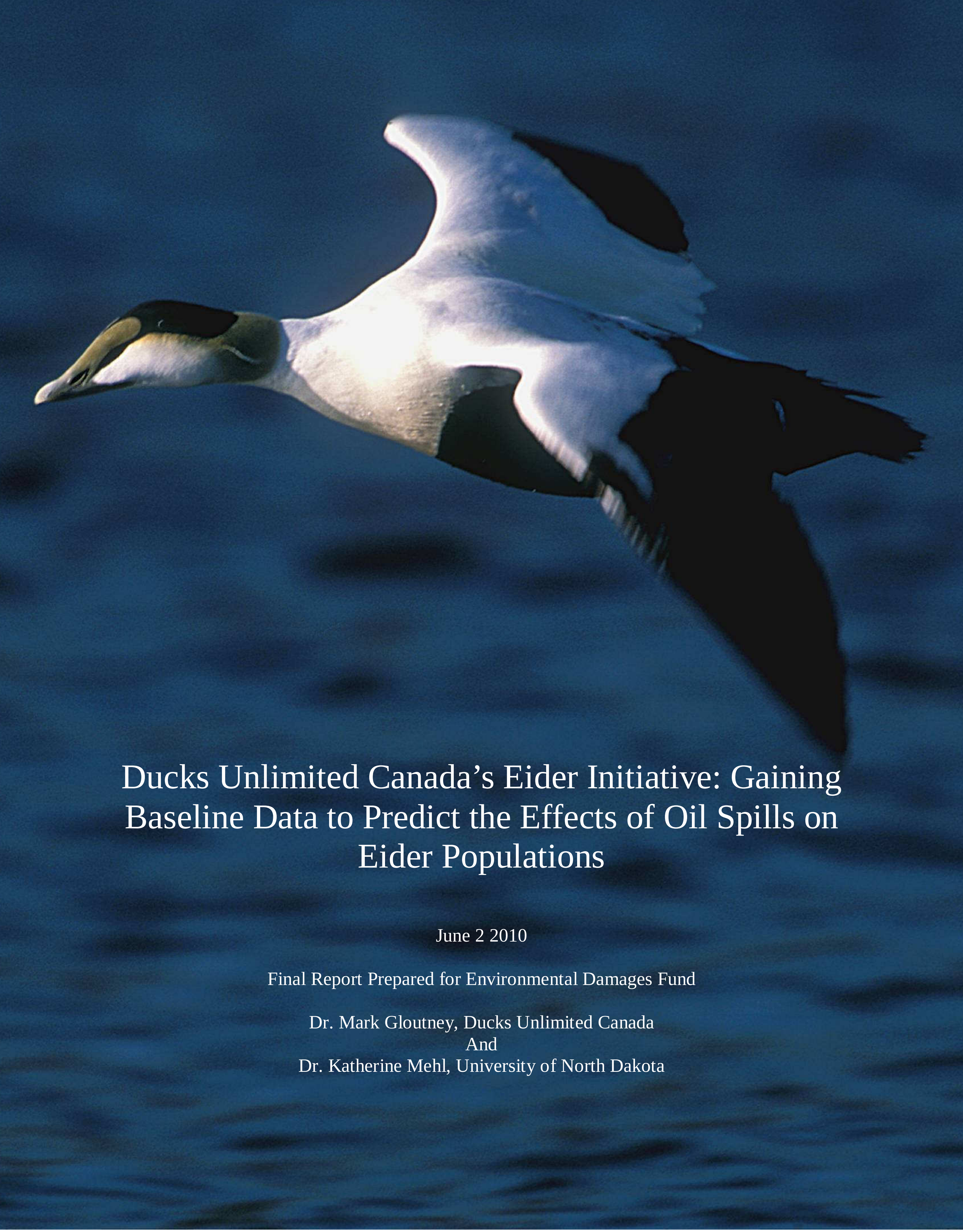

Ducks Unlimited Canada's Eider Initiative: Gaining Baseline Data to Predict the Effects of Oil Spills on Eider Populations

June 2 2010

Final Report Prepared for Environmental Damages Fund

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Executive Summary:

This project was implemented to gain baseline information on important vital rates for Newfoundland and Labradors breeding eiders. Vital rates assessed include: survival, breeding propensity, and age of first breeding. These data are essential to understand the dynamics of Common Eider *dresseri* populations. The ultimate goal of DUC's eider initiative was to collaborate with other research organizations to develop a population model that would allow researchers to accurately predict how eider populations would respond to effects of an oil spill. In addition, the model would strengthen the science foundation of habitat and harvest management strategies.

The project focused primarily on Table Bay on the Labrador coast and on the Grey Islands off the northern peninsula of the island of Newfoundland. The project spanned seven years (2003-2009) and used a capture-mark-recapture method to develop vital rates. During the study 2,250 individual nesting adult females and 9,716 day old ducklings were banded. In addition, submerged net captures in August and September resulted in capture of 1,225 eider ducklings > 30 days old, as well as 256 adult females. Over the course of the study recapture rates of breeding females at Table Bay and Grey Islands increased to 27 and 25%, respectively.

Models produced estimates of adult female survival of 0.78±0.04 and 0.76±0.10 for Table Bay and Grey Islands respectively. Annual rate of population growth at Grey Island and Table Bay was 1.29±0.18 SE and 1.08±0.06 SE, respectively. An ad hoc estimate of seniority suggests that the proportion of the population comprised of previous breeders and new recruits was 0.59 and 0.41, respectively at Grey Island, but 0.93 and 0.07 at Table Bay. Although local survival at both sites was similar, data indicate that new recruits to Grey Island were about 6 times higher than those of Table Bay, resulting in elevated growth rates seen at Grey Islands. A total of 35 known aged eiders were captured. The average number of years between marking as a duckling and first detection as a nesting female was 3.26 years. Results of these analyses enabled us to calculate that the Table Bay breeding population increased from 1459 to 2306 breeding females between 2003 and 2009. The breeding population at Grey Islands increased from 362 in 2003 to 772 in 2006.

One of the goals of this research was to develop a population model. We were limited in our ability to develop a population trajectory model by the lack of convergence of models for duckling and juvenile survival. However, the other vital rates established in this study will inform any future model development.

Results from this research provide essential baseline data for eiders nesting in Newfoundland and Labrador. Moreover, results from this research provide the first extensive estimates of eider vital rates (e.g., survival, population growth, recruitment) for this region. The duration of the research and the numbers of adults marked provides reasonable confidence in adult related vital rates. In the unlikely event of an oil spill, comparison of these data to those collected post spill will assist in assessing damage to eider populations.

A total of 471 bands were reported by hunters. The band recoveries were distributed between Newfoundland and Labrador (n = 259), Quebec (n = 48), Maritime Provinces (n = 88) and New

England (n = 34). Hatch year birds represented 78% of the reported bands. Direct harvest rates on this subset of ducklings was 2.58% (161/6247) compared to harvest rates for juveniles of 5.31% (92/1732; young marked at more than 30 days of age) and adults 1.23% (28/2279). Band returns also revealed that the Table Bay birds had a broader winter range then the Grey Island birds. Band returns also reveal hot spots around the Fogo Islands, Cape Bonavista and the Burin Peninsula suggesting that these areas support significant numbers of eiders during the fall and winter. The presence of oil spills at these sites would likely impact the eiders breeding at Table Bay and Grey Islands.

Since the inception of this study, significant research has also been conducted in more southerly parts of the breeding range of *S.m. dresseri*, therefore we believe that the timing is good for the development of a range wide population model.

INTRODUCTION

Problem Statement: Common Eider *Somateria mollisima dresseri* numbers in Newfoundland and Labrador remain below goal levels. Moreover, population dynamics of Common Eiders breeding in Newfoundland and Labrador appear to behave differently from that elsewhere. Specifically, eider abundance in Newfoundland and Labrador remain low and stable whereas eider populations south of Newfoundland and Labrador have recovered from lows in the 1900's and are at or near conservation target goals. Factors driving population dynamics are poorly understood for eider breeding along the coast of Newfoundland and Labrador. Importantly, the gregarious nature of eiders, combined with a life at sea leaves the species extremely susceptible to potential effects of oil spills. Marine traffic is expected to expand significantly in the near future. This, along with increases in off-shore oil activity along the coast of Newfoundland and Labrador, pose risks to the eider breeding populations of Newfoundland and Labrador.

