Sea Duck Joint Venture
Annual Project Summary
FY 2013 - (1 April 2013 - 31 March 2014)

Project Title: Sea Duck Research and Monitoring in the Atlantic Flyway: Development of a monitoring program for the American Common Eider. An assessment of repeatability and accuracy of aerial counts of males (SDJV Project #135)

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Project Description:
The current American Common Eider (*Somateria mollisima dresseri*) population estimate is around 300,000 birds (C. Lepage and D. Bordage, Canadian Wildlife Service, in prep.) and is among the most commonly harvested sea ducks in several coastal regions of eastern Canada and U.S. The sustainable harvest rate was estimated around 10%, and harvest was estimate to be about 32,000 birds (mean harvest 1998 to 2003) which exceeds the estimate of sustainable harvest for this subspecies (Savard et al. 2004). Although the distribution and relative abundance of American Common Eider has been well described, there exists no comprehensive monitoring program for this subspecies. Various state, federal and provincial agencies have intermittently conducted breeding surveys over the past 40 years within their jurisdictions in south-eastern Canada and the north-eastern U.S. Long term ground counts have been done in north shore Gulf of St. Lawrence and within the St. Lawrence estuary. The U.S. component of the wintering population has been partially surveyed on the Mid-Winter Inventories, and recent surveys in Canada have covered the Canadian component. Unfortunately, no coordinated, international survey of this population has occurred and therefore no reliable indices of continental population size or trend exist.

Two information gaps need to be addressed to assess the potential of using aerial counts of adult males surrounding eider colonies as an index of the breeding population: 1) development of the geo-spatial sampling regime and frequency of surveys, and 2) an assessment of the repeatability of the survey. In this phase of the project we attempted to assess repeatability and accuracy of aerial counts of male eiders during the breeding season.

An observer's ability to accurately count adult males from the air likely varies with colony size, nesting cover and sea-state conditions. There are several techniques that may be used to assess accuracy of count data (e.g. estimation of probability detection rates); a logical first step is an assessment of measurement error of the survey across a range of colony sizes. Here we assess measurement error using three replicate counts from up to twelve breeding areas spread across the breeding range. This design provides the ability to assess measurement error in different environmental conditions and spatial scales. We also compare estimates of the number of adult males around colonies made from high altitude photographs of the colonies to visual estimates made during the same survey.

Objectives:

- To measure sources of variance associated with male counts of eiders, including.
  - error in visual estimates
  - repeatability of the counts

Methods:

Survey Timing— To determine the approximate timing for the survey we canvased waterfowl managers and researchers in Maine, New Brunswick, Nova Scotia, Québec and Newfoundland and Labrador for information on breeding chronology for Common Eiders. We targeted surveys to the peak of nest initiation as most male were expected to be in attendance at the colony during this period. We asked managers for information on the location of the colony, how the initiation date was estimated and any general comments on the breeding season. The quality of information on peak nest initiation dates ranged from: 1) high (back-dating from stage of development of clutches, duckling ages or known hatch dates), medium (nest surveys that occurred when between 20% and 60% of nests had hatched), and low (nest surveys that occurred before or early in hatch or qualitative comments from the observer). We used a 2-week period, centered on the estimate of peak nest initiation date, to target survey dates.

Sampling Design—We selected a sample of archipelagos known to have breeding eiders in southwestern New Brunswick, eastern Nova Scotia and southern Québec. Within each province, we selected three areas which were to be surveyed three times each. The areas selected for survey covered the range of breeding conditions observed across the breeding range of *S. m. dresseri:* from the very large forested colonies in the St. Lawrence Estuary to the small offshore rocky islets of the eastern shore of Nova Scotia.

Visual Counts— The survey crews consisted of a navigator/recorder and a single observer. To control for observer biases in estimating groups sizes one observer made all the visual estimates. In Québec, the survey was flown at 500' (feet) above sea Level (ASL) using a P-68 Observer fixed-wing aircraft. In New Brunswick and Nova Scotia the first survey was flown at 350' ASL, and the replicates at 500' ASL, using a Cessna 172. The Québec crew used PCMapper AI to record the locations of all observations, while the crew in the Maritimes recorded observations on audio tape and later transcribed them into CWS coastal block to provide approximate locations of the observations.

Photo Counts— During each survey replicate, a sequence of overlapping images were taken from an altitude of 500 to 600 m ASL along the shoreline of selected eider colonies. Images were sorted and the best set of images was stitched together along to create a complete photo mosaic of the area surrounding the colony. The number of males and gulls were counted on the unique area of each image.

Preliminary Results:

Stakeholder Consultation— On 20 April 2012, CWS held a workshop on Common Eiders in Aulac, NB. Participants included resource managers from Maine, Québec, New Brunswick, Prince Edward Island and Nova Scotia. Each agency provided background on their eider programs and highlighted issues or concerns within eiders in their jurisdictions. We also discussed the need for a range-wide monitoring program, and provided an overview of the developmental spring survey planned for 2012. Notes form the meeting is provided in Appendix I.

Survey Timing— We compiled all information we obtained on breeding chronology of Common Eiders from New Brunswick, Nova Scotia, Québec, and Newfoundland and Labrador in Appendix II. This information is summarized in Table 1 to provide guidance on the appropriate timing for the survey across the breeding range of *S. m. dresseri* in Canada.

It is interesting to note that several researchers reported delays in breeding and reduction of breeding effort in some years. For example, McAloney (1973) reported that breeding effort was delayed and there was no real peak in nest initiation on Tobacco Island, NS in 1972. Similarly, Gilliland *et al.* (2005) estimated that nests were initiated 7-10 days later in 1984, and the size of the eider colony was less than half that estimated in 1986 or 1987 for an eider colony in New Brunswick. In the northern part of their breeding range, the breeding chronology of *S. m. dresseri* may be impacted by sea ice conditions. For example, eiders initiate breeding 7-10 days earlier on the warmer western side than the cooler eastern side of the Northern Peninsula in Newfoundland (Gilliland unpubl. data). In Labrador in 1995, Gilliland and Woolaver (unpubl. data) observed a delay in breeding by about 10 days between the inner ice-free part of Table Bay that when compared to the outer part of Table Bay where strong northeasterly winds had filled the area with sea ice. The effect of delays in breeding and reductions in breeding effort appear to occur periodically throughout their breeding range and little is known about how these delays may affect male attendance at colonies.

Sampling Design— Poor weather conditions during the survey period resulted in limited opportunities to conduct the surveys. No surveys were completed in Nova Scotia due to an extensive period of heavy fog, and only one survey was completed in New Brunswick; only one replicate survey was completed for the area around the Wolves Archipelago, hence Nova Scotia and New Brunswick were dropped from the analyses. In Québec, surveys were flown on 5, 7, 14, 17, 18 and 19 May 2012.

Visual and Photo Counts— Visual estimates of adult males by date and archipelago are presented in Appendix III. Obtaining estimates of males from the photos were more complicated and time consuming than expected. About 2,000 images were taken on the survey (only for the Québec portion of the survey) and many of the images had over-lapping coverage. Photo mosaics had to be stitched together for each island or archipelago and duplicated areas discarded. Once the photos were compiled, it was apparent that several of the mosaics were incomplete for at least one of the survey replicates and the sampling design was revised. When the photo mosaics were completed, we had three replicate photo and corresponding visual estimates for nine separate islands or archipelagos for surveys that took place on 17, 18 and 19 May. Each of the 834 photos that made up the photo mosaics were delineated into regions that: 1) overlapped with an adjacent photo(s), or 2) were unique to each photo (Figure 1). These photos were then sent to a consultant who counted the number of adult male eiders and gulls on the unique portion of the photo and for the regions shared with adjacent photos.

Comparison of Visual and Photo Estimates— Photo and visual estimates of adult male Common Eiders for each survey replicate and totals by Island/Archipelago are summarized in Table 2. Overall, about 5,200 adult males were estimated visually from the aircraft around the nine colonies. At the same time, we estimated from photos that there were about 10,400 adult males in the same areas (Table 3) suggesting that the visual counts may underestimate the number of adult males attending the colonies by half. Figure 2 shows the expected 1:1 relationship between visual and photo estimates as a red dashed line. All the visual estimates fall below this line, and the slope of the relationship between the visual and photo estimates is shallower then the expected suggesting that the magnitude of the underestimation likely increases with colony size.

Both the visual and photo estimates of adult male Common Eiders were highly variable across replicate surveys (Table 2, Figure 2). The confidence limits for the visual estimates were much wider than the corresponding photographic estimates suggesting that the visual estimates had very low repeatability among replicates. To understand how variation in estimation might vary with colony size, we calculated the within island/archipelago coefficient of variation (CV). Except for Baie Johan Beetz, the CVs for the photo estimates of males ranged between 0.01 and 0.17, the CV for Baie Johan Beetz was 1.05, while the CVs for the visual estimates ranged from 0.23 to 1.60. For the photo estimates, there did not appear to be a relationship between the number of males around a colony and colony size; however, the visual estimates did (Figure 3). Visual estimates not only had a greater dispersion than the photo estimates, but presented a negative relationship between the amount of dispersion around the visual estimate with colony size. Note that we dropped Baie Johan Beetz from Figure 3 as it was a clear outlier.

We hypothesize that the negative relationship with colony size observed in the visual estimates in Figure 3 may result from the processes the observer uses for counting. At low encounter rates the observer attempts to count each individual male, at some point, as the encounter rate increases, the observer is unable to count every individual and they switch to a different counting process as they start to estimate numbers of birds. The mean estimates of adult males for the five smallest colonies measured visually ranged in size between 105 and 268 males and had very high CVs among replicates (0.97-1.60). We speculate for these colonies that the observer may still be attempting to count all birds, but was overwhelmed by the high encounter rate which resulted in the highly variable counts among replicates. For the larger colonies, the observer may no longer counts individuals, but lumps estimates of many birds together: the more birds, the larger the bins used by the observer for lumping. Hence the "guesstimates" for larger colonies become more similar because the observer uses similar sized bins for counting, not because their counting process is more accurate.

A contract was let to the statistics department at Laval University to explore alternate approaches to analyzing the data; an English translation of their findings is provided in Appendices IV (report of the 22 March 2013) and V (report of the 6 November 2013). They quickly concluded that the visual estimates had very low repeatability and focused their exploratory analyses on the photo estimates. Producing estimates from the photos required an enormous effort as the photos had to be manual filtered for duplicates and the number of "unique" males on each photo had to be counted. An interesting finding of Daigle and Crépeau was that the proportion of unique to total males was consistent across photos (0.52±0.02; Daigle and Crépeau unpublished report 6 Nov 2013, Appendix V). Utilizing this ratio, they explore alternate methods for estimating the number of male eiders using the photos as the sampling unit. Their approach to estimating the population size of male eiders is novel, and worth further exploration should we decide to use photos as part of the methods monitoring Common Eiders.

Comparison of Visual and Photo Estimates With Nest Counts— We acquired 2012 nest counts for three of the eider colonies covered by the aerial survey (Giroux unpubl. data and CWS unpubl. data; Ile aux Pommes 2,142 nests, Ile aux Fraises 1,452 nests and Bicquette 8,107 nests). Comparisons of the visual and photo estimates of males with the nest counts are shown in Figure 4. The nest counts ranged 1.5 to 2.7 times and 2.5 to 3.8 times higher than either the photo or visual estimates, respectively.

Conclusions and Recommendations—

- Estimates of eider colony size using aerial counts of males or photographs had low repeatability. Visual estimates were of poorer quality than photo estimates.
- Compared to nest counts, our photo estimates underestimated colony size by 1.5 to 2.7 times, and visual estimate underestimated colony size by 2.5 to 3.8 times.
- Photo estimates were made using a mosaic of oblique aerial photos of water surrounding colonies. Reconstructing the unique area of coverage was difficult, and despite considerable effort, some areas may have been double counted and there may have been some gaps in coverage which could have contributed to error in the photo estimates. If photos are used as part of a monitoring program for Common Eiders, we should use vertical aerial photos with a known proportion of overlap to minimize these sources of errors.
- Our assessment was targeted at the scale of island/archipelago, it appears aerial assessments of colony size at this scale may not be possible and we suggest aerial monitoring programs be evaluated for larger regions.
- Our results suggest repeatability of population estimates using aerial counts of male Common Eiders in spring may be very low. If population monitoring program for Common Eiders are to be based on visual counts of males during spring we suggest that a component of the program include an assessment of the repeatability of observer counts.

