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Estimating abundance and total allowable removals for walrus in Foxe Basin

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Walruses are harvested in the Foxe Basin area for subsistence, and there is a limited sport hunt. Here we examine historic and recent walrus surveys, conducted by DFO over a time span of almost three decades, to assess whether there is any evidence of a change in walrus abundance. Aerial surveys were flown in 1983, 1988, 1989, 2010 and 2011. The 1983 surveys were counts of hauled out animals using methods similar to recent surveys flown in 2010 and 2011. The 1988 and 1989 surveys used strip transect survey methods. The 1983 survey had a haulout count of 2,314, while the strip transect surveys produced estimates of 5,128 (SE=4,390) and 5,510 (SE=1,644), respectively. Four recent counts in 2010 and 2011 were between 2,409 and 6,043. Although different methods were used, there is no evidence for a temporal trend in abundance over the last 28 years. The 2010 and 2011 surveys were re-analysed using a simple count approach only and a haulout proportion of 0.37 (SE=0.16) based on satellite transmitter deployments in Foxe Basin during the same years. The resulting abundance estimates are 10,435 (SE=4,513) in 2010 and 14,093 (SE=6,704) in 2011. The total allowable removals (TAR) were estimated from the Potential Biological Removal (PBR) calculations with an R_{max} of 0.07 or 0.08 and, a Recovery factor of 0.5 or 1.0. Depending on the R_{max}, recovery factors, and whether the 2010 or 2011 abundance estimate was used, the TAR varied from 129 to 385.

Estimation de l'abondance et prélèvements totaux autorisés de morses dans le bassin Foxe

RÉSUMÉ

Les morses du bassin Foxe font l'objet d'une chasse de subsistance et d'une chasse sportive restreinte. Le présent article étudie les relevés historiques et récents portant sur le morse réalisés par le MPO au cours des quelque 30 dernières années, afin de déterminer s'il y a des preuves de changement de l'abondance du morse. Des relevés aériens ont été effectués en 1983, 1988, 1989, 2010 et 2011. Le relevé de 1983 consistait à dénombrer les individus se trouvant dans les échoueries au moyen de méthodes similaires à celles employées pour réaliser les relevés de 2010 et de 2011. Les relevés de 1988 et de 1989 ont été effectués selon la méthode du dénombrement par transect en bande. Lors du relevé de 1983, on a recensé 2 314 individus, alors que les relevés par transect en bande ont donné lieu à des estimations de 5 128 individus (ET=4 390) et de 5 510 individus (ET=1 644), respectivement. En 2010 et 2011, quatre dénombrements ont chacun recensé de 2 409 à 6 043 individus. Malgré l'utilisation de méthodes différentes, il n'est ressorti aucune indication de tendance temporelle de l'abondance au cours des 28 dernières années. Les relevés de 2010 et de 2011 ont fait l'objet d'une nouvelle analyse au moyen d'une méthode de recensement simple et d'une proportion moyenne de 0,37 individu dans les échoueries (ET=0,16), en utilisant les données transmises par des émetteurs satellites installés au cours des mêmes années. Les estimations d'abondance obtenues sont de 10 435 individus (ET=4 513) pour 2010 et de 14 093 individus (ET=6 704) pour 2011. L'estimation des prélèvements totaux autorisés a été établie en fonction des calculs du prélèvement biologique potentiel, en tenant compte d'un taux d’accroissement maximum R_{max} du stock de 0,07 ou de 0,08 et d'un taux de rétablissement de 0,5 ou de 1,0. Selon le taux d’accroissement maximum R_{max} du stock et l'utilisation de l'estimation d'abondance de 2010 ou de 2011 aux fins de calcul, les prélèvements totaux autorisés allaient de 129 à 385 individus.

INTRODUCTION

Walruses in Canada and Greenland are harvested for subsistence, and in addition there is a limited sport hunt in Canada. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed Atlantic walrus as 'Special Concern' (COSEWIC 2006). Atlantic walruses in Canada are also listed under Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which means that a permit from the Canadian CITES authorities is required to export walrus parts from Canada.