Project Scope: Ducks Unlimited Canada used capture-mark-recapture methods to gain baseline information on important vital rates such as longevity, breeding propensity, and age of first breeding. These data are essential to understand the dynamics of Common Eider *dresseri* populations. Information gained from this research provides important baseline information. This information is especially important given anticipated increases in oil-based activity along the coasts of Newfoundland and Labrador. Because eider populations nesting in Newfoundland and Labrador behave differently from those outside of this range, population models produced from this study will be most helpful when applied to populations of Common Eiders nesting in Newfoundland and Labrador.

Goals and Objectives: The ultimate goal of DUC's eider initiative was to collaborate with other research organizations to develop a population model that would allow researchers to accurately predict how eider populations would be altered given the effects of an oil spill. However, population models require detailed information about the birds' lifecycle. The following objectives were met in support of this goal:

1. **Estimate adult survival for female eiders**. The purpose of this component was to investigate geographical variation in adult survival and its influence on overall population growth. Adult survival tends to have the greatest influence on overall population growth as higher adult survival allows for more breeding attempts (Rockwell et al. 1997, Crone 2001). Because the influence of

adult survival on population growth is most pronounced for long-lived species, such as Common Eiders, the loss of adults will undoubtedly have a ripple effect on future population size. Data gained from this study will help managers to quantify this ripple effect and thereby provide a quantifiable means of assessing damage to eider populations when an oil spill occurs. In addition, this study will provide important baseline data for future studies that address post oil spill impacts.

2. **Estimate seniority or the proportion of the population that is comprised of experienced breeders**. This objective is important, as birds do better at nesting and raising young if they nested in the years before. Therefore, experienced breeders have a significant impact on population growth, since their young will become the new breeders in the future. Results of this study provide a means of assessing the effects of age specific mortality (i.e., adult or juvenile).

3. **Estimate the proportion of first time breeders in the population (recruitment).** Understanding the percent of first time breeders is important for similar reasons as above because first time breeders generally do not raise as many young as their older, more experienced counter parts.

4**. Calculate the annual population growth**, so that we can begin to quantify population changes and understand population trends. Results of this study are of special importance following an oil spill as it will provide a means of quantifying the effects that an oil spill has had on eider breeding populations.

5. **Estimate juvenile survival and age at first breeding**. It is suspected that most eiders are about three years of age before they nest for their first time. However, the percent of females that nest for their first time at two, three, or even four years of age is unknown. In order to predict the rate of population change in the event of an oil spill, it is crucial that we first understand how many ducklings survive to breeding age and the age that they begin to breed.

6. **Identify links between breeding and wintering areas and migration pathways**. Understanding where these birds winter and the paths they take to get there will assist managers by linking areas used by eiders to those areas most susceptible to oil spills thus, enabling responders to set priorities in the event of an oil spill.

Environmental Benefits: This research addressed the following Environmental Damages Fund priorities:

1) *Enhance natural resources in the local area where oil incident occurred by improving eider management*. Results from this study provide valuable baseline data useful to assess eider management practices. Importantly, by comparing similar data collected under future studies this information can be used to validate population models and improve management techniques.

2) *Develop methods useful for assessing the impacts of oil spills*. This study provides important baseline data to compare with that data collected post oil spill. In addition, population models produced from this study will be useful to quantify effects on the population in the unlikely event of an oil spill.

3) *Develop methods that lead to improved eider management and thus, restoration of this natural resource*. Population growth of Common Eiders nesting in Newfoundland and Labrador is depressed relative to those nesting south of this range. Improving eider management practices (see no. 1 above) will help to restore this natural resource.

4) *Promote this natural resource through education and awareness*. Ducks Unlimited Canada strives to involve the local communities in which we work through hiring and training of local personnel, by involving the local development associations in the decisions that we make, and by generating local revenue from project expenditures. Local involvement raises project awareness and support among community members. Lastly, results from this work will be submitted for publication in international peer review journals.

Project Location

Newfoundland and Labrador is the focal point for this research because of intense heavy ship traffic in the area, posing potential threat of oil spills and bilge water release (Figure 1). Research sites were selected based on 1) high nesting density of *dresseri* Common Eiders, and 2) logistical considerations (i.e., ease of boat travel). North of Table Bay, a higher proportions of *S. m. dresseri* are hybridized with northern subspecies *S. m. borealis* and thus, we did not consider sites north of Table Bay (see Goudie et al. 2000).

The study area includes 1) islands near Grey Islands, located about 13 km SE of Conche, Newfoundland; and 2) coastal islands within Table Bay, located about 30 km SE of Cartwright, Labrador (Figure 2). In addition, complementary research conducted by Ducks Unlimited Canada, Canadian Wildlife Service and the Newfoundland and Labrador Wildlife Service occurred on islands within St. John Bay, near Barr'd Harbour, Newfoundland (Figure 2).

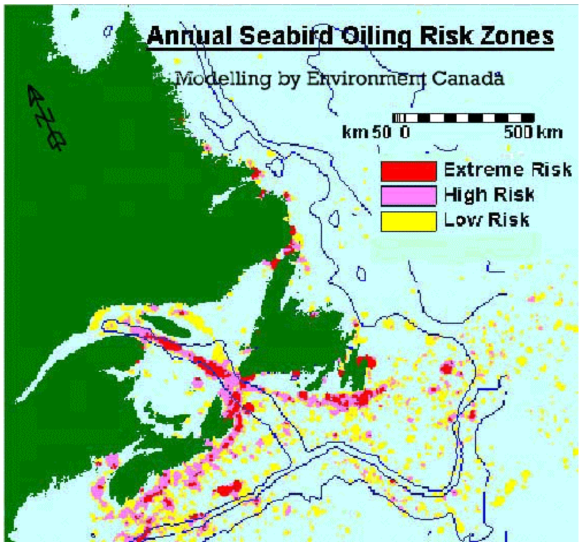

Figure 1. Zones of extreme risk to oiling coincide with Ducks Unlimited Canada's Eider Initiative study areas. Figure provided by Environment Canada.

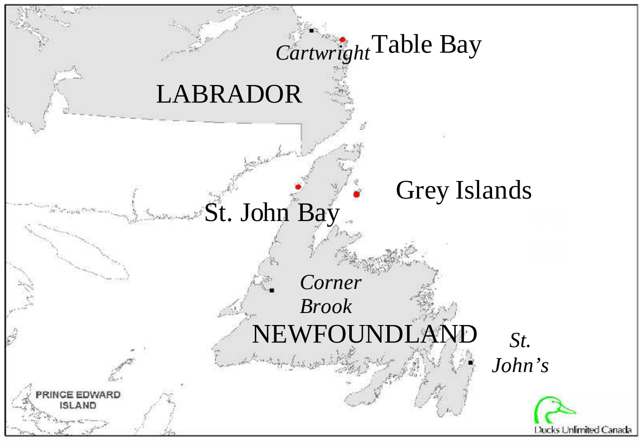

Figure 2. Study areas within Newfoundland and Labrador.

Table Bay is at the northern extreme of the breeding range for *S. m. dresseri*. Table Bay is a large bay with more then 25 islands (Figure 3 and 4). Eider nesting occurs primarily on 13 islands in Table Bay (Figure 3). The area has been a key area for DUC eider nest box program since 1990 (Figure 5). Since 1990, 1485 next boxes and shelters have been deployed on the islands in Table Bay. There are currently approximately 700 operational nest boxes on islands in Table Bay. The nest boxes often support multiple nesting eiders (Figure 6). Presence of nest boxes facilitated capture of nesting females.

Figure 3: Islands where nesting eiders were caught in Table Bay, NL

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Figure 4. Table Bay, NL

Figure 5. Nest boxes on Cape Greep Grassy Island, Table Bay, NL

Figure 6. Photo depicting multiple eiders nesting within a single nest shelter.

Grey Islands, comprised of Groais and Bell Islands collectively, differs from Table Bay in that there is a single large nesting eider colony on Green Island (Figure 7 and 8). DUC has deployed 880 nest boxes on the breeding colony since 1995.

Figure 7. Grey Islands, NL eider nest locations.

Figure 8.Bell Island south to Green Island, the primary nest colony at Grey Islands, NL

The third lower intensity site involved the islands in St John Bay (Figure 9). There are 14 islands within St. John bay of which 12 support nesting eiders (Figure 10). DUC has deployed 302 nest boxes on three islands in St. John Bay.