Table 1. Recommended timing for spring male counts across the range of the American Common Eider in eastern Canada

Jurisdiction	Area	Survey Period[1]	Quality
New Brunswick	Southwestern Bay of Fundy	10 to 25 May	High
Nova Scotia	Eastern Shore	1st or 2nd week May	Low
Québec	St. Lawrence Estuary	2nd or 3rd week May	Medium
	North Shore	12 to 26 May	Medium
Newfoundland and Labrador	Northern Peninsula (east)	15 to 30 May	High
	Northern Peninsula (west)	10 to 25 May	High
	Labrador (southern)	30 May to 12 Jun	High

1. Based on ~1 week period either side of the estimated peak of nest initiation.

Table 2. Visual and photo estimates of adult male Common Eiders by replicate and Archipelago, Québec, 2012.

Archipelago	Area	Date	Replicate	Visual Estimate	Photo Estimate
Baie Johan Beetz	Mingan	2012-5-18	1	136	228
Baie Johan Beetz	Mingan	2012-5-18	2	250	770
Baie Johan Beetz	Mingan	2012-5-19	3	140	342
Bicquette	Estuary	2012-5-17	1	2500	3197
Bicquette	Estuary	2012-5-19	2	1600	2533
Bicquette	Estuary	2012-5-7	3	2350	3296
Ile aux Fraises	Estuary	2012-5-17	1	267	1048
Ile aux Fraises	Estuary	2012-5-7	2	520	808
Ile aux Fraises	Estuary	2012-5-19	3	360	1144
Ile aux Pommes	Estuary	2012-5-17	1	475	994
Ile aux Pommes	Estuary	2012-5-7	2	815	1034
Ile aux Pommes	Estuary	2012-5-19	3	1700	1490
Ile de la Maison	Mingan	2012-5-17	1	230	572
Ile de la Maison	Mingan	2012-5-18	2	200	570
Ile de la Maison	Mingan	2012-5-18	3	375	722
Ile Gull	Mingan	2012-5-18	1	150	258
Ile Gull	Mingan	2012-5-18	2	55	271
Ile Gull	Mingan	2012-5-19	3	110	321
Ile Innu	Mingan	2012-5-18	1	900	2202
Ile Innu	Mingan	2012-5-18	2	225	2057
Ile Innu	Mingan	2012-5-19	3	850	2384

Archipelago	Area	Date	Replicate	Visual Estimate	Photo Estimate
L'Ilot	Mingan	2012-5-18	1	450	774
L'Ilot	Mingan	2012-5-18	2	12	791
L'Ilot	Mingan	2012-5-17	3	235	595
WR-8	Watshishou	2012-5-18	1	440	712
WR-8	Watshishou	2012-5-18	2	200	1003
WR-8	Watshishou	2012-5-19	3	158	1035

Table 3. Totals of adult male Common Eiders estimated visually and from photos across nine Archipelagos, Québec, 2012.

Replicate	Visual	Photo	Visual/Photo
1	5548	9985	56%
2	3877	9837	39%
3	6278	11329	55%
Mean	5234	10384	50%

Table 4. Summary of 2013/14 expenditures.

Area	Project component	Year	Item	Cost
Quebec	Contract Laval University	2013	Statistical analyses	13,800
Total				13,800

Project Funding Sources (US$).

SDJV (USFWS) Contribution	Other U.S. federal contributions	U.S. non-federal contributions	Canadian federal contributions	Canadian non-federal contributions	Source of funding (name of agency or organization)
0 (for FY13)					USFWS
			13,800		CWS

Total Expenditures by Category (SDJV plus all partner contributions; US$).

ACTIVITY	BREEDING	MOLTING	MIGRATION	WINTERING	TOTAL
Banding					
Surveys	**13,800**				**13,800**
Research					

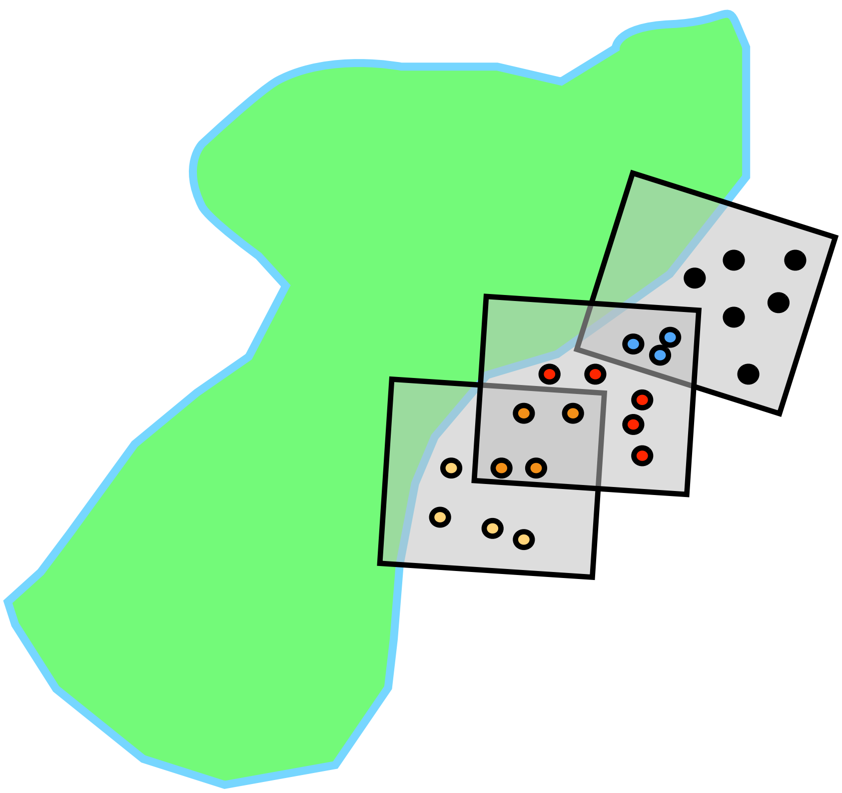


Figure 1. Illustration of how male eiders (circles) were counted on images (squares) in unique and overlapping areas of the photos.

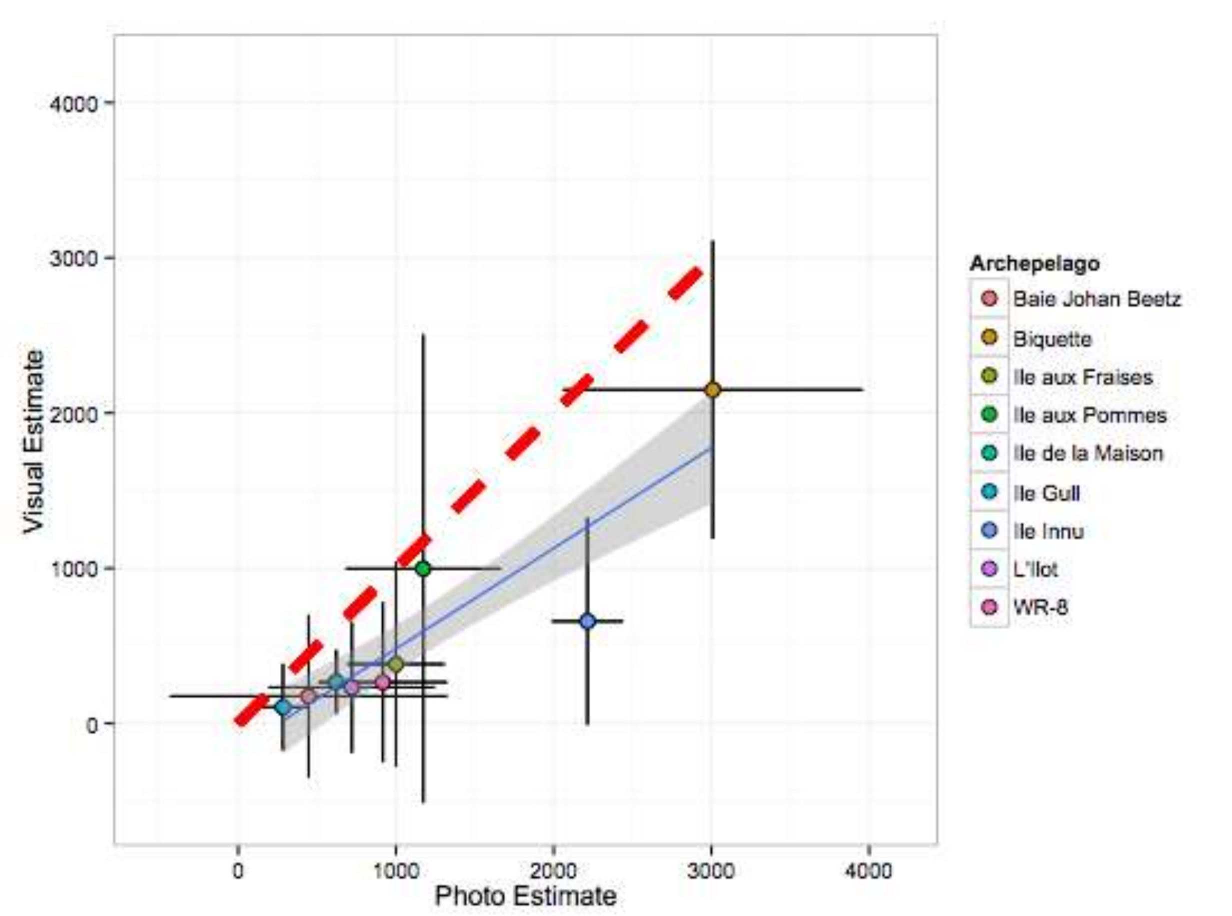


Figure 2. Relationship of visual vs. photographic estimates of adult male Common Eiders made for nine Archipelagos/Islands in Québec, 2012. Error bars are calculated for repeated-measures from the three replicate surveys of each Archipelago; red dashed line represents 1:1 relationship between visual and photographic estimates.

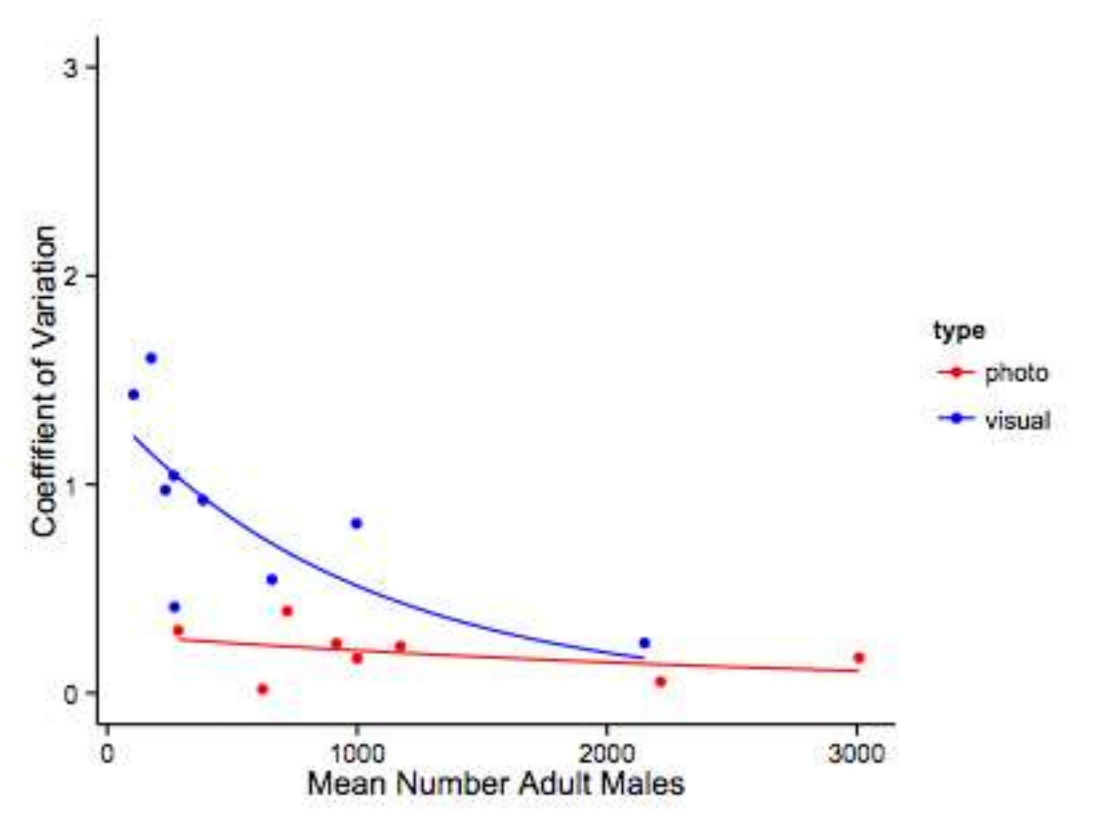


Figure 3. Average colony size (number of adult males) measured from 3 replicate surveys vs. the coefficient of variation calculated across the replicates.