Walruses in Canada can be divided into two populations, a High Arctic population and a central Arctic population based on analysis of microsatellite DNA (Shafer et al. 2014). A total of seven stocks have been identified, based on a combination of scientific data (genetic, distributional, telemetry, and stable isotope), and Traditional Ecological Knowledge, with three stocks occurring within the High Arctic population: Penny Strait-Lancaster Sound, West Jones Sound and Baffin Bay (shared with Greenland) stocks and four stocks occurring in the Central Arctic population: Hudson Bay-Davis Strait (shared with Greenland), Northern Foxe Basin, Central Foxe Basin, and a South and East Hudson Bay stock (Fig. 1)(Stewart 2008; DFO 2013; Shafer et al. 2014). For management purposes the Foxe Basin stocks are combined into a single management unit.

Data are limited on walrus abundance in Canada. Consequently, walrus populations have been considered data poor and the Potential Biological Removal (PBR) approach (Wade 1998; Stenson et al. 2012) has been used to estimate Total Allowable Removals (e.g., Stewart and Hamilton 2013).

For the Foxe Basin management unit, Stewart and Hamilton (2013) presented Total Allowable Removal (TAR) estimates of 106 to 166, depending on the abundance estimate that was used, an R_{max} of 0.07 and a Recovery factor (F_R) of 0.5. They argued that since there was insufficient information available to determine population trend, a F_R of 0.5 should be used. However, during consultations with hunters in 2014, other data sources that might provide insights into changes in walrus abundance in the Foxe Basin area were identified. Fisheries Management requested that Science explore whether other information on walrus abundance was available and if so, whether this information could provide insights into changes in walrus abundance in the Foxe Basin area. Stewart and Higdon (unpublished report) recently completed a review of available information on walrus abundance and harvests in Foxe Basin and were able to obtain information on survey efforts in the 1980s, which provide insights into walrus abundance at that time. In this study, we examine some of the previous estimates of abundance from Foxe Basin, and discuss whether values other than 0.5 would be appropriate as a F_R.

MATERIALS AND METHODS

SURVEYS/COUNTS

The material for this study used haulout counts from surveys flown in August-September 1983, 2010 and 2011, and systematic strip transect surveys flown in July-August 1988, and 1989 (Orr et al 1986; Richard unpublished report[1]; Stewart and Hamilton 2013; Stewart and Higdon unpublished report). These data are presented, analysed to estimate abundance, corrected for animals not hauled out at the time surveys were flown, and used to estimate TAR.

In September 1982, a boat reconnaissance was undertaken from Igloolik. This survey was not used in any analyses, because of limited coverage. In 1983, harvest information and information from hunters was used to determine areas where walruses were most likely to be encountered.

On 19 and 20 August 1983, surveys were flown, at an altitude of 61-457m, with 150 m being the preferred altitude (Orr et al. 1986).

During August 1988 and July 1989, east-west systematic strip transects were flown using a de Havilland Twin Otter (Richard unpublished report). The aircraft flew at an altitude of 457 m and speed of 185 km/h. Struts and windows were marked to delimit strip widths of 800 m on each side of the aircraft. Transect spacing was 18.52 km. Data were analysed using the methods developed for strip transect visual surveys (Richard unpublished report).

During August and September of 2010 and 2011, boat and aerial surveys were completed in Foxe Basin (Stewart et al. 2013). Scientific literature, Inuit Qaujimajatuqangit (IQ) and other sources were used to identify haulout sites in northern Foxe Basin. The surveys attempted to include all known and suspected walrus haulout sites in the area along with most of the coastline and islands. Sites were examined repeatedly each year, as weather and logistics allowed, in the season when maximum numbers were expected to occur. Boat surveys were conducted on or around the same dates as the aerial surveys, depending on weather and water conditions. It is understood the boat-based photographs underestimate walrus at haulout sites since the images are captured from the same plane as the walrus; animals behind the first row have a high probability of being unavailable for counting. Aerial surveys were flown using a de Havilland Canada DHC-6 Twin Otter at a target altitude of 300 m ASL and at about 210 km/h flying about one km off of the coastline (Stewart et al. 2013). There were at least two observers, one per side, on all flights, but usually also a third observer. Walrus numbers were estimated independently by each observer and oblique aerial photographs were taken when possible using digital cameras. The surveys spanned several days due to weather and logistic delays, and walruses could have moved from one haulout to another. A time-distance criterion (45 km/24 h) was applied to reduce the probability of double-counting, which meant that final counts were based on fewer haulout sites than were examined in total (Stewart et al. 2013). The survey was designed to directly count walruses at haulouts sites (colony counts), and the largest counts of walruses that satisfied the distance-time criterion were added to produce the Minimum Counted Population (MCP) (Stewart et al. 2013). Walruses counted opportunistically in the water between haulouts were included in the MCP.