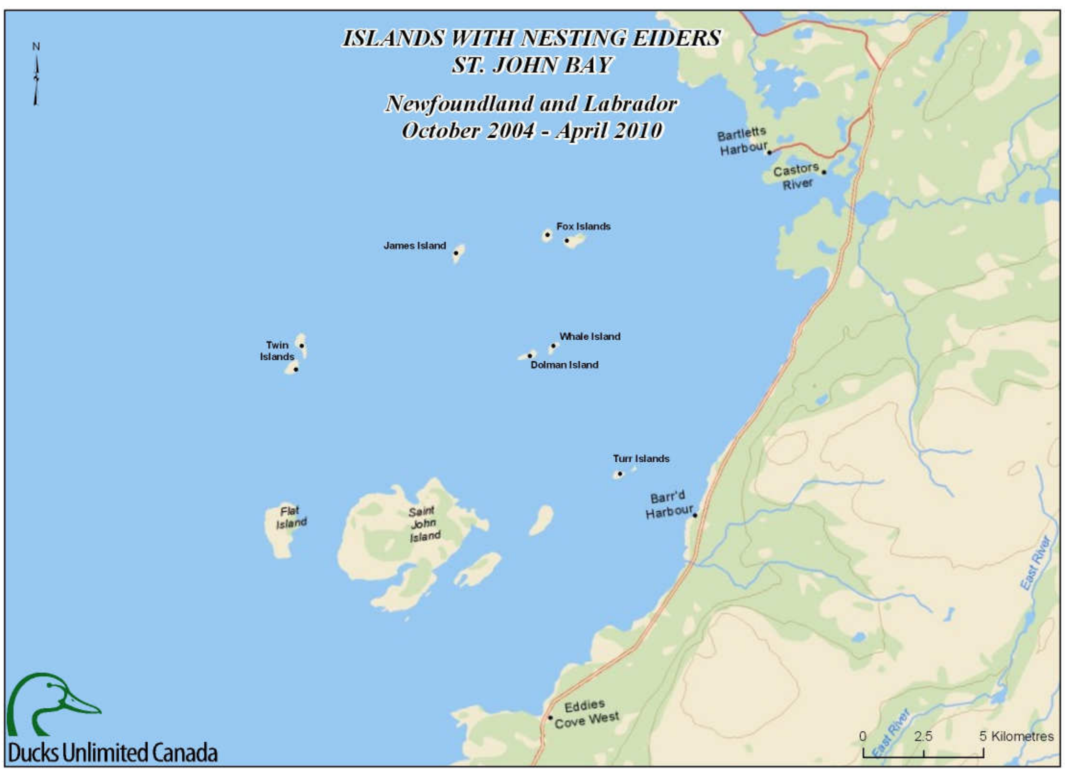


Figure 9. Islands within St John Bay, NL

Figure 10. Twin Island in St John Bay, NL.

Methods

Breeding Season Captures

Adults were captured during the breeding season using mist nets, dip nets, drive nets or by hand (Figures 11 and 12). Capture success was highest for eiders nesting in nest boxes. Captures typically occurred during the last two weeks of incubation in June and July. Captured eiders were marked with standard, uniquely numbered metal USFWS leg-bands (Figure 13).

At hatch ducklings were captured at the nest site and banded with uniquely numbered, plasticine-filled, oval metal bands specifically designed for marking ducklings (Figure 14). The plasticine filling enables ducklings to wear an adult-sized band at an early age (Blums et al 1994). To contain mobile ducklings and minimize gull predation, ducklings were returned to their original nest in a paper-towel envelope (Korschgen et al. 1996). Sex of most ducklings was undetermined and thus, recorded as unknown.

Figure 11. Trapping nesting eider females with dip nets in a nest box.

Figure 12. Drive nets used to trap eiders nesting in dense Tuckamore.

Figure 13. Standard USFWS leg band.

Figure 14. Plasticine-filled metal leg band on day old eider duckling

Submerged net captures

Pre-fledged juveniles (4-5 weeks of age) were captured on the water using floating gill-nets (Figures 15 - 16). This technique was employed solely at Table Bay. Groups of young flightless eiders and accompanying adults were initially located by boat and gill nets with light lead lines were stretched across the water nearby. Eiders were then herded by slow moving boats toward the nets. When eiders were within 25m of the nets, starting pistols and air horns were used to create loud noises that scared the eiders, making them dive away from the boats and into the nets. Once eiders were entangled in the net they floated to the surface. Eiders were quickly removed from the net following capture and placed into holding boxes (Figure 17). Captured eiders were banded with a standard metal leg-band. Molting adult male eiders and adult females were also captured using this method. Eiders were released as a group to create minimal disruption to crèche groups.

Figure 15. Submerged gill net with captured eider.

Figure 16. Submerged net with captured male eiders

Figure 17.Juvenile eiders in holding box prior to release.

Age Specific Recruitment
Recaptures of adults marked as juveniles and ducklings were used to estimate age of first breeding. Analyses based on recaptures of breeding adults were used to estimate adult survival.

Linking Breeding and Wintering Areas
We used hunter band recovery data for birds marked on the breeding sites to help link wintering and breeding areas. Connectivity between breeding and wintering areas is important to understanding potential impacts of oils spills throughout the eider's annual cycle as environmental and habitat conditions encountered during one season can have profound affects on survival and productivity during the next (Dierscheke 1998, Marra and Holmes 2001, Alisauskas 2002). Knowledge of these factors is imperative for making sound management decisions. Moreover, in the event of an oil or chemical spill, such information will enable responders to prioritize their response.

Analyses: Model Development
In addition to abundance, *N*, annual rate of population growth, λ is a useful metric to measure the health of populations (Nichols and Hines 2004). There are two approaches to inferences about the rate of population growth. One is the prospective use of matrix projection requiring information about different components of population growth (e.g. Caswell 2000). In brief, this approach allows researchers and managers to predict future changes in population size given known rates of longevity for juveniles and adults. The other approach is retrospective and is the direct estimation of population growth rate and associated components from capture-recapture of individually-marked animals (Nichols et al. 2000). Rather than predicting future population size, a retrospective approach provides insight into how a population has changed over a past period of time.

The life-cycle, composed of state and probabilities of transition between states, can be summarized by a life cycle graph. Most transition probabilities of free-ranging animals that are of interest to population biologists can be estimated using modern methods of Mark-recapture or mark recovery models for hunted populations. If estimates exist of all transition probabilities (Figure 18A), or products of subsets of transition probabilities (Figure 18B), then λ can be determined using a Leslie matrix (projection models). Often the parameter of interest is survival probability, S, the complement of which, mortality (1-S), represents removals from the adult population. Additions to the adult population, denoted as recruitment, R. Thus, in simple terms, the annual rate of population growth can be decomposed as

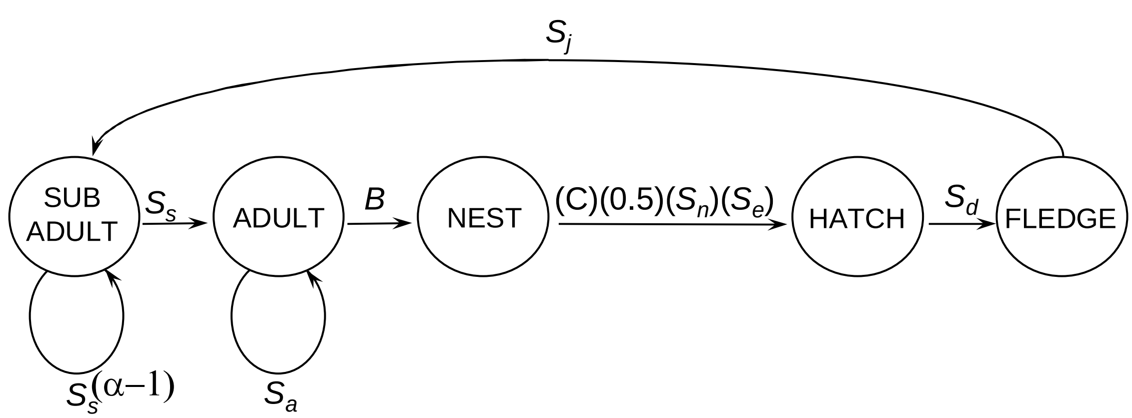
$$\lambda_i = \frac{N_{i+1}}{N_i} = S_i + R_i. \quad (1)$$

In open populations, such as those defined by each breeding aggregation that together compose a larger metapopulation, additions and removal include immigrants and emigrants.