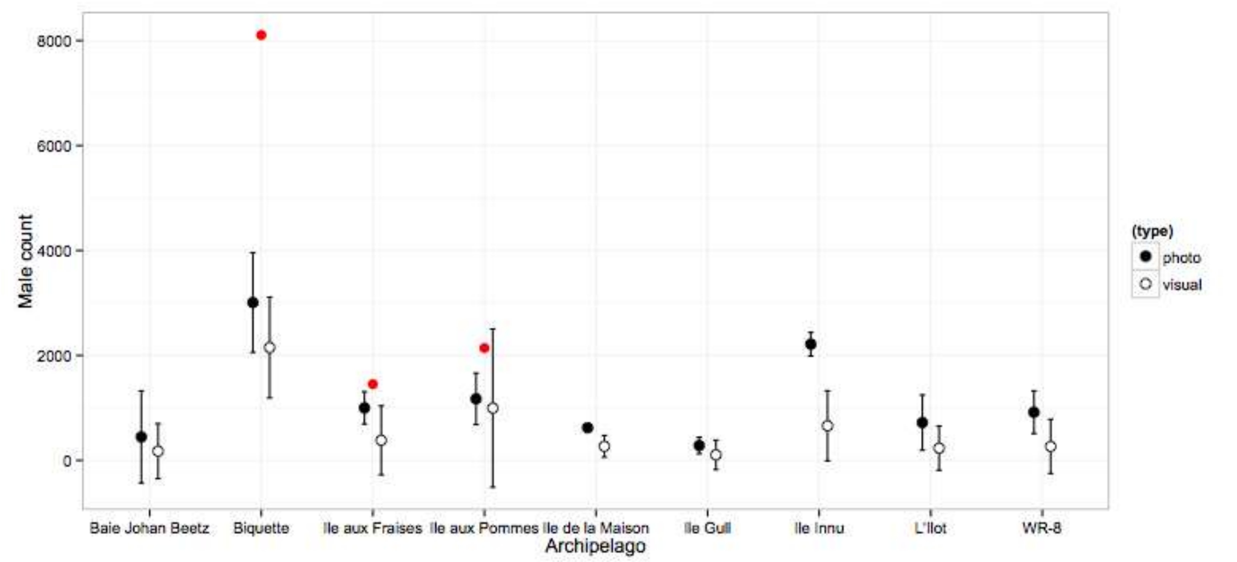


Figure 4. Visual and photographic estimates of adult male Common Eiders made for nine Archipelagos/Islands in Québec, 2012. Error bars are calculated for repeated-measures from the three replicate surveys of each Archipelago; red dots are estimates of colony size based on nest counts in 2012 (J.-F. Giroux unpubl. data and CWS unpubl. data).

Appendix I. Minutes of Common Eider (*dresseri*) Workshop held 20 April 2012 – Aulac, NB - Beaubassin Research Station. Notes take by P. Edwards.

A. Breeding Population Trends

i. Maine (Brad Allen)

- Late 1990s ~ 30,000 pairs, since '90s harvest has been very high, started to see data suggesting population overharvested therefore started population studies
- Reducing bag from 7-4 per day within the context of a sea duck harvest (7)
- Harvest reduced to 6,000-7,000
- Interested to see how female survival rates have changed since the 90s
- May have seen a reduction of at least 30%
- Production poor due to Black Backed gull predation on ducklings
- River otters have been decimating river colonies
- Large outfitter harvest
- Myriad of factors for the decline

ii. Quebec (J.F Giroux)

- St. Lawrence River (SLR) estuary annual harvest collection at end of incubation, eiderdown harvested
- 20 colonies surveyed by Société Duvetnor; 1 colony served by Société protectrice des eiders de l'estuaire
- Amount of down collected provides idea of number of birds
- 5 islands 1984-2011
- Wide fluctuations between years. Some years there are no birds due to foxes

- Are fluctuations synchronous and are there long term trends?
    - Pair-wise correlations - found that that trend was synchronous
    - 1.7-2.5% per year
    - Not a sampling bias due to disturbance because there are up and down fluctuations
    - Temporal trends – 2.4% decline per year
- Direct benefit of down collection: can obtain population data
- Believe that the same factors may influence the fluctuation in population on the islands
- Between late 1960s and 2001 not much variation; populations stayed relatively stable in the estuary
- Sharp decline post 2002 following avian cholera outbreak (lost at least 20% of females) Colonies declined further between 2002 and 2006
- Post 2006 number fluctuates but the trend is unclear
- North shore: Migratory Bird Sanctuary – population trend different from estuary. Populations were at their lowest levels in the 1970s but have been increasing since. Surveys have been conducted annually. Mingan Archipelago – large eider population. Surveys every 10 years beginning in 1985; trend has shown similar increases.
- Sharp population increase for the past 30 years.
- Mingan = 7,000 pairs; sanctuary = confounding. Perhaps 20,000 pairs on the North shore

iii. NB (Kevin Connor, Scott Gilliland)

- Spring male counts every 2 years since 1994
- Cover coast from Maine to Saint John, NB
- 9,000 males in 1994, has been declining 3% per year
- Grand Manan archipelago = largest breeding area

- Declines consistent across all colonies – consistent across the NB range
- Saint John colony does not seem to be exhibiting a trend
- Appears to be a stronger decline since 2000/2004, shallower decline in the 1990s
- Appears numbers were stable in the Wolves/Fundy in the 1990s

iv. NS (Randy Milton, Glen Parsons)

- Counts on Tobacco Island 1970-2000 fluctuations in populations but overall an increase on these islands of 900 breeding females
- Numbers have decreased since
- Mid-1990s-2000s started to see declines. Switched from nest counts to survival estimates
- Some aerial surveys along coastline
- Tony Lock estimated 8000 females on colonies, may have increased to 12,000 but has decreased since….seeing low numbers of birds
- Increase in common eiders as well as double-crested cormorants. Found eiders in cormorant colonies, providing good habitat for eiders. Cormorants have now moved from tree to ground nesting, islands are more open and more open to predation
- Some colonies have likely been impacted by mink, otter, and eagle predation

v. NL (Scott Gilliland)

- Compared Tony Lock surveys 1980s to 1994 survey: Growing 4-5% per year
- Northern sector surveyed by Keith Chalk, trend continuing in Labrador
- Eastern Waterfowl Surveys (EWS) have shown that there are many areas where birds are breeding – appears the expansion is not just in existing colonies but also into new colonies
- Island of Newfoundland: St. John Bay, Grey Island, Hare Bay, growing up to about 2,000 or 4-5% /year. No longer able to conduct ground surveys – difficult to conduct

- 2006 male survey approx. 2,000 birds
- Strong signals of growth in the Northern range.
- Appear to have stable or increasing population on the South shore Labrador and NL, North shore
- Steep documented decline in NB, Maine, SLR estuary, and NS

B. Molting Population Trends

i. Maine

- Counted 100,000 molting birds in 2006. Have not seen that number since. Appear to be molting elsewhere. Missing the 8,000 birds in survey area – seem to be molting elsewhere
- Capturing many NS banded birds
- Have not flown these surveys since 2006 because of the lack of birds
- Do not appear to be in the Bay of Fundy

ii. NS

- 2002 survey indicated estimated 40,000 birds off south shore
- Late 1990s banded using helicopter and nets; started at Lockeport and worked west
- 2011 did not find birds where they were traditionally – flew other areas, counting about 1,000 birds; in previous year there were birds so did not look to other areas of coast. Molting birds do not appear to be off southern NS.
- Last winter extreme storms affected much infrastructure, (band eiders on shoals); the storms may have affected the mussel beds upon which eiders are feeding

iii. QC

- 1998 eider and scoter surveys about 40,000 molting in gulf and estuary of SLR. Large proportion found around Anticosti Island – no breeding eiders, but habitat was used for molting

- Surveys repeated in 2010 but not analyzed yet – contact Christine Lepage and/or François Bolduc for information.

- J.-P. Savard and J.-F. Rail wrote up the information about the molting on and around Anticosti

- Keith – travelling along north shore Gaspe Peninsula in mid-September 2011 saw many flocks of eiders but does not know if they molted there or molted in estuary and were moving south. Mostly males in the flocks, females passed overhead as if on migration.

- Matane is about as far as the brood or molt survey extends; the Peninsula is usually overlooked as it is not known as an eider area

For consideration: is there a need for a range-wide survey during molting season to determine where birds are – are they just no longer in the traditional areas or are the numbers truly in decline or have declined?

C. Wintering Trends

i. Maritimes

- Flew all of NB and NS coastline in 2006 as part of wintering *borealis* survey; observed 57,000 eiders (22,000 in NB and 37,000 in NS)

- Repeated survey in 2012 –did not find a flock of eiders on NB mainland, historically had seen flocks of 7,000-8,000 birds. There were birds on the Grand Manan archipelago but numbers appear to be significantly lower, perhaps 8,000-10,000. Did not find a significant flock of birds on coastal mainland NS until Cape Breton. Expected to see birds there as this was the principal wintering area in 2006.

- 1992-2000 NS DNR mid-winter surveys (Glen Parsons) used helicopter surveys for near shore areas. Averaged 10,000 birds (5,000-20,000) during this period; distribution: predominantly mainland, eastern, south shore NS. Significantly fewer in Cape Breton. In 2011 observed 14,000 birds; 2012 – hot spots surveyed, mainland = 1,700, Cape Breton 9,200.

- Purple sandpiper surveys Lockeport area/islands – every 2-3 weeks flew fixed track counting Purple Sandpipers – huge influx of eiders from one week to the next

ii. U.S. Northeast

- Mid-winter survey and SDJV Wintering Sea Duck survey (Silverman)

- 2008: surveyed Florida to Cape Cod, following years extended to Northern part of Maine. 2008: 38,000; 2009: 108,000; 2010: 156,000; 2011 switched count to birds/nautical mile

- Midwinter nearshore 2012 = 60,000; similar to both 2010 and 2011, 95,000 in 2009, 100,000+ in 2008

- Distribution appears to be shifting significantly

- Midwinter inventory designed to count ABDU but count everything, used to see 40,000 on Maine coast. Winter inventory now only about 10,000 birds – likely more a distributional issue as the birds are wintering further south than previously. Cape Cod populations appear to still be wintering there, less off Maine Coast. A few years ago Massachusetts had a mussel die off – saw a dietary shift in the sea ducks but this does not explain the Maine shift where there are very few mussel aquaculture facilities. Population decline does not appear to be point source issues related to aquaculture.

- Cape Cod – starting to get more complaints from shellfish and finfish aquaculture operators but likely not just eiders, scoters as well.

Question – Emily Silverman – this is a data analysis year but what is the potential for this to become an operational survey. Planning to have a full report available for summer SDJV meeting in July.