ADJUSTED COUNTS

Satellite transmitters were deployed during the 2010 and 2011 surveys and these were used to adjust the surveys flown in 2010 and 2011 (Stewart et al. 2013). Data from satellite-linked radio tags (11 deployed in 2010, 23 deployed in 2011) were used to obtain estimate the proportion of animals hauled out. The MCP of walruses hauled out (MCP_{HO}) was converted to an estimate of total stock size using two different adjustments:

1. Stewart et al. (2013) suggested that haulout count data were collected during optimum periods and used an estimate of the maximum proportion of a population hauled out concurrently (0.74, SE=0.015) based on pooled data from studies in Alaska, Greenland and Norway, which was applied to the MCP counts.
2. A second adjustment factor was applied to the MCP counts based on the proportion of animals determined to be hauled out at the time of the survey.

The proportion hauled out differed slightly between 2010 (0.375, N=8 transmitters) and 2011 (0.36, N=11 transmitters). We combined the two estimates, resulting in a mean proportion of animals hauled out of 0.37 (SE=0.16).

NEW ANALYSES

The haulout counts from 1983 were not changed. The data from the strip transect surveys flown in 1988 and 1989 were re-analysed using slightly different methods (Stenson et al. 2005), but the estimates of animals observed remained the same.

The 2010 and 2011 surveys consisted of counts at haulout sites. These data were re-examined and where multiple counts for a haulout were available without contradicting the distance rule, the average count was used. Counts from haulouts visited once, and average counts for sites visited multiple times were summed. These are referred to as a Simple Count (SC).

Counts from the different studies were adjusted to account for animals in the water at the time the surveys were flown by dividing counts by 0.37 (SE=0.16) to provide an estimate of total abundance.

CATCH DATA

Catch data from 1960 to 2014 were obtained from Stewart et al. (2014a) and DFO Fisheries Management (Table 1). The harvest data suffer from three sources of bias. In all hunts, some animals may be killed or wounded, but not all of these animals are recovered. This is referred to as Struck and Lost (SL). Information on SL from harvesting in Canada is limited. Loss rates of 20-30% have been reported for Greenland (Witting and Born 2005). Some early hunts observed during the 1950s in Canada reported SL of 30-60% (Loughrey 1959). More recent SL estimates from the 1970s and 1980s range from 30-38% (Mansfield 1973, Orr et al. 1986, Freeman 1974/75 in Stewart et al. 2014a). NAMMCO assumes a SL of 30% unless there is more specific information available (NAMMCO 2006). DFO has used a SL of 30% (DFO 2002). Hunters report SL of only 5% (Stewart and Higdon unpublished report). A second source of bias is non-reporting of harvests by individual hunters. The third source of bias is the non-reporting of community harvest statistics, such that no data are available for the community in a given year. To estimate average harvests, when data were missing from the community, we used the average harvest for the nearest five years to interpolate for the missing year.

MODEL ANALYSES

Strip transect surveys

The number of animals for the i^{th} survey was estimated by: $N_i = \sum_{j=1}^{J} x_i \bullet k_i$ [1]

where: J_i=the number of transects in the i^{th} survey;

k_i=weighting factor for the i^{th} survey determined by dividing the transect interval by the transect width; and x_j=the number of animals on the j^{th} transect.