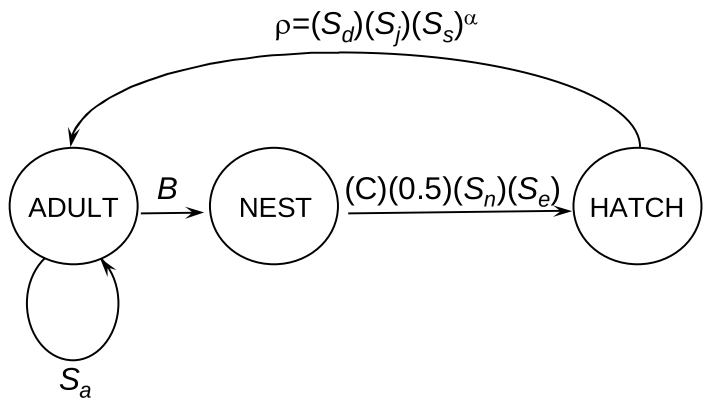
An alternative to projecting the population prospectively is to estimate λ and its components directly (retrospective analyses; Nichols et al. 2000). Use of reverse-time capture-recapture models (Pradel 1996) permit concurrent estimation of population parameters using marked free-ranging animals. This report provides estimates, where the data permit, according to objectives outlined above.

Figure 18. Life cycle graphs for Common Eiders showing (A) all major life stages and transition probabilities, and (B) composite transition from hatchlings to adulthood. Transition probabilities between stages shown are breeding propensity, B, clutch size, C, nest success, S_n, egg survival in successful nests (S_e), duckling survival, S_d, subadult survival (>1 year old, but prebreeding), S_s, and adult survival, S_a. Mean age of first breeding is denoted α.

A)



B)



Local population dynamics

Captures-recaptures of nesting females allows estimation of several population parameters using Pradel's (1996) models, including local (or apparent) survival, $\hat{\phi}$, seniority, $\hat{\gamma}$, entry, $(1-\hat{\gamma})$, and annual rate of population growth, $\hat{\lambda}_i$. Local survival, $\hat{\phi}_i$, is the probability that a member of a defined population in year *i* , i.e., nesting females in this case, survives one year and returns to the study area in year *i* +1. Seniority, $\hat{\gamma}_i$, is the probability that a member of the population in year *i* was also a member a year previously, year *i* -1, i.e., is a senior member. Entry, $(1-\hat{\gamma})$, is the probability that a member of the population is a new recruit in year *i,* and thus was not a member in the previous year . Seniority can also be thought of as the contribution of $\hat{\phi}_i$ to $\hat{\lambda}_i$ or

$$\gamma_i = \frac{\phi_i}{\lambda_i}. \qquad (2)$$

In other words, it is the proportion of annual population growth rate due to survival, and is analogous as survival elasticity (Nichols et al. 2000).

Several of Pradel's models, based on reverse time capture-recapture (Nichols et al. 2000) are implemented in Program MARK (White and Burnham 1999), used for all model construction and model selection in this report. Pradel's model was used for estimation of $\hat{\phi}_i$ and $\hat{\lambda}_i$ as well as capture or detection probability $\hat{p}_i$. Depending on assumptions, size of the local population, in this case of nesting female common eiders, $\hat{N}_i$, can be estimated from the number of captures in year *i* , n_i and detection probability in that year

$$\hat{N}_i = \frac{n_i}{\hat{p}_i}, \qquad (3)$$

as was applied in a study of a population of nesting White-winged scoters at Redberry Lake, SK (Alisauskas et al. 2004). Thus, this model can provide estimates of the major contributions to population growth, as well as population growth itself, for a local population. $\hat{\phi}_i$, $\hat{p}_i$, and $\hat{\lambda}_i$ were estimated for each study area, Grey Islands, St. John Bay and Table Bay separately. This was due to asynchrony of captures among study areas (Tables 1 and 2). For example, there were uninterrupted years of 512 captures of nesting females at Grey Islands that spanned 2003 to 2006. Captures of only 140 nesting females also began in 2003 at St. John Bay, but none were captured in 2004, and then marking ended in 2007. The best data set was acquired from 2241 nesting females at Table Bay, although only 9 nesting females were captured in the first year of 2003.

First, Cormack-Jolly-Seber models (Lebreton et al. 1992) were constructed from capture histories of nesting females, and median $\hat{c}$ tests (White and Burnham 1999) were conducted for goodness-of-fit testing of global models $\{\phi(t), p(t)\}$. The variance inflation factor, $\hat{c}$, was subsequently used to adjust AICc to QAICc in Pradel models.

Table 1. Summary of captures of Common Eider adults from nesting islands at Grey Islands, St. John Bay, and Table Bay in Newfoundland and Labrador during May, June or July, 2003-2009.

	Grey Islands		St. John Bay		Table Bay	
Year	Females	Males	Females	Males	Females	Males
2003	73	0	30	0	9	0
2004	75	0	0	0	123	0
2005	200	5	26	0	395	1
2006	164	4	51	1	578	10
2007	0	0	33	0	241	0
2008	0	0	0	0	319	0
2009	0	0	0	0	578	0
Total	**512**	**9**	**140**	**1**	**2,243**	**11**

Table 2. Summary of captures of Common Eider ducklings from nesting islands at Grey Islands, St. John Bay, and Table Bay in Newfoundland and Labrador during May, June or July, 2003-2009. Ducklings were marked with plasticine-filled metal leg bands (Blums et al. 1994); it is strongly suspected that, due to a change in formula of plasticine filling applied in 2007-2008, retention of plasticine-filled metal bands was very low in those years.

Year	Grey Islands	St. John Bay	Table Bay
2003	0	0	0
2004	420	0	1,078
2005	914	66	1,418
2006	482	41	1,785
2007	10	0	1,966*
2008	0	0	1,341*
2009	0	0	143
Total	**1,826**	**107**	**7,731**

* Suspected low retention rate of plasticine-filled metal leg bands due to change in plasticine formula.

Survival and recovery of AHY and HY Common Eiders

In addition to captures and recoveries of nesting hens and ducklings in May, June and July, Common eiders were capture with submerged nets only at the Table Bay study site (Table 3) in August and September. There were 983 HY eiders of known sex and 194 HY eiders of undetermined sex captured from 2005 to 2009; also, there were 676 AHY eiders of known sex and 5 of undetermined sex concurrently captured.

The band recovery models of Brownie et al. (1985) was used to attempt to estimate true survival, $\hat{S}$, and recovery probability, $\hat{f}$, of (A) hens and ducklings marked on nesting colonies, and (B) separately of AHY and HY females captured with submerged nets. However, median $\hat{c}$ tests failed to converge in some cases suggesting very poor fit of Brownie et al. models, or estimation produced estimates which were suspect. Part of the probably was likely related to failure of one of the assumptions of Brownie et al models: bands are not lost, but such was the case for plasticine-filled bands applied to ducklings in 2007 and 2008.

Table 3. Summary of captures of Common Eiders using submerged nets near Table Bay in Newfoundland and Labrador during August or September, 2003-2009.

	Hatch Year			After Hatch Year		
Year	Females	Males	Unknown	Females	Males	Unknown
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	36	20	185	14	30	5
2006	142	181	1	54	97	0
2007	143	135	1	68	159	0
2008	127	122	7	64	102	0
2009	39	38	0	7	81	0
Total	487	496	194	207	469	5

Recovery matrices of (A) hens and ducklings marked on nesting colonies are shown in Tables 4 and (B) those of AHY and HY females captured with submerged nets (Table 5). Note that there were very few recoveries of adults in any year, and of ducklings in after 2006, in the latter case likely due to very poor band retention of plasticine-filled metal bands in those years. Also, very few adults were marked in 2004, so that there were no recoveries in the following hunting season. Thus, even though there were many ducklings marked in 2004, the very low number of adults required that data from 2004 be ignored. Thus, all recovery matrices shown are for 2005-2009.

Table 4. Recovery matrices of Common Eiders captured as adult hens or ducklings at Grey Island, St. John Bay and Table Bay, Newfoundland and Labrador, 2005-2009. Reading the matrix from left to right provides the number of new marks/year (diagonal) and number of subsequent annual recaptures of those marked individuals through time.

```
recovery matrix group=1; /*COEI NESTING HENS ALL SITES*/
12  5   6   3   2;
    8  13  10   5;
        6   1   0;
            8   1;
                3;
628 807 274 320 578;
recovery matrix group=2; /*COEI DUCKLINGS ALL SITES*/
63  17   9   1  1;
    36  13   4  0;
         3   0  0;
             2  0;
                0;
1498  2398  2308  1341  143;
```

Table 5. Recovery matrices of Common Eiders captured as adult females (AHY) and males, and juvenile (HY) females and males at Table Bay, Newfoundland and Labrador, 2005-2009 with submerged nets. Reading the matrix from left to right provides the number of new marks/year (diagonal) and number of subsequent annual recaptures of those marked individuals through time.

```
recovery matrix group=1; /*COEI AHY FEMALES*/
0   0   0   0   0;
    1   1   0   1;
        2   3   0;
            1   1;
                0;
14 54  68  64   7;
recovery matrix group=2; /*COEI AHY MALES*/
0   1   2   0   0;
    1   1   2   1;
        2   3   1;
            1   0;
                0;
30  97 159 102 81;
recovery matrix group=3; /*COEI HY FEMALES*/
2   0   1   0   0;
   13   4   3   2;
       11   2   0;
            9   4;
                5;
36 142 143 127 39;
recovery matrix group=4; /*COEI HY MALES*/
2   1   0   0   0;
   12   2   1   0;
        9   1   0;
           11   1;
                1;
20 181 135 122 38;
```

Results

The project resulted in the capture and banding of 13,837 eiders. This includes totals of 2,250 nesting females (Table 6), 9,712 day old ducklings (Tables 7), 1,875 adults and juveniles with submerged nets (Table 8).