D. Trends in Survival Rates from Ongoing Band Analysis

i. QC

- Adult female survival

- Islands and archipelagos banded 8,000 adult females

- Recoveries 87% from shot birds

- Spatial distribution 2/3 from US 2003-2012
- 1962-1997 ¾ from Quebec – hunting pressure has been reduced in QC
- 18% recaptured on North Shore
- Birds are faithful to their colony, only 19 (1%) changed islands…very little exchange among the islands
- Survival estimates: Joint analysis between 4 groups of islands (Rivière-du-Loup, Isle Bicquette, North shore, lower North shore)
- Annual survival 2003-2004; lower survival in 2005 on Isle aux Pommes due to a small, localized outbreak. Increased slightly in 2010-2011 - there was a reduced harvest of adult females in the US at this time.
- Other parameters: Recapture probability, recovery probability, fidelity probability - is this related to breeding propensity?
- Number of carcasses since eiderdown harvest begun. Isle Blanc-Sablon affected in 1984 and earlier. 2002 lost 20% of adult females, particularly on Bicquette
- 90% survival where population showing long-term decline.

ii. U.S. Northeast

- How have survival rates changed since Krementz (et al 1996) analysis?
- Update annual survival and recovery rates; trends in survival; assess live-recapture data; movements among nesting locations
- Banded 12,000 birds: 7,000 females, 967 live recaps, 458 recoveries. Can determine survival rates for males which is different from Krementz
- NL/QC/Maritimes and ME
- March-May females captured in subsistence hunting (Aboriginal hunters are returning bands) not band recaps.
- Female survival still very high (89%); recovery rate 0.02

- Live recapture for females just during breeding period (ended about 1July). Combination of breeding and molting for males.
- Males have a higher recovery rate which corresponds to harvest data from Paul Padding, but it appears that there was a peak and now a decline.
- Female survival dropped as of 2003 but began to increase again in 2006; male survival has gradually increased or at least remained constant
- Regional results – similar results across all regions. Have not seen a dramatic decrease in survival over time as compared to the Krementz study.
- Next steps: model - are there distinct periods within the breeding season?; if so are movement probabilities seasonal?, can we estimate survival by season?; Closer look at trends in recovery rates; explore trends and spatial differences at the regional scale; Continue to work with more complex models.
- ***Discussion points:*** What do these survival rates tell us?; What do we want from banding data? – are we getting it from current banding effort?; Recruitment rates and regional viability; Other variables and demographic rates

iii. NS

- Banding since 1970s at Tobacco Island
- 7,331 birds banded; 437 recovered
- Survival and recovery rate assessed with dead recoveries model
- Recovery rate is a combination of harvest and reporting rate; reporting rate and how it varies is poorly understood
- Model selection indicated that constant survival and time-dependant recovery rate was 0.818
- Survival rate of females increased from 1970; great variation in recovery rate of females
- Increased harvest in the 1990s almost 50% recovered in Canada; largest increase in harvest in U.S. for Nova Scotian birds (to 70%) during period 1970s to 1990s
- Slight increase in survival in 1980s but decreased to 2000

- Male and female analysis – male survival rate significantly higher between males and females - is there something other than harvest governing this survival rate?

- Possibly related to changes in habitat? now that cormorants are ground nesting, the habitat is no longer as conducive to nesting female eiders, nor survival of nestlings due to predation.

- Survival in NS is much lower than in the Gulf or along the NB and ME coastlines.

E. Plan to Complete Comprehensive Analysis of All Bandings

- Does any of the analysis incorporate the information from NL band recovery initiative? Maine used all bandings and all recoveries (dead recovery); live-recap data has not been incorporated from NL. Mark Gloutney (DUC) has forwarded the NL data to Guthrie Zimmerman (USFWS); the QC data has not yet been obtained.

- Does everyone wish to combine data to undertake an overall analysis similar to Krementz?

- Look at movements of birds in the recapture data between areas during the different life stage. Are they moving between these areas? Where are the molting areas?

- Ensure that there is an understanding of how the data was collected, correct for same period, etc.

- NS publication – included on author list

- **Lead:** Brad, Dan, Guthrie (analyses)

- **ACTION:** Dan and Brad to coordinate receipt of data and a conference call

    - Estimation of growth rates might be able to be extracted from banding data once it is pooled. Estimated date: end June. Get mark recapture data formatted similarly (identify fields and structure) so that it can be run. Model output only takes a few days. QC data in ACCESS database.

- **ACTION:** What is the objective of the analysis which will allow Guthrie to specify the format of the data request?

    - Hunting regulations mid-late October.

- Greg: Could look at QC recruitment directly from banding data; this could begin in advance of the pooling data.

- Appears to be a recruitment question but not in NS.

F. Harvest Trends

i. Canada

- Most of the harvest in NL; *dresseri* highest harvest pressure

- For the most part, relatively low harvest in NB and QC

- Overall decline in harvest

ii. U.S.

- Relatively stable

- Massachusetts undertook a large cut in the bag limits in the mid-late 90s

- Fairly steep decline in harvest in Maine in the past 4-5 years.

- Larger proportion of harvest in U.S. in 1980s and relatively low in Canada. The harvest increased in Canada but has been stable over last 10 years, therefore the overall decline in harvest is being driven by declines in the U.S.

- Canada: no apparent trend in the sex ratio. May be driven by sample size.

- Age ratio in Canada – steep decline from 2 immature/adult to less than 1 indicating that it appears to be a recruitment issue

- U.S. sex ratio - seems to be a male bias – obvious reason: there are 2 concentration areas where outfitters working, by the end of the hunting season it is not uncommon to see nothing but female birds flying the area post season

- U.S. age ratio – relatively stable, low relative to Canadian age ratio. Immature/adult females likely a better estimate given the male bias in the harvest than would the combined

- 4-month seasons and 7-bird bags are likely too high, set up 70 years ago when sea ducks were thought to be underutilized and abundant; the general feeling in the USFWS is that these regulations should be amended downward.

G. Issues with Existing Harvest Surveys

- Isotopic analysis of hatch year birds – harvest derivation. Chris Dwyer was surprised at how few wings there were from Parts Collection Survey.

- Sea duck wing returns are likely underestimated. Likely do not send out enough envelopes nor at the correct time to capture sea duck harvest (late harvest). Sea duck hunters are likely clumped so may not be represented appropriately in the card survey.

- Guided hunt - hunters are not from Maine or Massachusetts so are not getting sampled at all. The way *HIP* is set up (early 2000s), likely missing a lot of out-of-state hunters. Brad tried to survey the outfitters 15 years ago…showed that the harvest was being overestimated. Brad suggested he could try this again as they likely represent 90% of the harvest.

- Canada – card determines number of birds. Wings determine species composition.

- Do not currently specifically sample sea duck hunters in Canada, developed some questions similar to the *HIP* survey but have not been analysing the responses.

- Labrador – agreement with NunatuKavut – to collect information annually. 80 interviews of harvesters, there will be an opportunity to ask some more specific questions about location, detecting outbreaks, etc.

- SDJV – Harvest Management Sub Committee – pulling together survey information for the 5 species. State of Washington to evaluate Parts Collection Survey and participation. Does the current survey provide useful information and if so, what is it? Modelling may shed light on whether there is useful information and how to use it. Providing general information about age ratio and harvest but are the models we are using able to detect difference at the sample sizes being collected?

- ***Discussion Question:*** Where should resources be best invested? in a better harvest survey?, a better banding program? Return to this question next year.

H. Potential Impacts of Disease and Planned Studies

i. QC

- Presence of P.multocida in dead birds 2004-2006 – serotype 1

- Live birds (oral swabs) – 7 different serotypes; different from South Hampton and East Bay sampling

- Low prevalence so required large sample sizes

ii. ME

- Wellfleet Bay – Dr. Julie Ellis. Birds sent to Health Centre in Madison

- Many had few Acanthocephalans

- 2007 had a large die off of birds – viral detection

- 2010 USDA disease biologist – forwarded to South Eastern Cooperative Wildlife Disease study – ortho-mixo virus not previously seen nor reported. Preliminary reports suggested it was similar to a tick-borne virus. How would ticks be involved in the transmission cycle of this virus particularly for adult males?

- Some progress on the DNA has been made. Have not determined the host.

- Trying to determine the significance and what to do, if anything.

- Collected eggs – conducted virus testing of eider ducklings, concluded the ducklings were susceptible. Looked at whether any of the ducklings would recover but study truncated - too early to tell

- Some of the birds submitted revealed previous exposure to the virus and appeared to have healed (based on liver tissue damage and scarring)

- Looking at collecting serum from eiders at nesting colonies – closest = Boston Harbour not far from where die offs occurring. Number of nesting eiders (225) has remained relatively stable over time – concluded that the virus is not affecting local birds. Early September 2011 the males were very light.

- November 1, 2011 flew a survey in Cape Cod Bay. Saw 15,000 scoters on inside, lower portion saw 10,000 eiders offshore. Why are so many birds there in late fall?

- Planned studies this fall: Jennifer Ballard (PhD) will be working with JF, Randy, Brad, Stephan to collect blood samples for previous exposure detection

- Rhode Island telemetry study + blood collections – had detected the antibody in at least one bird this past fall.

- In 2012 funding another lab trial to examine rate of transmission; working with DNA structure research to ensure continued funding.

- No-one able to determine prevalence nor what to do about the issue if it exists. There may be a body condition issue particularly if light birds are showing up in Rhode Island.

- Some people clipping wings in an effort to determine harvest derivation based on isotopic analysis (Keith Hobson).

- Similar location to a well-publicized dolphin die off this year.

- ***Sample sizes for Jennifer*** – asked for high number of samples. Likely whatever she can get. QC – banded birds, same birds will be sampled for Pasturella (Catherine) and then another vial for Jennifer (300 birds)

I. Spring Male Survey across Breeding Range 2012 and into Future

- Working group of the Waterfowl Technical Committee developed Canadian Eider monitoring strategy for all species including dresseri outlining developmental needs for the design of the survey

- 2012: receiving money from SDJV and potentially from Atlantic Region to deliver a developmental-level survey that will examine: repeatability – how variable the counts are from one survey to the next; higher altitude surveys comparing visual estimates and aerial photographs of males. Particular difficulties may exist in the large colonies in the SLR estuary in QC.

- Look at sites in 3 jurisdictions: Quebec, Maritimes, Maine

- Identify 3 areas where you would not expect exchange between sites

- Surveyed 3 times each – one of which would also have a photographic count

- NB has been flying spring counts of surveys every 2 years – are looking to support that again this year and keep it going until can confirm that another survey is up and running

- Delivery is possible in QC but looking for location, timing, and crews in Maritimes and Maine.

- Can do replicate surveys in the same day.

- Best time appears to be during peak nest initiation; Mingan archipelago comparing ground counts

- Males are gathering around colonies around mid-April to mid-May; complete laying ~ May 25 – plan survey a bit earlier so that no males are missed (early nesters to later ones).

- ***ACTION:*** Scott looking for more information on timing

- NS: earliest recorded brood in water South Shore May 23; Tony Locke May 18-23; dramatic variability between

- Just counting males not females.

- Timing may be confounded by tidal cycle. Mendel et al. concluded that rising ½ tide likely best, a lot of variability at low tide,

- NB1: Kevin, Keith, tech – complete survey + replicates and photo survey

- NB2: Wolves, Grand Manan, Lepreau-Pocologan

- ME (Brad) fully supportive for 2013, timeline too tight for 2012

- NS – could potentially use same plane used in NB; if CWS could commit one person, could NS supply an individual? – work plan tight but will look for a qualified observer. Which might be the best sites: 3 areas that NS has been surveying in past years: archipelago, South Shore Islands (Johns, Goodwin Island), Tobacco Island, potentially also Isle Madame.

- Cannot time survey to tide since if the survey is launched it will run from Maine to Labrador. Tidal noise will be part of the survey – will not be controlling for tide. If there was dispersion due to the tides this is the year to look at that.

- Try to select in an area that is logistically feasible but it will also depend on size requirements.

- **ACTION (Keith, Scott, Randy, Kevin, Glenn):** call 13:00 Monday, 23 April 2012

J. *NEXT STEPS DISCUSSION*:

- This session is hopefully leading to an updated status report between now (April) and October 2012:

- Where do we go with banding program based on analysis to-date?