The estimates of sampling variance, based on serial differences between transects

(Kingsley et al. 1985), were calculated as: $V_i=\frac{k_i\,(k_i-1)}{2}\sum_{J=1}^{J_{i-1}}(x_j - x_{j+1})^2$ [2]

Correcting for animals in the water

The estimates of hauled out walrus (N_{uncor}) can be corrected for animals in water when the survey was flown, by dividing by the proportion of animals hauled out from satellite telemetry

(Pi). The estimates of N_{uncor} and P_i are independent and therefore the error variance can be estimated using:

$$var(Count_{corr}) = \frac{var(Count)}{p^2} + Count\,\frac{1-p}{p} + \frac{Count_{corr}^2}{p^2} var(p) \qquad [3]$$

where: Var=the variance in the survey count (count) and proportion hauled out (p) (Thompson and Seber 1994)

Total Allowable Removals

Total allowable removals were calculated using the Potential Biological Removal (PBR), which is calculated from :

$$PBR= 0.5 \quad R_{max} \cdot F_R \cdot N_{min}; \qquad [4]$$

where R_{max} is the maximum rate of population increase, F_R is a recovery factor (between 0.1 and 1), and N_{min} is the estimated population size using the 20-percentile of the lognormal distribution (Wade 1998). In previous assessments, an R_{max} of .07 has been used (e.g., Stewart and Hamilton 2013). However, in the most recent assessments, of Pacific walrus in the United States, an R_{max} of 0.08 is used as the default. Here, we calculate PBR using an R_{max} of 0.07 and 0.08.

RESULTS

The area covered by the 1983, 1988, 1989, 2010 and 2011 aerial surveys is shown in Fig. 2. A total of 2,722 walrus were observed in 1983, the majority of which were observed on the 19 August (Table 2) survey. Approximately 85% of the sightings were of hauled out animals.

In 1988, a total of 443 walrus were detected on transect, resulting in an estimated abundance of 5,128 (SE=4,390, CV=0.86)(Table 3. The CV was very high on this survey due to 89% of the walrus sightings occurring on a single transect. In 1989, a total of 476 walrus were detected on transect resulting in an estimated index of abundance of 5,510 (SE=1,644, CV=0.30) (Table 3, Fig. 2). More animals were seen in the water during the 1989 survey, but the proportion of animals in the water was not determined. Thus estimates may be positively biased.

Stewart et al (2013) examined haulouts in 2010 and 2011 (Fig. 2). MCP estimates for Foxe Basin were 3,861 and 6,043 for 2010 and 2011 respectively. The 2010 estimate was based on counts carried out over the 29 and 31 August and 1 September from six haulouts, and included 13 animals seen at sea. The 2011 count was also based on six haulouts surveyed on 12 and 13 September and included 10 animals seen at sea. SC estimates based on aerial survey counts from five haulout sites were 5,945 for 12-13 September 2011 and 4,484 from the 19 September, when four sites were counted using aerial counts only (Table 4).

In 2010, Stewart et al. (2013) assumed that the proportion of animals hauled out was 0.74, which produced an adjusted MCP of 5,200 animals. In the same year 2,409 animals at two haulouts, plus another 25 at sea were also counted. Eight satellite transmitters were transmitting at the time. Correcting the count for the proportion of animals hauled out, resulted in an adjusted estimate of 6,480 animals (Table 5). In 2011, the count of 6,033 was adjusted by dividing by 0.74 to produce an adjusted MCP of 8,153 (Stewart et al. 2013). In the same year, a count of 3,368 was made at South Ooglit Island. At this haulout, four of the 11 tagged animals were hauled out, resulting in a proportion hauled out of 0.36. Adjusting the counts for the Ooglit Island haulout only, resulted in an adjusted estimate of 9,262, to which 1,117 walrus at three other haulout sites were added to produce an estimated count of 10,379. In the data, used in the earlier study, there appears to be a minor calculation error, correcting for this results in an estimate of 10,472 (Table 5).

RE-ANALYSIS

The counts and estimates of hauled out animals from studies completed in 1983, 1988, and 1989, were adjusted assuming that the proportion of the population hauled out was 0.37 (SE=0.16)(Table 5). The survey completed in 2010 also appear to represent Simple Counts (N=3,861), so we adjusted the counts from this survey using a proportion hauled out of 0.37, which resulted in an abundance estimate of 10,435 animals (Table 6). We also re-examined the estimates from the surveys flown on 12 and 13 September 2011, and recalculated these using the Simple Count approach. This resulted in a count of 5,945 animals, which was adjusted assuming that a proportion of 0.37 of the stock was hauled out when the survey was flown, which resulted in an abundance estimate of 16,068 animals (Table 6). Animals counted in the water during these haulout surveys were not included. We also adjusted the counts from the survey that focused on the South Ooglit animals. Instead of correcting only the counts from the south Ooglit islands for animals not hauled out, we also include the counts from the 3 additional haulouts surveyed at the time, and divided the combined total of hauled-out animals by 0.37 resulting in an abundance estimate of 12,119 animals (Table 6).