Table 6. Number of adult female Common Eiders captured in Newfoundland and Labrador under DUC's Eider Initiative during 2003-2009. This resulted in 2250 unique females. **2003 = pilot year only.*

	Year							
Field Site	2003	2004	2005	2006	2007	2008	***2009***	***Total***
Grey Islands	73	67	205	168	0[a]	0[b]	NA	**513**
St. John Bay	30	27	26	51	33	NA	NA	**167**
Table Bay	9	116	396	499	232	306	513	**2071**
Total	**112**	**210**	**627**	**718**	**265**	**306**	**513**	**2751**

[a] Polar Bear disrupted eider nesting [b] Fox disrupted eider nesting

Table 7. Number of one-day-old Common Eider ducklings captured and banded under DUC's Eider Initiative during 2003-2009. **2003 = pilot year only*

	Year							
Field Site	2003	2004	2005	2006	2007	2008	2009	***Total***
Grey Islands	0	420	914	482	10[a]	0[b]	NA	**1826**
St. John Bay	23	NA	66	41	NA	NA	NA	**130**
Table Bay	20	1078	1418	1785	1978	1334	143	**7756**
Total	**43**	**1498**	**2398**	**2308**	**1988**	**1334**	**143**	**9712**

[a] Polar Bear disrupted eider nesting [b] Fox disrupted eider nesting

Table 8. Number of adult and Juvenile eider caught with submerged nets.

	Year					
Sex and Age	2005	2006	2007	2008	2009	***Total***
Adult – Female	21	70	75	73	17	**256**
Adult – Male	2	31	98	160	103	**394**
Juvenile - Female	40	147	143	129	41	**500**
Juvenile - Male	22	204	135	122	38	**521**
Juvenile – Unknown	185	3	2	8	6	**204**
Total	**270**	**455**	**453**	**492**	**205**	**1875**

Our ability to recapture previously marked birds influenced the precision to predict survival and population growth (i.e., increases our knowledge that these birds are alive and in the population). Figure 19 shows how recapture rates increased to 27% at Table Bay over the period of the study.

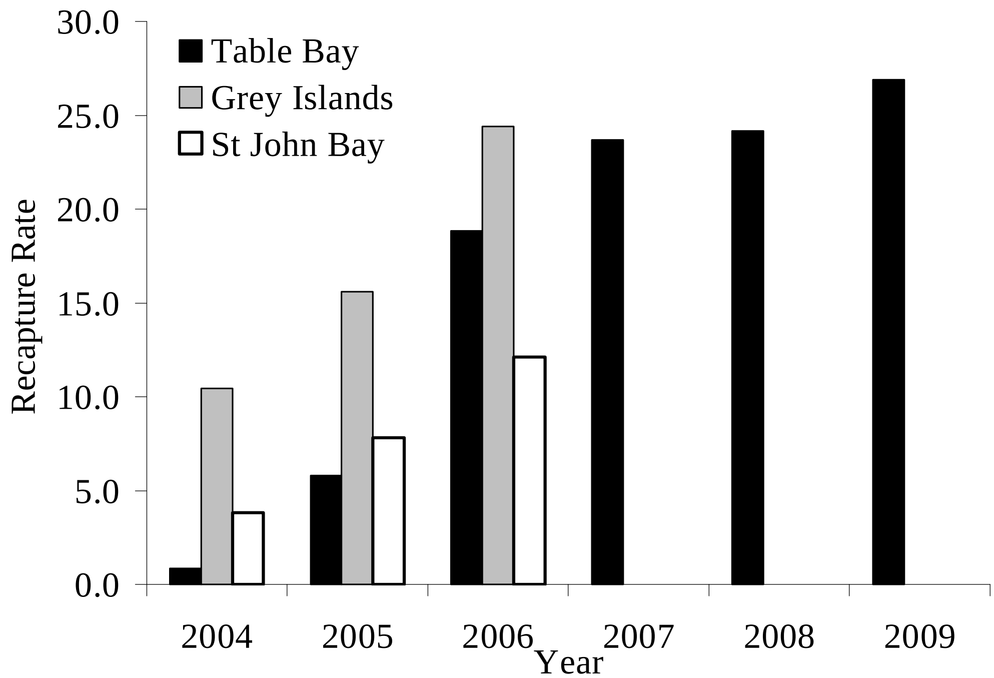


Figure 19. Recapture rates of nesting adult female eider 2004 – 2009.

Model Results:

Local population dynamics

Although capture histories from each study area were modeled (Tables 9 - 11), data from St. John Bay were considered too sparse for reliable estimation of $\hat{\phi}$ or $\hat{\lambda}$, although a pooled estimate for years 2005-2007 was available for $\hat{p}$. The best models for both Grey Islands and Table Bay were {ϕ(.) p(t) λ(.)}, in which local survival and annual rate of population growth were constant, but capture probability varied among years. Local survival at Grey Island and Table Bay was 0.76±0.10 SE and 0.78±0.04 SE, respectively. Annual rate of population growth at Grey Island and Table Bay was 1.29±0.18 SE and 1.08±0.06 SE, respectively. Using Equation (2) as an ad hoc estimate of seniority suggests that the proportion of the population comprised of previous breeders and new recruits was 0.59 and 0.41, respectively at Grey Island, but 0.93 and 0.07 at Table Bay. Although local survival at both sites was similar, data indicate that new recruits to Grey Island were about 6 times higher than those of Table Bay, resulting in elevated growth rates at Grey Islands.

Using the canonical estimator of local population size (Equation 2) suggests that the population at Grey Island grew from about 362 nesting females in 2003 to 772 by 2006 (Table 12). Only an estimate of capture probability that was pooled over the span of years covered at St. John Bay was available, but when this was applied to Equation 2, the population estimate was about 373 nesting common eiders there. Finally, the local population was highest of the 3 study areas at Table Bay, where the number of nesting common eider females increased from about 1459 in 2003 to about 2306 by 2009 (Table 12).

In general, where estimation was possible over time at Grey Island and Table Bay, both survival and recruitment were sufficiently high to cause local populations to increase.

Table 9. Results of model selection for captures of nesting female Common Eiders from Grey Islands, Newfoundland and Labrador, 2003-2006. $\hat{c}$=1.0

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{Phi(.) p(t) Lambda(.)}	1591.72	0.00	0.40	1.00	6	7.63
{Phi(.) p(t) Lambda(t)}	1592.62	0.91	0.26	0.64	7	6.48
{Phi(t) p(t) Lambda(.)}	1594.21	2.49	0.12	0.29	8	6.00
{Phi(t) p(t) Lambda(t) global}	1594.21	2.49	0.12	0.29	8	6.00
{Phi(t) p(.) Lambda(t)}	1594.47	2.75	0.10	0.25	6	10.38
{Phi(.) p(.) Lambda(t)}	1601.75	10.03	0.00	0.01	5	19.70
{Phi(.) p(.) Lambda(.)}	1631.03	39.32	0.00	0.00	3	53.06

Table 10. Results of model selection for captures of nesting female Common Eiders from St. John Bay, Newfoundland and Labrador, 2003-2006. $\hat{c} = 1.79$

Model	QAICc	Delta QAICc	QAICc Weights	Model Likelihood	Num. Par	QDeviance
{Phi(.) p(.) Lambda(t) }	152.00	0	0.28	1	3	0.80
{Phi(t) p(.) Lambda(t) }	152.00	0	0.28	1	3	0.80
{Phi(.) p(t) Lambda(.) }	153.56	1.57	0.13	0.46	4	0.17
{Phi(.) p(t) Lambda(t) }	153.56	1.57	0.13	0.46	4	0.17
{Phi(t) p(t) Lambda(t) }	153.56	1.57	0.13	0.46	4	0.17
{Phi(t) p(t) Lambda(.) }	155.76	3.77	0.04	0.15	5	0.17
{Phi(.) p(.) Lambda(.) }	181.90	29.91	0	0	2	32.79