- Do not have survival data for the north shore of Quebec but do have DUC Eider Initiative data showing the same thing

- Molting males – do we know all of the major molting sites, when the birds are not in Maine or Nova Scotia do we know where the birds are molting or does it mean there has been a real population decline? Likely points to an exploratory range-wide, fixed-wing survey to determine location of molting sites and distribution of molting birds.

  - **ACTION:** NS will be flying eider banding survey; ME phalarope survey – talk to Mark re: August availability. Gaspe: August – perhaps hold over the spring survey money to next year and look to the JV to cover flight costs for Gaspe. BOAS survey will be covering molting scoter so could likely cover molting eiders in Gaspe. Would want to look from Anticosti to Blanc-Sablon to Labrador.

- ***ACTION:*** check with Tim Bowman if breeding male funds could be carried over to next year and other monies from JV could be put toward the molting study.

- Greg: telemetry would provide more elegant information and shed light on whether the birds you are finding are the birds you thought were missing or displaced from other locations.

- More discussion required to determine if it is more important to be looking at molting birds or looking for presence of juveniles.

- If recruitment is the big issue what do we do about it? Do we penalize hunters or do we tackle issues on the islands. NS: may have to look at both for a short time. May have to look to habitat restoration. Might be more palatable to hunters; demonstrate a 5-10 year plan to improve recruitment rates on the island

- Brad interested in some “surgical” gull removal

- CWS does not support predator removal on hunted populations. Could potentially revise the CWS policy or permit if this was to become an operational initiative. Initially however a scientific permit might be able to be issued to investigate the efficacy of removal of predators on recruitment…looking at productivity. If attempted the research angle in year one or two the results, backed up by the data that lack of recruitment of ducklings may be a far higher restriction than protection of females from the hunt; this may not change unless other actions are taking.

Survey

Comprehensive Banding

Research topics on juvenile dispersal

ACTION: To maintain momentum, form core Eider working group with the following membership:

Keith McAloney (chair), Brad, Chris, Dan McAuley, PEI, Adam (DUC), NS, NB, Greg, Jean Francois Giroux, Mark Mallory

Appendix II. Observations on breeding chronology of American Common Eiders in eastern Canada

			May (week)					June (week)					
Region	**Year**	**Site**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**Source**	**Comment**	**Location**
QC	2006	Battures aux Loups Marins				1%[1]					J.-F. Rail		47.2348,-70.4276
QC	2009	Battures aux Loups Marins					0%				J.-F. Rail		47.2348,-70.4276
QC	2003	île Rouge					6%				J.-F. Rail		48.0687,-69.5557
QC	2011	Caye de la baie des Plongeurs						14%			J.-F. Rail		48.7637,-68.989
QC	2010	Corossol Island					10%				J.-F. Rail		50.091,-66.3865
QC	1998	Corossol Island					10%				J.-F. Rail		50.091,-66.3865
QC	2010	le à Calculot des Betchouanes, Betchouane					0%				J.-F. Rail		50.19413,-63.22019
QC	1998	le à Calculot des Betchouanes, Betchouane						3%			J.-F. Rail		50.19413,-63.22019
QC	2010	île Innu, Betchouane					1%				J.-F. Rail		50.19413,-63.22019
QC	1998	île Innu, Betchouane						3%			J.-F. Rail		50.19413,-63.22019
QC	2010	Watshishou MBS,						2%			J.-F. Rail		50.2713,-62.635
QC	1998	Watshishou MBS,							1%		J.-F. Rail		50.2713,-62.635
QC	2010	Île à la Brume MBS								20%	J.-F. Rail		50.1777,-60.5059
QC	1998	Île à la Brume MBS								32%	J.-F. Rail		50.1777,-60.5059
QC	2010	Baie des Loups MBS								47%	J.-F. Rail		50.189,-60.2572
QC	1998	Baie des Loups MBS								47%	J.-F. Rail		50.189,-60.2572
QC	2010	îles aux Perroquets, îles Ste-Marie MBS								29%	J.-F. Rail		50.2779,-59.7433

			May (week)					June (week)					
Region	**Year**	**Site**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**Source**	**Comment**	**Location**
QC	1998	îles aux Perroquets, îles Ste-Marie MBS							50%		J.-F. Rail		50.2779,-59.7433
QC	2010	îles Ste-Marie, îles Ste-Marie MBS							18%		J.-F. Rail		50.3103,-59.6506
QC	1998	îles Ste-Marie, îles Ste-Marie MBS							45%		J.-F. Rail		50.3103,-59.6506
NB	1984	Wolves			Laying[2]						P. Hicklin	Delayed	44.904523,-66.746063
NB	1985	Wolves		Laying							P. Hicklin		44.904523,-66.746063
NB	1988	Wolves			Duck[3]						P. Hicklin		44.904523,-66.746063
NB	1989	Wolves			Duck						S. Gilliland		44.904523,-66.746063
NB	1995	Maces Bay				Duck					S. Gilliland		45.119084,-66.508484
NB	1998	Maces Bay			Duck						S. Gilliland		45.119084,-66.508484
NS	1970	Tobacco Is	Lay								K. McAloney		45.014331, -61.916199
NS	1971	Tobacco Is			Laying						K. McAloney	Delayed	45.014331, -61.916199
NS	1986	Eastern Shore					13%				R. Milton		45.014331, -61.916199
NF	1993	Hare Bay						Egg			S. Gilliland	Delayed	51.261915,-55.964355
NF	1996	Hare Bay			Egg						S. Gilliland		51.261915,-55.964355
NF	2000	Hare Bay				Egg					S. Gilliland		51.261915,-55.964355
NF	1993	St. John Bay					Egg				S. Gilliland	Delayed	50.875311,-57.205811
NF	1996	St. John Bay			Egg						S. Gilliland		50.875311,-57.205811
LB	1995	Inner Table Bay						Egg			S. Gilliland		53.678815,-56.67984

			May (week)					June (week)					
Region	**Year**	**Site**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**Source**	**Comment**	**Location**
LB	1995	Outer Table Bay							Egg		S. Gilliland		53.659289,-56.287079
LB	1995	Isthmus Bay						Egg			S. Gilliland		53.734294,-56.644135
LB	2005	St. Peter's Bay						Egg			K. Chaulk		52.056713,-55.720253

1. % represents proportion of nest hatched when island was visited.
2. Peak nest initiation estimated from nests with known laying dates.
3. Peak nest initiation calculated by back-dating foreknown age broods.
4. Peak nest initiation calculated by back-dating from candled eggs.

Appendix III. Aerial counts of adult male Common Eiders from selected archipelagos/islands in the St. Lawrence Estuary and Gulf of St. Lawrence, Québec, 2012.

Survey	Date	Archipelago	Males
1	05/05/12	Bicquette	1195
1	05/05/12	Ile aux Fraises	273
1	05/05/12	Ile aux Pommes	348
1	05/05/12	Ile Blanche	415
1	05/05/12	Ile du Bic	425
1	05/05/12	Ile Rouge	335
1	05/05/12	Pot de Vie	350
1	05/17/12	Grande Ile	73
1	05/17/12	Grosse Ile au Marteau	210
1	05/17/12	Ile Calculot	200
1	05/17/12	Ile au Goeland	264
1	05/17/12	Ile aux Lievres	325
1	05/17/12	Ile aux Perroquets	138
1	05/17/12	Ile Bouleau de Terre	31
1	05/17/12	Ile de la Maison	205
1	05/17/12	Ile du Fantome	1429
1	05/17/12	Ile du Wreck	328
1	05/17/12	Ile Herbee	221
1	05/17/12	Ile Niapiskau	78
1	05/17/12	Ile Nue	195
1	05/17/12	Ile Quarry	35
1	05/17/12	L'ilot	235
1	05/17/12	Petite Ile au Marteau	162
1	05/17/12	Petite Romaine	225
1	05/18/12	unnamed	54
1	05/18/12	Baie Johan Beetz	136

Survey	Date	Archipelago	Males
1	05/18/12	Grosse Romaine	350
1	05/18/12	Ile Bouchard	15
1	05/18/12	Ile la Chasse	200
1	05/18/12	Ile Firmin	500
1	05/18/12	Ile Gull	150
1	05/18/12	Ile Innu	900
1	05/18/12	Ile Jaune	55
1	05/18/12	Petite Ile St-Genevieve	280
1	05/18/12	WR-1	94
1	05/18/12	WR-10	27
1	05/18/12	WR-11	35
1	05/18/12	WR-12	219
1	05/18/12	WR-13	36
1	05/18/12	WR-14	95
1	05/18/12	WR-15	117
1	05/18/12	WR-16	183
1	05/18/12	WR-2	168
1	05/18/12	WR-3	42
1	05/18/12	WR-4	33
1	05/18/12	WR-5	33
1	05/18/12	WR-8	440
1	05/18/12	WR-9	28
2	05/07/12	Bicquette	2350
2	05/07/12	Ile aux Fraises	520
2	05/07/12	Ile aux Pommes	815
2	05/07/12	Ile Blanche	764
2	05/07/12	Ile du Bic	500

Survey	Date	Archipelago	Males
2	05/07/12	Ile Rouge	277
2	05/18/12	Baie Johan Beetz	247
2	05/18/12	Grosse Romaine	160
2	05/18/12	Ile Calculot	325
2	05/18/12	Ile la Chasse	56
2	05/18/12	Ile au Goeland	120
2	05/18/12	Ile aux Perroquets	280
2	05/18/12	Ile de la Maison	200
2	05/18/12	Ile de la Fausse passe	450
2	05/18/12	Ile du Fantome	300
2	05/18/12	Ile du Wreck	710
2	05/18/12	Ile Firmin	1075
2	05/18/12	Ile Gull	49
2	05/18/12	Ile Herbee	70
2	05/18/12	Ile Innu	163
2	05/18/12	Ile Nue	413
2	05/18/12	L'ilot	450
2	05/18/12	Petite Ile au Marteau	145
2	05/18/12	Petite Ile St-Genevieve	260
2	05/18/12	Petite Romaine	375
2	05/18/12	WR-1	80
2	05/18/12	WR-12	180
2	05/18/12	WR-14	60
2	05/18/12	WR-16	125
2	05/18/12	WR-2	90
2	05/19/12	Ile aux Lievres	350
3	05/14/12	Ile aux Fraises	320

Survey	Date	Archipelago	Males
3	05/17/12	Bicquette	2375
3	05/17/12	Ile aux Pommes	419
3	05/17/12	Ile du Bic	902
3	05/17/12	Ile Rouge	105
3	05/17/12	Pot de Vie	210
3	05/18/12	Grosse Ile au Marteau	206
3	05/18/12	Ile Calculot	275
3	05/18/12	Ile au Goeland	150
3	05/18/12	Ile aux Perroquets	35
3	05/18/12	Ile de la Fausse passe	165
3	05/18/12	Ile du Fantome	925
3	05/18/12	Ile du Wreck	685
3	05/18/12	Ile Herbee	125
3	05/18/12	Ile Nue	1480
3	05/18/12	L'ilot	12
3	05/18/12	Petite Romaine	280
3	05/19/12	Baie Johan Beetz	133
3	05/19/12	Grosse Romaine	190
3	05/19/12	Ile la Chasse	219
3	05/19/12	Ile Firmin	1700
3	05/19/12	Ile Gull	110
3	05/19/12	Ile Innu	850
3	05/19/12	Petite Ile au Marteau	165
3	05/19/12	Petite Ile St-Genevieve	352
3	05/19/12	WR-1	216
3	05/19/12	WR-12	111
3	05/19/12	WR-14	37

Survey	Date	Archipelago	Males
3	05/19/12	WR-15	6
3	05/19/12	WR-16	207
3	05/19/12	WR-2	109
3	05/19/12	WR-8	158
4	05/17/12	Ile aux Fraises	195
4	05/17/12	Ile Blanche	333
4	05/19/12	Grosse Ile au Marteau	220
4	05/19/12	Ile Calculot	220
4	05/19/12	Ile au Goeland	230
4	05/19/12	Ile aux Perroquets	145
4	05/19/12	Ile aux Pommes	1400
4	05/19/12	Ile de la Maison	135
4	05/19/12	Ile du Bic	980
4	05/19/12	Ile du Fantome	440
4	05/19/12	Ile du Wreck	735
4	05/19/12	Ile Herbee	100
4	05/19/12	Ile Nue	125
4	05/19/12	Ile Rouge	195
4	05/19/12	L'ilot	475
4	05/19/12	Petite Romaine	110
4	05/19/12	Pot de Vie	1216
5	05/19/12	Ile aux Fraises	360
5	05/19/12	Ile Blanche	378

Appendix IV. University Laval Statistical Consultation Service Report, 22 March 2013.