Table 11. Results of model selection for captures of nesting female Common Eiders from Table Bay, Newfoundland and Labrador, 2004-2009. $\hat{c} = 2.95$

Model	QAICc	Delta QAICc	QAICc Weights	Model Likelihood	Num. Par	QDeviance
{Phi(.) p(t) Lambda(.) }	3203.05	0.00	0.88	1.00	9	53.47
{Phi(t) p(t) Lambda(.) }	3208.15	5.10	0.07	0.08	13	50.49
{Phi(.) p(t) Lambda(t) }	3208.84	5.78	0.05	0.06	13	51.18
{Phi(t) p(t) Lambda(t) }	3215.82	12.77	0.00	0.00	17	50.05
{Phi(t) p(.) Lambda(t) }	3225.28	22.22	0.00	0.00	11	71.66
{Phi(.) p(.) Lambda(t) }	3236.10	33.04	0.00	0.00	8	88.53
{Phi(.) p(T) Lambda(.) }	3444.77	241.72	0.00	0.00	4	305.25

Table 12. Number of captures, and estimates for capture probability, $\hat{p}$, and population size, $\hat{N}$, for 3 local populations of nesting Common Eider females in Newfoundland and Labrador, 2003-2009.

Site	Year	n	$\hat{p}$	$\hat{N}$
Grey Island	2003	73	0.20	362
	2004	75	0.16	465
	2005	200	0.34	590
	2006	164	0.21	772
St. John Bay	2005-2007	26	0.07	373
Table Bay	2003	9	0.01	1,460
	2004	123	0.08	1,463
	2005	395	0.25	1,576
	2006	578	0.32	1,785
	2007	241	0.13	1,866
	2008	319	0.15	2,074
	2009	578	0.25	2,306

Age of first breeding

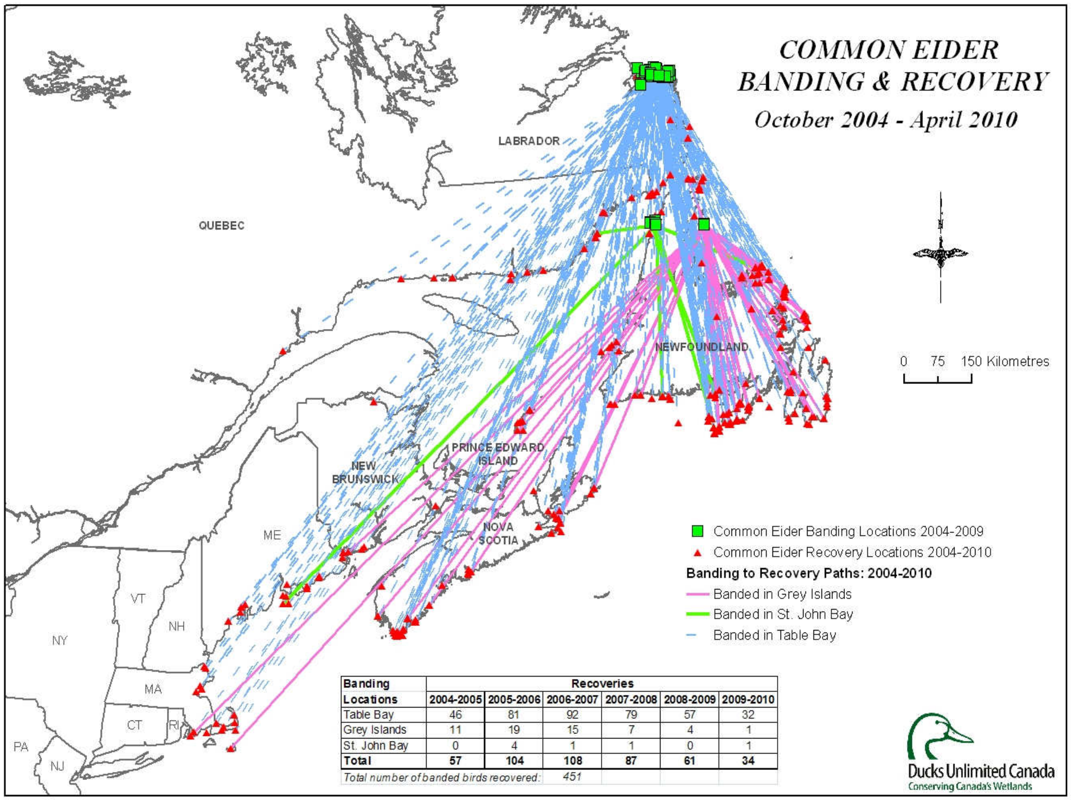
Of 9,712 ducklings with plasticine-filled leg bands, only 23 were subsequently recaptured as nesting females. Notably none of these ducklings were banded after 2006, confirming our suspicion that changes in plasticine-filled formula resulted in band loss. Also note that presence of a Polar Bear in 2007 and a fox in 2008 on the Grey islands resulted in total breeding failure so no recoveries were made at this colony. Therefore, for Table Bay a total of 4,301 ducklings were assumed to be available. In addition, 12 juveniles were subsequently caught as breeding adults. The average number of years between marking as a duckling and first detection as a nesting female was 3.26 years (Table 13).

Table 13. Average number of years between marking as a known local female eider and first detection as a nesting female.

Age	Ducklings	Juveniles	Number of Eiders
1			0
2	5	4	9
3	10	1	11
4	5	7	12
5	3	0	3
Total	**23**	**12**	**35**

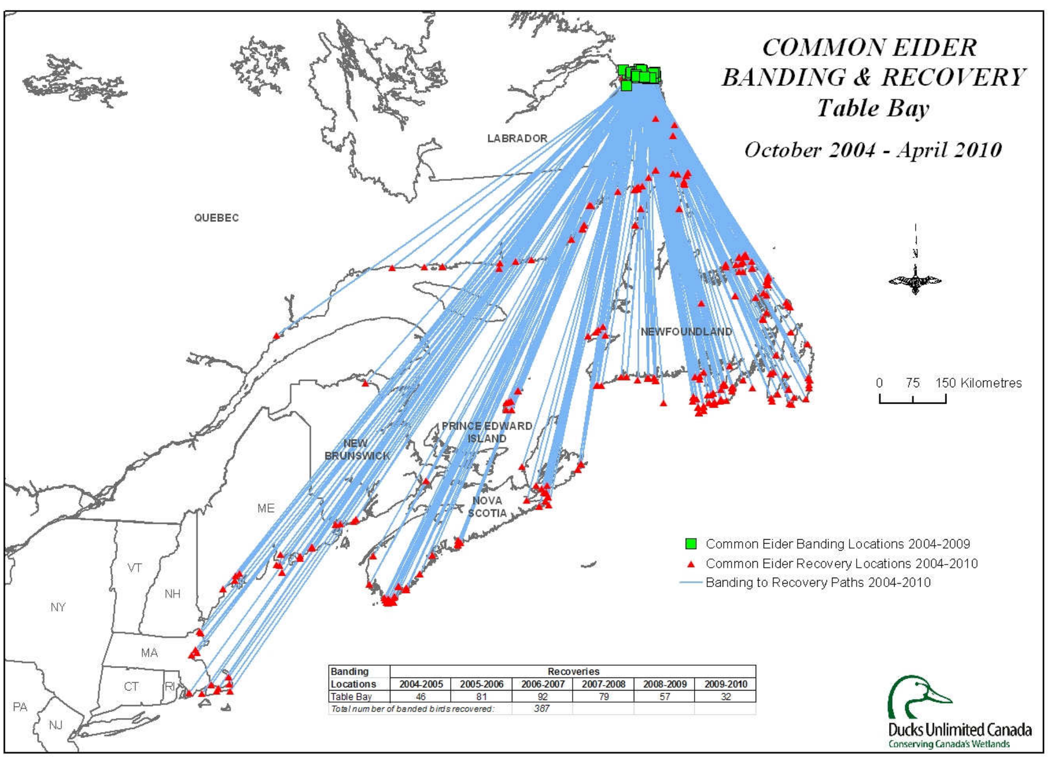
Linking Breeding, Migration and Wintering Locations

To date we have received a total of 471 band recoveries (Figures 20 - 22). Band recoveries for birds banded during this project are as follows: Newfoundland and Labrador (n = 259), Nova Scotia (n = 81), New Brunswick (n = 7), Quebec (n = 48), St. Pierre Miquelon (n = 42), Maine (n = 16), Massachusetts (n = 17), and Rhode Island (n = 1). Most band recoveries are for hatch year eiders marked as day old ducklings or juveniles (n = 366) and adults (n = 105).



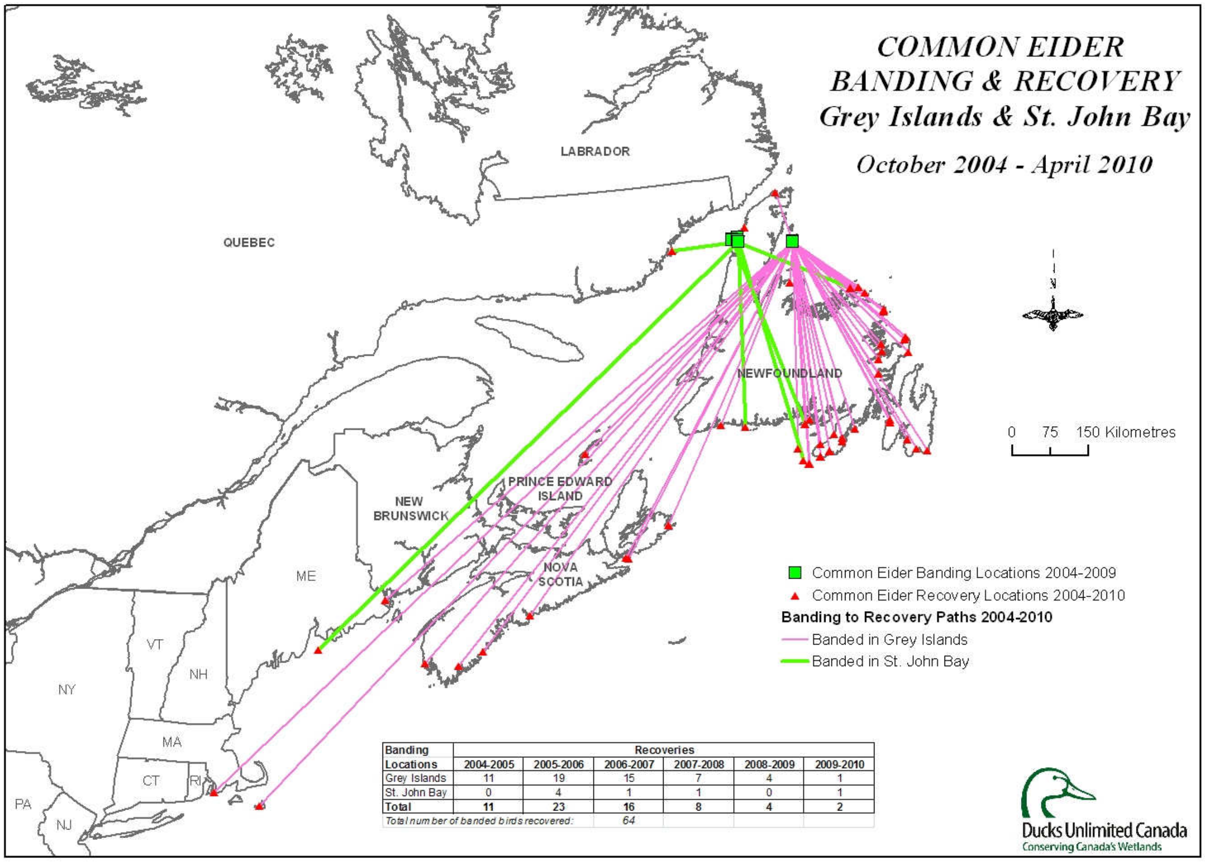
Banding Locations	Recoveries 2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Table Bay	46	81	92	79	57	32
Grey Islands	11	19	15	7	4	1
St. John Bay	0	4	1	1	0	1
Total	**57**	**104**	**108**	**87**	**61**	**34**
Total number of banded birds recovered:	451					

Figure 20. Harvest locations for all recoveries of eiders marked in Newfoundland and Labrador.



Banding Locations	Recoveries 2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Table Bay	46	81	92	79	57	32
Total number of banded birds recovered:	387					

Figure 21. Harvest locations for eiders banded at Table Bay, NL.



Banding Locations	Recoveries					
	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Grey Islands	11	19	15	7	4	1
St. John Bay	0	4	1	1	0	1
Total	**11**	**23**	**16**	**8**	**4**	**2**
Total number of banded birds recovered:		*64*				

Figure 22. Harvest locations for eiders banded at Grey Islands and St John Bay, NL.

Excluding ducklings banded in 2007 – 2009 (years of substantial loss of duckling bands), the project resulted in 6,247 banded ducklings. Direct harvest rates on this subset of ducklings was 2.58% (161/6247) compared to harvest rates for juveniles of 5.31% (92/1732; young marked at more then 30 days of age) and adults 1.23% (28/2279).

Harvest was not equally distributed along the eiders range. Figures 23 – 24 show the number of eiders harvested within 25 x 25 km grid cells along the coast of Newfoundland and Labrador. Hot spots represent a congruence of eider abundance and hunter effort, but do provide a visual representation of the distribution of the eiders in fall and early winter.

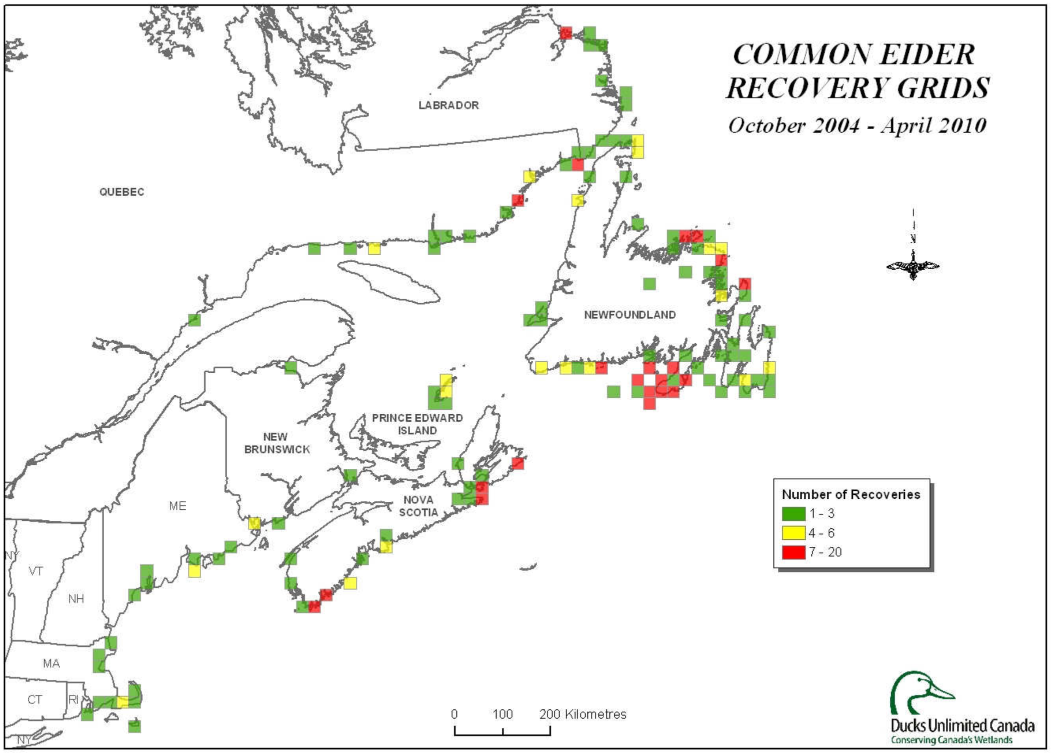


Figure 23 – Numbers of eiders harvested within 25x25km blocks of the coast of the range of *S.m. dresseri*.