Exploratory statistical analyses of aerial breeding eider male surveys in 2012 (summary of French version)

Par
Gaétan DAIGLE et
Hélène CRÉPEAU

Service de consultation statistique
Université Laval

En collaboration avec (and translated by)
François BOLDUC

Environnement Canada

Le 22 mars 2013

UNIVERSITÉ LAVAL
Faculté des sciences et de génie
Service de consultation statistique

Photos were taken along the shores of selected eider colonies in the spring 2012. As stitching consecutive photos together along with discerning eider males from gulls and the environment, and finally counting them quickly becomes a daunting task, we explored ways to subsample photos to optimize photo processing while obtaining a reliable estimate. Three methods were explored: 1) use the unique part of each consecutive picture as sampling units; 2) use the whole picture as sampling unit; and 3) model visual counts at the colony level. In these exploratory analyses, we use only the first replicate of the survey (out of three conducted), as only this one is available at this time. Further analyses will use the full 3 replicates.

Each picture is divided in two zones, the unique part and the overlap with the neighbouring photos (fig. 1).

<u>Figure 1 :</u> The unique and overlap zones of consecutive photos for the breeding eider aerial survey in 2012.

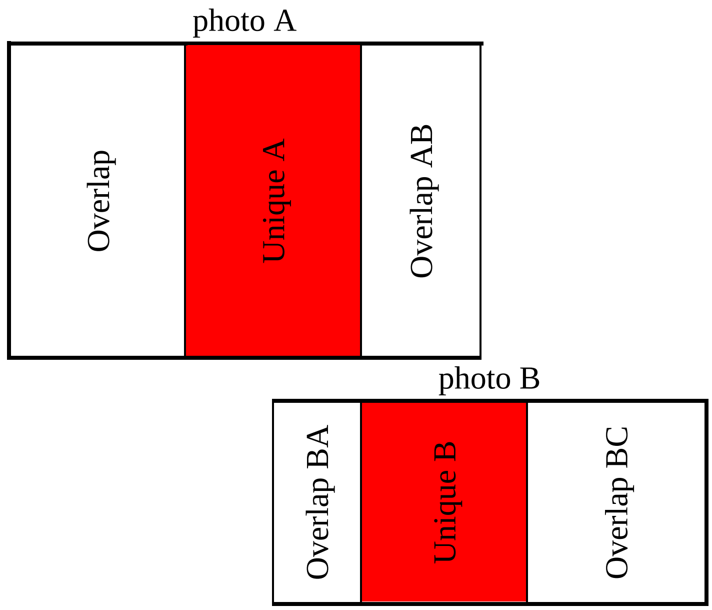


Table 1 : Number of photos (n), with average no. of eider males, its sum, standard deviation, and minimum and maximum on the UNIQUE part of pictures by colony in 2012.

Colonie	n	average	sum	sd	Min.	Max.
BAIE JOHAN BEETZ	14	16.29	228	19.22	0	61
ILE AUX FRAISES	72	14.56	1048	16.85	0	76
ILE AUX POMMES	27	36.81	994	51.05	0	189
ILE BIQUETTE	24	133.21	3197	182.39	1	829
ILE DE LA MAISON	2	286	572	117.38	203	369
ILE GULL	8	35.5	284	25.09	5	73
ILE INNU	31	71.03	2202	71.32	1	338
WR-8	44	16.18	712	20.99	0	84

Table 2 : Number of photos (n), with average no. of eider males, its sum, standard deviation, and minimum and maximum on the ENTIRE pictures by colony in 2012. Note that necessarily, many birds were counted several times as they may appear on several overlaps.

colonie	n	average	sum	sd	Min.	Max.
BAIE JOHAN BEETZ	14	35.64	499	28.8	0	81
ILE AUX FRAISES	72	34.42	2478	31.01	2	129
ILE AUX POMMES	27	62.63	1691	65.66	0	222
ILE BIQUETTE	24	412.63	9903	381.03	42	1527
ILE DE LA MAISON	2	296	592	131.52	203	389
ILE GULL	8	110.13	881	52.02	51	178
ILE INNU	31	132.16	4097	87.72	9	339
WR-8	44	40.52	1783	52.91	0	178

Table 3 : Photo and visual estimates by colony for the Breeding eider aerial survey in 2012.

	Count		
colony	Photo	Visual	Ratio Visual/Photo
BAIE JOHAN BEETZ	228	136	59.65%
ILE BIQUETTE	3197	2500	78.20%
ILE AUX FRAISES	1048	267	25.48%
ILE AUX POMMES	994	475	47.79%
ILE DE LA MAISON	572	230	40.21%
ILE GULL	284	150	52.82%
ILE INNU	2202	800	36.33%
WR-8	712	440	61.80%

The colony ÎLE DE LA MAISON was removed from further analyses as only two pictures were taken.

Estimates with the unique part of pictures as sampling unit.

Here, each colony includes a set of unique parts of the whole picture set. Therefore, we propose a sampling plan based on a simple random sample of unique photo parts.

The sample fraction necessary to obtain a relative error margin of *d%* at the level α, use the following formula :

$$n = \frac{n_0}{\left(1 + \frac{n_0}{N}\right)} \quad \text{avec} \quad n_0 = \frac{z_{\alpha/2}^2 cv^2(y)}{d^2}$$

where

N = total no. Of unique parts within a survey;

$cv(y) = \frac{s(y)}{\bar{y}}$ is the coefficient of variation of y, the latter being the no. of eider males counted on the unique part of each picture.

Table 4 shows that the picture population by colony generally is small and coefficients of variation often very large. Hence, a large percent of the unique picture parts are necessary to obtain reliable estimates of eider males by colony.

<u>Tableau 4</u> : No. of samples necessary to obtain an error margin of *d%* at alpha= 5% on the total no. of eider males by colony in 2012 when the unique parts of pictures are considered.

Colony	N	CV	*d*				
			5%	10%	15%	20%	25%
BAIE JOHAN BEETZ	14	1.18	14	14	14	13	13
ILE AUX FRAISES	72	1.16	70	64	55	47	39
ILE AUX POMMES	27	1.39	27	27	25	24	22
ILE BIQUETTE	24	1.37	24	24	23	22	20
ILE GULL	8	0.71	8	8	8	7	7
ILE INNU	31	1.00	31	29	27	24	21
WR-8	44	1.30	44	42	39	35	31

Estimates with the entire picture as sampling unit.

This method is implemented in three steps : First, we randomly select pictures, secondly, we model no. of eider males on unique parts of the pictures, finally, we combined the two steps above to obtain the eider male population by colony.

1- Sampling of entire pictures

Here, each colony is a population, but note that each bird may appear on several pictures because of the overlaps. Same formulas as for the preceding estimation method were used for the error margin of *d%* and alpha = α.

Table 5 shows that coefficients of variation were smaller compared to using the unique part of pictures as the sampling unit, and therefore a smaller percent of the no. of pictures are necessary to reach a given *d%*. However, we need to correct those estimates for multiple bird counts.

Table 5 : No. of samples necessary to obtain an error margin of *d%* at alpha= 5% on the total no. of eider males by colony in 2012 when the ENTIRE pictures are considered.

			d				
Colonie	N	CV	0.05	0.10	0.15	0.20	0.25
BAIE JOHAN BEETZ	14	0.81	14	14	13	12	11
ILE AUX FRAISES	72	0.90	69	59	48	38	30
ILE AUX POMMES	27	1.05	27	26	24	22	20
ILE BIQUETTE	24	0.92	24	23	21	19	17
ILE GULL	8	0.47	8	8	7	6	6
ILE INNU	31	0.66	30	27	22	18	15
WR-8	44	1.31	44	42	39	35	32

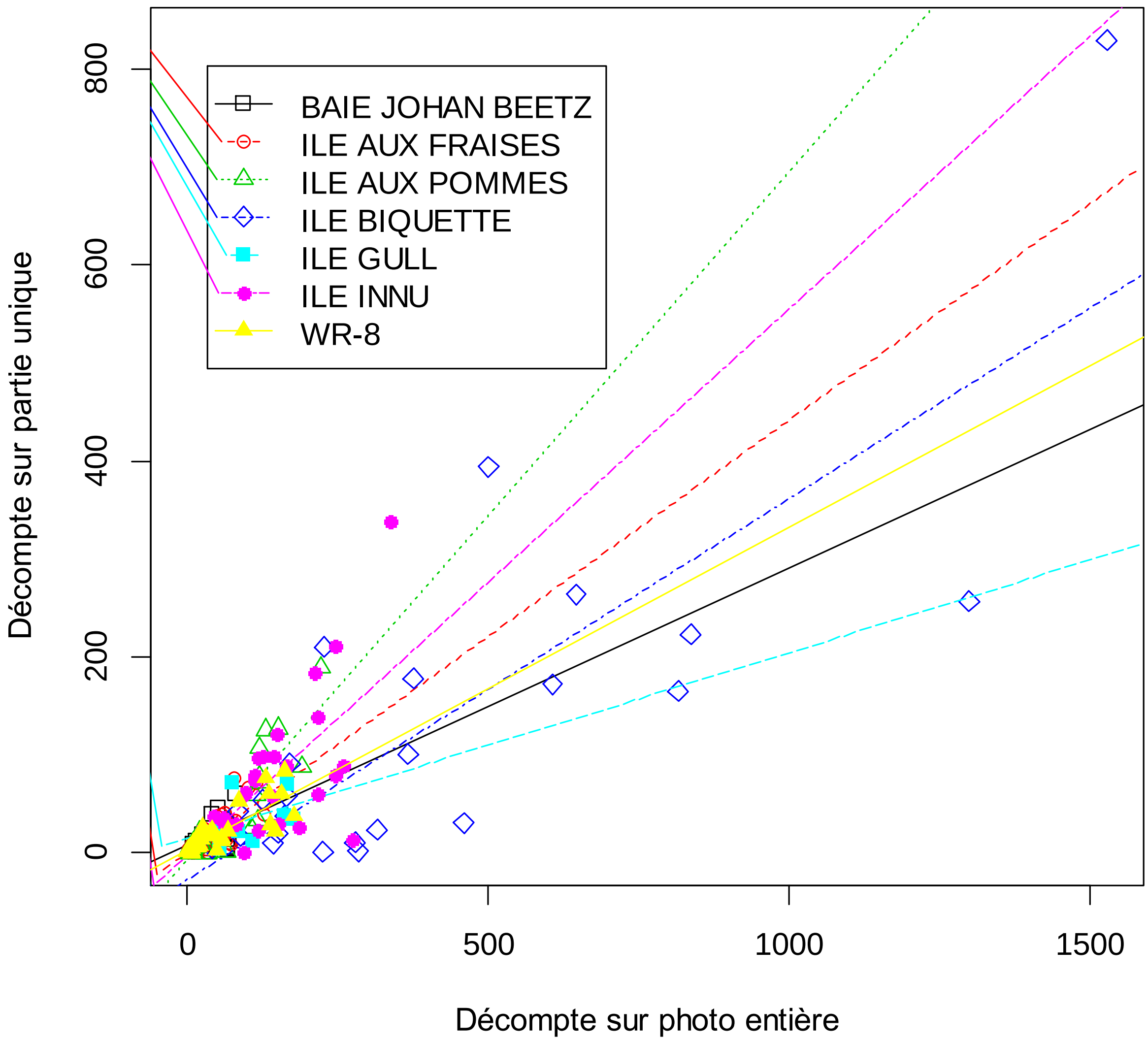
2- Relationship between counts on unique parts and on the entire pictures

Figure 2 shows that variance increased with the photo count on the entire picture and that slopes varied largely among colonies, while they all get close to the 0:0 intercept. A test of equality among slopes taking account for variance heterogeneity shows that intercepts were similar (F=0.99; df=6,194, p=0.4313), and that this common intercept did not differ from 0 (F=1.30, df=1, 194, p=0.2557), but slopes did differ among colonies (F=2.59, df=6,194, p=0.0195, Table 6).