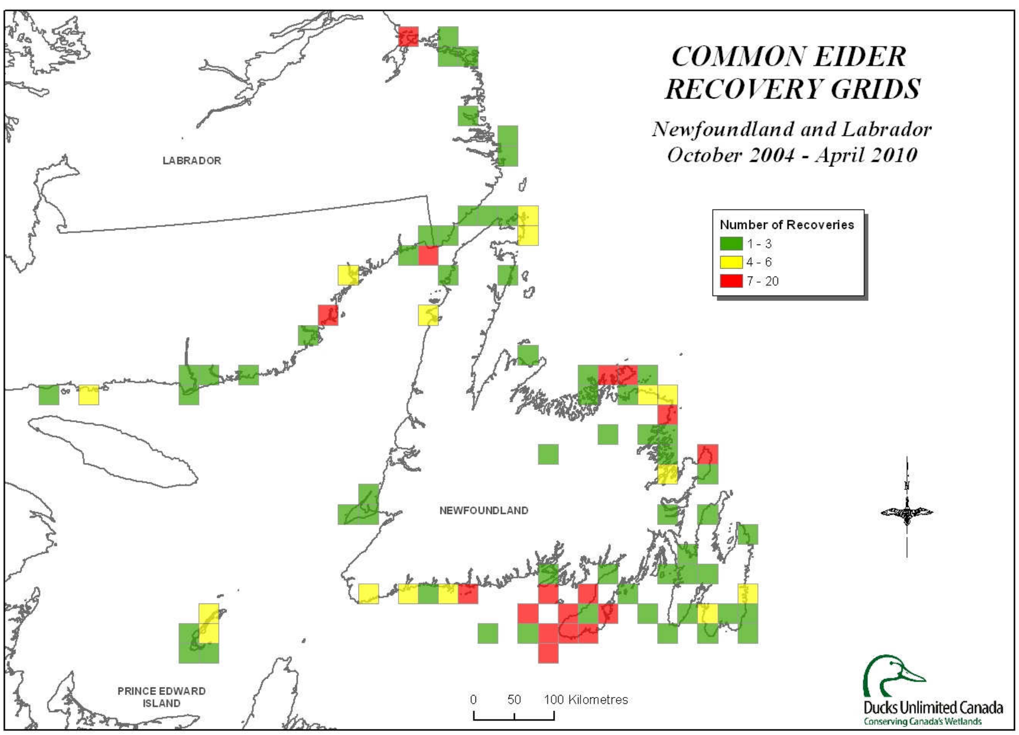


Figure 24 – Numbers of eiders harvested within 25x25km blocks of the Newfoundland and Labrador coast.

Education and Community Involvement

This project provided important benefits to the local communities through: 1) job creation, 2) job training, 3) local revenue generated directly from project expenditures, and 4) education about local nesting eiders. Specifically, DUC provided 391 weeks of employment to 28 people, 23 from Newfoundland and Labrador. In addition, the project purchased $275,000 of supplies from local communities. Management of personnel and expenses was accomplished through the White Bay and Eagle River Development Associations. All staff that worked on the project were provided with extensive hands on experience relating to wildlife research, skills that are be transferable to other projects.

The project also engaged community college students from the College of the North Atlantic, providing them with experience and insights into eider conservation and research. Junior Forest Rangers were also involved in the project, with special efforts directed at exposing rangers in Cartwright to research and habitat restoration. This project linked directly with the Government of Newfoundland and Labrador's Coastal Stewardship Program, delivered under the Eastern Habitat Joint Venture Partnership. Finally, the project supported a M.Sc. student at Memorial University of Newfoundland.

Discussion

Results from this research provide essential baseline data for eiders nesting in Newfoundland and Labrador. Moreover, results from this research provide the first extensive estimates of eider vital rates (e.g., survival, population growth, recruitment) for this region. The duration of the research and the numbers of adults marked provides reasonable confidence in adult related vital rates. In the unlikely event of an oil spill, comparison of these data to those collected post spill will assist in assessing damage to eider populations. Specifically, in quantifying the ripple effects that an oil spill would have on the population.

Results from the hunter returns provide a picture of the areas with high numbers of eiders in fall and winter. The harvest information shows that the Tale Bay eiders generally range further then the Grey Island eiders. This places the Table Bay eiders at higher risk of mortality from anthropogenic factors like oil spills, and commercial fisheries. Figure 24 shows a number of hotspots in Newfoundland and Labrador where relatively high numbers of eiders are harvested. This includes Fogo Islands, Cape Bonavista, with the most significant area being around the Burin Peninsula. Therefore, oil spills in these areas during late fall and winter will have an effect on the local breeding populations at Grey Islands and Table Bay.

Although the south coast of Newfoundland experiences intense ship traffic (Figure1), this area contains relatively low density of nesting eiders (<5% of Newfoundland and Labrador's nesting population). Thus, the south coast of Newfoundland experiences a lower overall risk of oil contaminants to large nesting populations, relative to more northern areas of the province. However, eiders migrating and wintering along the southern and eastern coasts of Newfoundland are potentially vulnerable to encounters with oil. Given the low densities of human settlements along the southern coast, this area is likely underrepresented in figures of harvest distribution.

A population's growth can be simplified into two major components 1) adult survival (individuals that are alive and return to breed) and 2) recruitment (new, young breeders that enter a population). In long-lived species, adult survival is responsible for population stability, as the majority of the population is comprised of older, experienced breeders (Rockwell et al. 1997, Nichols et al. 2000, Crone 2001). In contrast, the number of young produced annually (recruitment) is highly variable. In the absence of major events that impact adult survival, annual fluctuations in population growth are due primarily to the recruitment of new breeders (Coulson 1984, Gaillard et al. 1998, Cooch et al. 2001). Therefore, the factors that regulate recruitment are most likely to influence short-term changes in population size, as long as adult survival rates remain naturally bounded. Thus, oil spills that primarily impact adult females will have a larger and longer-term impact on populations then spills that impact subadults.

We were limited in our ability to develop a population trajectory model by the lack of convergence of models for duckling and juvenile survival. These are key elements in the population model (Figure 18). This is partly a result of poor duckling band retention in 2007 and 2008 following recommended changes in formulation of the plasticine mix. Fewer juvenile birds we caught in submerged nets than expected, and those that were, were recaptured and reported as harvested less frequently than expected. The poor retention of the leg bands also precluded analyses contrasting eiders and juvenile survival which would have provided a direct measure of duckling survival.

Since the inception of this study, significant research has also been conducted in more southerly parts of the breeding range of *S.m. dresseri*, therefore we believe that the timing is good for the development of a range wide population model. This would provide a more comprehensive model that would incorporate best new estimates of vital rates and spatial variability. The results of this study would contribute significantly to the model development.

The population models produced could be used to quantify how an oil spill would affect a local breeding population. For example, if an estimated 1400 adults are lost, as estimated from a 2004 bilge oil release, the impact of this on the population will be far greater, as the loss of these breeders will have a ripple effect on future production of young. Ultimately, a population model would allow managers to estimate future population size under the scenario that no spill occurred and to compare this with estimates of future population size after incorporating an estimated loss of the population due to an oil spill (e.g., 1400 birds following the 2004 bilge oil release). This would provide a quantifiable means of assessing the impacts of an oil spill on current and on future population growth.

We acknowledge that habitat differences between these study sites, including presence of nest shelters, may introduce some bias among sites. However, we expect habitat differences to have the greatest effect on nest success. Because adult survival has the greatest influence on population dynamics (Rockwell et al. 1997, Nichols et al. 2000, Crone 2001), effects of recruitment, such as that potentially introduced by habitat biases, should be minimal to overall population change.

The differences in population growth between Table Bay and Grey Island populations are striking. Population growth may be due to immigration (adults from another colony that enter the local population) or insitu recruits (local hatch young that return to breed). This may be the result of differences in overall vulnerability of the populations to activities of predators. For example,

Table Bay should have relatively low risk as the colony is distributed across 13 Islands, so the annual presence of a predator on a single nesting island will impact only a small proportion of the overall populations. In contrast, the eiders at the Grey Island colony nest on a single island adjacent to 2 large islands. These large islands could support predators, which periodically, significantly, impacts local production, as experienced in 2 of 6 years during this study. Under this scenario, the substantial population growth seen at Grey Islands may include a substantive immigration component, with eiders potentially coming from birds associated with islands in Hare Bay. The results for Table Bay could be considered representative on a closed system where growth is attributable to recruitment, while Grey island population would have strong components of both recruitment and immigration.

Further work will be required to resolve the problem of unbalanced design and poor duckling band retention in Table 4, and very few recoveries of adults in both Tables 4 and 5. There may be merit in using a joint capture-recovery approach to estimate true survival (Burnham 1993), but this will require further work. As well, concentrating on only Table Bay captures instead of data pooled among all three sites during nesting and hatch may improve fit of Brownie et al. band recovery models.

Acknowledgements:

This project could not have happened without the dedicated effort of a multitude of field staff that spent long periods of time in remote field camps under various conditions. In addition, the project benefited significantly from the administrative support of Wendy Greenleaves and Ethel Patey from the Eagle River and White Bear Development Associations. Special thanks are extended to Regina Wells for her passion for the project, including 3 summers working on the project, 18 months managing the project, as well as a return trip as a volunteer in 2009. She was instrumental in developing and implementing the educational aspects of the project. Finally, thanks to Dr. Ray Alisauskas for completing the analyses.

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