Tableau 6 : Comparison of slopes and intercepts in the relationship between eider male counts on unique parts and entire pictures.

Effect	DF	F	Pr > F
colony	6	0.99	0.4313
eiders	1	67.95	<.0001
eiders*colony	6	2.59	0.0195

dfe = 194;
intercept: F=1.30, df= 1,194, p=0.2557



<u>Figure 2</u> : Relationship between counts of eider males on unique parts and entire pictures by colony.

To find where differences were, a model without intercept was tested. Slopes still differed largely (F=3.35, df=6, 201, p=0.0037). Table 7 shows detailed results of the above test.

Table 7: Slopes of the relationship between counts of eider males on unique parts and entire pictures by colony.

colony	slope	Standard error	CV	t	Pr > |t|
BAIE JOHAN BEETZ	0.4427	0.1202	27.15%	3.68	0.0003
ILE AUX FRAISES	0.4186	0.0401	9.58%	10.44	<.0001
ILE AUX POMMES	0.5488	0.0752	13.70%	7.30	<.0001
ILE BIQUETTE	0.3197	0.0480	15.01%	6.66	<.0001
ILE GULL	0.2849	0.0163	5.72%	17.49	<.0001
ILE INNU	0.5601	0.0573	10.23%	9.78	<.0001
WR-8	0.3782	0.0408	10.79%	9.27	<.0001

dfe=201

If we assume a common slope within colony by survey, it would be possible to use the above information to estimate the total no. of eider males by colony. It would not be possible to extrapolate to other colonies however, unless other assumptions are given.

3- Combination of sampling and modelling

The model from section 2 above is :

$$Y_{ij} = \beta_i X_{ij} + \varepsilon_{ij}$$

where

$$\varepsilon_{ij} \sim N\left(0, \sigma_i^2 \left|\beta_i X_{ij}\right|^{\theta}\right)$$

Y_{ij} = Eider male count on unique part of the j photo from colony i;

X_{ij} = Eider male count on entire photo j from colony i;

After randomly selecting n_i photos and computing the average $\bar{x}_{i.}$, we estimate the eider male population as:

$$Y_i = N_i \beta_i \bar{x}_{i.}.$$

Assuming independence between β_i et $\bar{x}_{i.}$, Mood et Graybill (1974)[1] showed that this estimate variance, as the product of two random variables is:

[1] Mood, A.M., Graybill, F.A. Boes, D.C. (1974), *Introduction to the Theory of Statistics, 3rd edition,* McGraw Hill, New York

$$\begin{aligned} \mathrm{var}(Y_i) &= N_i^2 \,\mathrm{var}(\beta_i \overline{x}_{i.}) \\ &= N_i^2 \left[\beta_i^{\,2} \,\mathrm{var}(\overline{x}_{i.}) + \overline{x}_{i.}^{\,2} \,\mathrm{var}(\beta_i) + \mathrm{var}(\overline{x}_{i.}) \,\mathrm{var}(\beta_i) \right] \end{aligned}$$

At this moment, we only know β_i and their variances. When variance of the random variables is:

$$\begin{aligned} \mathrm{var}\left(\overline{x}_{i.}\right) &= \left(c_{1i} \overline{x}_{i.}\right)^2 \\ \mathrm{var}\left(\beta_i\right) &= \left(c_{2i} \beta_i\right)^2 , \end{aligned}$$

we obtain :

$$\begin{aligned} \mathrm{var}(Y_i) &= N_i^2 \left[\beta_i^{\,2} \left(c_{1i} \overline{x}_{i.}\right)^2 + \overline{x}_{i.}^{\,2} \left(c_{2i} \beta_i\right)^2 + \left(c_{1i} \overline{x}_{i.}\right)^2 \left(c_{2i} \beta_i\right)^2 \right] . \\ &= N_i^2 \beta_i^{\,2} \overline{x}_{i.}^{\,2} \left[c_{1i}^2 + c_{2i}^2 + c_{1i} c_{2i} \right] \end{aligned}$$

and

$$cv(Y_i) = \frac{se(Y_i)}{Y_i} = \sqrt{\left(\frac{\mathrm{var}(Y_i)}{Y_i^2} \right)} = \sqrt{\left(c_{1i}^2 + c_{2i}^2 + c_{1i} c_{2i} \right)} .$$

Note that c_{1i} and c_{2i} are coefficients of variation respectively of $\overline{x}_{i.}$ and β_i . Table 8 shows coefficients of variation of Y in relation to c_1 and c_2 (alpha = 5%). Error margins are computed as Coefficient of variation multiplied by 1,96.

Table 8: Coefficients of variation of Y in relation to c_1 and c_2

	c2											
c1	**2.5%**	**5.0%**	**7.5%**	**10.0%**	**12.5%**	**15.0%**	**17.5%**	**20.0%**	**22.5%**	**25.0%**	**27.5%**	**30.0%**
2.5%	4.3%	6.6%	9.0%	11.5%	13.9%	16.4%	18.9%	21.4%	23.8%	26.3%	28.8%	31.3%
5.0%	6.6%	8.7%	10.9%	13.2%	15.6%	18.0%	20.5%	22.9%	25.4%	27.8%	30.3%	32.8%
7.5%	9.0%	10.9%	13.0%	15.2%	17.5%	19.8%	22.2%	24.6%	27.0%	29.5%	31.9%	34.4%
10.0%	11.5%	13.2%	15.2%	17.3%	19.5%	21.8%	24.1%	26.5%	28.8%	31.2%	33.6%	36.1%
12.5%	13.9%	15.6%	17.5%	19.5%	21.7%	23.8%	26.1%	28.4%	30.7%	33.1%	35.4%	37.8%
15.0%	16.4%	18.0%	19.8%	21.8%	23.8%	26.0%	28.2%	30.4%	32.7%	35.0%	37.3%	39.7%
17.5%	18.9%	20.5%	22.2%	24.1%	26.1%	28.2%	30.3%	32.5%	34.7%	37.0%	39.3%	41.6%
20.0%	21.4%	22.9%	24.6%	26.5%	28.4%	30.4%	32.5%	34.6%	36.8%	39.1%	41.3%	43.6%
22.5%	23.8%	25.4%	27.0%	28.8%	30.7%	32.7%	34.7%	36.8%	39.0%	41.2%	43.4%	45.6%
25.0%	26.3%	27.8%	29.5%	31.2%	33.1%	35.0%	37.0%	39.1%	41.2%	43.3%	45.5%	47.7%
27.5%	28.8%	30.3%	31.9%	33.6%	35.4%	37.3%	39.3%	41.3%	43.4%	45.5%	47.6%	49.8%
30.0%	31.3%	32.8%	34.4%	36.1%	37.8%	39.7%	41.6%	43.6%	45.6%	47.7%	49.8%	52.0%

For example using l'ÎLE BIQUETTE, no. of photos necessary with c_2 = 15% at a given value of c_1 is:

$$n = \frac{cv^2(x)/c_1^2}{1 + \frac{cv^2(x)}{Nc_1^2}}.$$

Assuming we have taken 26 pictures (N), and the coefficient of variation of the total count is similar to that of 2012 (0.92), and that we require a coefficient of variation of 19.8% for the population estimate, this means that we need to sample 22 pictures, for an error margin of 38.6% (=1.96* 19.8%).

If this method allows us to skip stitching the consecutive pictures within a colony, it requires to work with a large number of pictures. From the two sources of variation, i.e., sampling and modelling, we can only decrease the former by increasing n, as the latter is fixed and determined by the model at section 2.

Population estimate using the visual counts

Following examination of R^2 and residuals, the best model describing the relationship between total photo counts (sum of unique parts, DR) and visual estimates (DV) by colony is:

$$\log(\mathrm{DR}_i) = \beta_0 + \beta_1 \log(\mathrm{DV}_i) + \varepsilon_i, \quad i = 1,...,n$$

where

Parameter	Estimation	Standard error	t	Pr(>|t|)
β_0	1.3486	0.9648	1.398	0.2210
β_1	0.8950	0.1579	5.669	0.0024

n = no. Of colonies; standard error of residuals: 0.3916 with 5 df.
R^2: 0.8653, adjusted R^2 0.8384

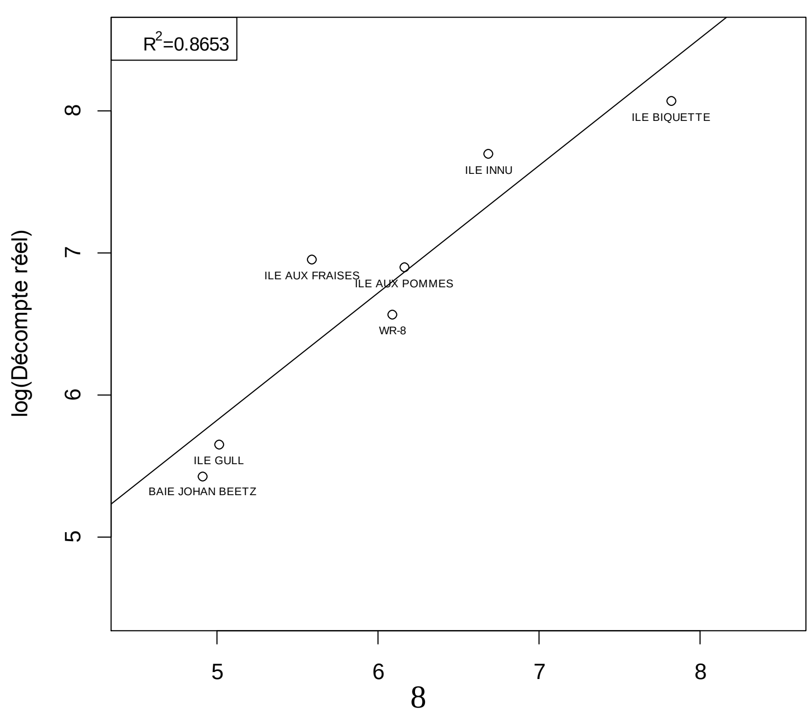


Figure 3: Linear relationship between photo counts and visual estimates (log-transformed) by colony for eider males in 2012.

New colony count can be estimated from a visual estimate using:

$$\begin{aligned} \mathrm{DR} &= \exp(\beta_0) \times DV^{\beta_1} \\ &= 3.8520 \times \mathrm{DV}^{0.8950} \end{aligned}.$$

The variance of this prediction, i.e., var(DR), is:

$$\begin{aligned} \operatorname{var}\left(DR\right) &= \begin{pmatrix} \dfrac{\partial DR}{\partial \beta_0} & \dfrac{\partial DR}{\partial \beta_1} \end{pmatrix} \begin{pmatrix} \operatorname{var}(\beta_0) & \operatorname{cov}(\beta_0, \beta_1) \\ \operatorname{cov}(\beta_0, \beta_1) & \operatorname{var}(\beta_1) \end{pmatrix} \begin{pmatrix} \dfrac{\partial DR}{\partial \beta_0} \\ \dfrac{\partial DR}{\partial \beta_1} \end{pmatrix} + MSE \\ &= \left(\frac{\partial DR}{\partial \beta_0}\right)^2 \operatorname{var}(\beta_0) + \left(\frac{\partial DR}{\partial \beta_1}\right)^2 \operatorname{var}(\beta_1) + 2\left(\frac{\partial DR}{\partial \beta_0}\right)\left(\frac{\partial DR}{\partial \beta_1}\right)\operatorname{cov}(\beta_0, \beta_1) + MSE \\ &= \left(\exp(\beta_0) DV^{\beta_1}\right)^2 \left[\operatorname{var}(\beta_0) + \log^2(DV)\operatorname{var}(\beta_1) + 2\log(DV)\operatorname{cov}(\beta_0, \beta_1)\right] + MSE \end{aligned}$$

Assuming this model is valid during another survey, photo counts of eider males derived from visual counts would be:

Table 9 : Photo count estimates (DR) for various values of visual estimates (DV) following the above model. Error margins = 1.96*cv(DR).

DV	DR	se(DR)	cv(DR)
150	341	75.0	22.0%
200	442	83.3	18.9%
400	821	121.7	14.8%
600	1180	187.0	15.8%
800	1527	274.5	18.0%
1000	1865	376.4	20.2%
1200	2195	488.2	22.2%
1400	2520	607.6	24.1%
1600	2840	732.9	25.8%
1800	3155	863.2	27.4%
2000	3467	997.5	28.8%
2200	3776	1135.4	30.1%
2400	4082	1276.5	31.3%
2500	4234	1348.1	31.8%

Precision of estimates is better for small values of visual counts (Table 9). Please note that :

1- The model is based on one year of field work only;
2- The model is valid within range of visual estimates observed in this case;
3- The model is based on few observations, rendering the parameter estimates less reliable.

Conclusion

The first method tested using the unique parts of the pictures requires large sample size to obtain an acceptable margin of error. The second method using the entire picture counts allows skipping the stitching the pictures, but also requires using a large no. of pictures. The latter also assumes that the model is stable in time, which is not testable at this time, and is not applicable to other colonies. The third method is based the colony as the sampling unit, and therefore only based on a small sample (n=7), and provides population estimates with little precision.

Appendix V. University Laval Statistical Consultation Service Report, 6 November 2013.

Sampling plan proposal to estimate the breeding eider male population in Eastern Canada (summary of French version)

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Le 6 novembre 2013

UNIVERSITÉ LAVAL
Faculté des sciences et de génie
Service de consultation statistique

Summary of previous findings

The CWS conducted exploratory surveys of breeding eider males in 2012. Eider males in the colony vicinity were photographed along the shores. Stitching photos together and counting birds quickly became a daunting task. We therefore wanted to explore ways to sample pictures to optimize our work while obtaining a reliable population estimate. A report detailing our findings is available.

We looked into sampling “unique” parts of consecutive pictures, but preliminary work suggested that a large proportion of the pictures would still be needed to obtain a reliable population estimate by colony. We also explored sampling entire pictures. This method also required a large sample of the pictures within colony to obtain a reliable population estimate. Finally, we modelled photo counts via visual estimates obtained during the surveys, with the colony as sampling unit. Sample size was small, and therefore estimates were associated with a low precision.

The preliminary work described above was based on one replicate over 9 colonies. We now have three replicates available to work with, and further aim at the estimation of the entire population over all colonies.

Measure error

Population size within colony is the sum of eider males on all « unique » parts in a given survey (replicates). Without measure error, the above number should be the same among replicates within colony. Since total count within colony among replicates differed (Table 1), the measure error was not zero, as estimated using count standard deviation.

Table 1 : Descriptive statistics of eider male counts derived from aerial photos of 9 colonies in 2012

colony	Replicate	N	Sum	Standard deviation	Minimum	Maximum
Baie Johan Beetz	1	14	228	19	0	61
	2	31	770	25	0	99
	3	17	342	22	0	74
		Standard Dev. =	286			
Biquette	1	24	3197	182	1	829
	2	28	2533	68	8	294
	3	63	3296	90	0	536
		Standard Dev. =	415			536
Ile Gull	1	8	284	25	5	73
	2	11	271	29	0	83
	3	9	321	28	0	77
		Standard Dev. =	26			
Ile Innu	1	31	2202	71	1	338
	2	34	2057	51	3	224
	3	36	2384	61	2	262
		Standard Dev. =	164			
Ile aux Fraises	1	72	1048	17	0	76
	2	158	808	6	0	29
	3	43	1144	20	0	81
		Standard Dev. =	173			
Ile aux Pommes	1	27	994	51	0	189
	2	65	1034	20	0	113
	3	23	1490	54	3	196
		Standard Dev. =	276			
Ile de la Maison	1	2	572	117	203	369
	2	12	570	61	0	164
	3	13	722	50	0	159
		Standard Dev. =	87			
Ilot	1	3	774	135	111	375
	2	6	791	140	7	342
	3	6	595	104	3	295
		Standard Dev. =	109			
WR-8	1	44	712	21	0	84

2	27	1003	36	0	155
3	26	1035	47	0	158
	Standard Dev. =	178			

The measure error over all colonies is computed over all 3^9 = 19,683 possible combinations over all 9 colonies and their associated three replicates. Population size varied between 8,755 and 11,953, with an average size of 10,388. The measure error over this estimate is 541 (standard deviation), or 5.21% (Table 2).

Table 2 : Descriptive statistics of the entire eider male population in 2012.

N	Mean	Median	CV	Standard deviation	Minimum	Maximum
19 683	10 388	10 402	5.21	541	8 755	11 953

Error related to the sampling plan and model

We use the method presented in the last section of our previous report to estimate the entire population size. We first sampled entire pictures. Secondly, we predicted their associated "unique" parts. Finally, we combined the two steps to model population size.

We modelled the relationship between eider male counts on "unique" parts based on counts over entire pictures using a regression model with random slopes without intercepts, based on the 834 pictures available over all replicates. There is a slope for every replicates within colony (27 slopes), but expressed as random deviations of the common slope.

$$Y_{hij} = (\beta + \delta_{i(h)}) X_{hij} + \varepsilon_{hij} \tag{3.1}$$

where

Y_{hij} = Eider count on unique parts of the j photo of replicate i of colony h;

X_{hij} = Eider count on the entire j photo of replicate i of colony h;

β = common slope;

$\delta_{i(h)}$ = random deviation of the slope of replicate i of colony h of β;

ε_{hij} = residual error,

with

$$\delta_{i(h)} \sim N\left(0,\sigma_{\delta}^{2}\right) \quad \text{and} \quad \varepsilon_{hij} \sim N\left(0,\sigma_{\varepsilon}^{2}\right).$$

The model above provided the estimates below :

Table 3 : Parameter estimates from model described at equation (3.1).

Parameter	Estimate	Standard error
β	0.5249	0.0248
σ_δ^2	0.0117	0.0044
σ_ε^2	1192.9645	59.2957

From this model, we can estimate the total eider count in the population by multiplying β with the sum of eiders over all complete pictures. Therefore, this parameter can be used as a correction factor for eiders potentially found on several pictures.

Secondly, we consider a sampling plan to reduce work necessary for counting eiders over all entire pictures taken during the survey. We propose a random sampling stratified proportionally by colony. Considering $\overline{x_h}$, h=1, …, 9, the average eider count over n_h entire photos sampled in stratum h, the eider population is :

$$Y = \sum_{h=1}^{9} Y_h = \sum_{h=1}^{9} \beta\left(N_h \overline{x_h}\right),$$

where N_h is the number of pictures taken during the survey of stratum h. Since $Y_h = \beta\left(N_h \overline{x_h}\right)$ is the product of two random variables, its variance computed using the delta method. Assuming independence between β et $\overline{x_h}$,

$$\begin{aligned}\operatorname{var}(Y_h) &= N_h^2 \operatorname{var}(\beta \overline{x}_h) \\ &= N_h^2\left[\beta^2 \operatorname{var}(\overline{x}_h) + \overline{x}_h^{\,2} \operatorname{var}(\beta) + \operatorname{var}(\overline{x}_h)\operatorname{var}(\beta)\right],\end{aligned}$$

and

$$\operatorname{var}(Y) = \sum_{h=1}^{9} \operatorname{var}(Y_h).$$

The confidence interval (95%) associated with the population estimate is:

$$Y \in \left[Y \pm \Delta\right] \quad \text{où} \quad \Delta = 1.96\sqrt{\operatorname{var}\left(Y\right)}.$$

Quantity Δ is the absolute error margin. The relative error margin is Δ divided by Y.

We conducted simulations to explore the precision of the above population estimate, based on the 19,683 populations described previously. We sampled each population, every time varying the sampling fraction between 25 and 100%. We estimated the population size and its variance using the above method. The mean error margin provided us with an estimate of the magnitude of the precision we may have in a future survey (Table 4).

Table 4 : Eider male population size in 2012 (Y), its associated standard error (se(Y)), and its relative error margin ($\Delta_r = \Delta / Y$) at alpha = 95%, by sampling fraction 5% class within a stratified sampling plan proportinnal to the colony.

f	Parameter	Mean	Min	Max
25%	Y	10 862	6 153	21 038
	se(Y)	1 389	568	3 150
	Δ_r	24.6%	14.3%	50.2%
30%	Y	10 884	6 124	18 418
	se(Y)	1 233	504	2 456
	Δ_r	21.9%	13.2%	39.9%
35%	Y	10 882	6 390	17 273
	se(Y)	1 128	571	2 123
	Δ_r	20.0%	13.1%	34.3%
40%	Y	10 868	6 548	17 265
	se(Y)	1 044	552	1 922
	Δ_r	18.6%	13.0%	30.6%
45%	Y	10 875	6 171	16 950
	se(Y)	982	524	1 727
	Δ_r	17.5%	12.7%	28.6%
50%	Y	10 875	6 900	16 672
	se(Y)	931	522	1 609
	Δ_r	16.6%	12.0%	25.6%
55%	Y	10 867	7 253	16 671
	se(Y)	846	495	1 335
	Δ_r	15.1%	11.8%	21.4%
60%	Y	10 868	7 594	15 523
	se(Y)	803	489	1 230
	Δ_r	14.4%	11.4%	19.4%

f	Parameter	Mean	Min	Max
65%	Y	10 870	7 444	15 382
	se(Y)	761	440	1 147
	Δ_r	13.6%	11.2%	18.0%
70%	Y	10 873	7 779	15 074
	se(Y)	712	436	1 055
	Δ_r	12.7%	10.7%	16.3%
75%	Y	10 870	7 862	15 107
	se(Y)	678	441	993
	Δ_r	12.1%	10.4%	15.3%
80%	Y	10 873	7 991	14 826
	se(Y)	631	432	875
	Δ_r	11.3%	10.2%	13.1%
85%	Y	10 869	8 057	14 593
	se(Y)	594	425	811
	Δ_r	10.7%	9.9%	11.9%
90%	Y	10 867	8 226	14 489
	se(Y)	565	410	764
	Δ_r	10.2%	9.6%	11.0%
95%	Y	10 867	8 457	14 314
	se(Y)	537	410	713
	Δ_r	9.7%	9.4%	10.1%
100%	Y	10 869	8 509	14 204
	se(Y)	514	402	672
	Δ_r	9.3%	9.3%	9.3%

Similar simulations using a simple random sampling plan provided larger error margins.

Combination of the two error margins

The variance associated with the population estimate is constituted of the measure error and the sampling error. Assuming their independence, the estimate error is the sum of these variances. The relative global error margin $\Delta_r^{(g)}$, is the sum of ($se(Y)^2$) and ($s_T^2 = 541^2$):

$$Y \in \left[Y \pm \Delta_r^{(g)} Y \right] \text{ au niveau de confiance 95\%,}$$

with

$$\Delta_r^{(g)} = \frac{1.96\sqrt{se(Y)^2 + 541^2}}{Y}.$$

For example, at f=50%, we get:

$$\Delta_r^{(g)} = \frac{1.96\sqrt{931^2 + 541^2}}{10875} = 19.4\%.$$

5. Conclusion

Number of pictures in the 19,683 populations varies between N=175 and N=427, with an average of N=278. Using f=50%, we can expect to use about n=139 photos. With this kind of effort, it remains that it will not be possible to obtain a reliable estimate by colony. With a global margin of error of 19.4% at f=50%, we can expect a much higher margin of error for each colony. Our proposed stratified sampling plan has for advantage to ensure the usage of photos from each colony, which still be able to provide a magnitude of order of colony size; albeit associated with a low precision. Finally, a primary assumption for future survey is that β doesn't vary among years, at 0.5289.