From the surveys completed in 2010 and 2011, there are several estimates of total abundance, and consequently PBR. Three surveys represent Simple Counts, while a fourth count from 2010 was not included because it represented counts from only two haulouts. The 2010 estimate was 10,435 (SE=4,513, CV=0.43). We took the average from the two haulout the counts from 2011 (5,945 and 4,484) (Table 6), which resulted in a mean estimate of hauled out animals of 5,214 (SD=1,033). Adjusting this estimate for animals not hauled out during the survey using a haulout proportion of 0.37 (SE=0.16), results in a total estimate of 14,093 (SE=6,704; CV=0.47) for 2011(Table 7). PBR estimates ranged from 129 animals using the 2010 abundance estimate of 10,439, a R_{max} of 0.07, and a F_R of 0.5 to a PBR of 385 animals using the 2011 abundance estimate of 14,093, a R_{max} of 0.08 and F_R = 1. PBR estimates using a third value for F_R of 0.75 were intermediate (Table 7).

Reported harvests for the communities of Igloolik and Hall Beach are listed in Table 1. Harvests have varied without trend since the 1950s (Fig. 3). The average reported harvest for the five years ending in 2014 was 170 animals (SE=25). The average harvest for 1980-2014, when allowable harvests per hunter were reduced from 7 to 4, is 189 (SE=61) (Stewart and Hamilton 2013). Using the average harvest from the last five years, and assuming a SL rate of 30%, reported removals from this stock would have averaged 243 animals.

DISCUSSION

Two approaches are generally used to assess walrus abundance. One design is to survey along parallel lines and record walrus sightings using line-transect or strip transect methods. Such surveys are usually flown during the spring (April-May), when walruses may be hauled-out on ice (e.g., Udevitz et al. 2001; Heide-Jørgensen et al. 2014). This approach was used by Richard (unpublished report) to survey walruses in Foxe Basin, but during July-August 1989 and 1990. A second approach, which was used by Orr et al. (1986) and Stewart et al. (2013), involves coastal surveys, visiting terrestrial haulout sites and floating ice in areas where walruses are known to occur during summer or early fall. These counts or survey estimates of animals hauled out, are then adjusted for the proportion of animals that are thought to be in the water during the survey to obtain an estimate of abundance. Walruses are very clumped in distribution (Udevitz et al. 2001, 2009; Lydersen et al. 2008). In a traditional transect survey an estimate of survey variance is obtained as part of the survey design. Owing to the clumped distribution of walrus, the resulting estimates are highly uncertain, making it hard to detect changes in population abundance. In the coastal haulout approach, it is assumed that the count uncertainty is close to zero. Multiple counts of the same sites have been completed but these counts are more likely to reflect changes in the proportion of animals hauled out, than the uncertainty in counts, unless these counts are repeated within a very short time frame. Haulout count data may also be problematic when trying to examine population trends if different sites and number of haulout sites are visited during different surveys; even when the same sites are visited there may be uncertainty concerning whether animals have abandoned sites, chosen new sites, or have shifted to another previously identified site during the survey (e.g., Stewart et al 2014b, c).

The studies completed in Foxe Basin between 1983 and 2011 all used different methods (strip transect surveys, count studies), flown at different periods (July-August, August-September) to obtain information on walrus abundance. The studies provide useful information with respect to broad trends in walrus abundance over a 30 year period. The different studies essentially represent three data points with 1 survey flown in 1983 (Orr and Rebizant 1987), a second study, resulting in two remarkably similar estimates of walrus abundance, one in 1988 and the second in 1989 (Richard unpublished report) and a third study, which also produced very similar counts over a two year period (2010, 2011) (Stewart et al. 2013). From these data, there is no obvious temporal trend in abundance (Fig. 4). Also, over the period examined, harvests have remained relatively stable, which is also consistent with local hunter views that the population is stable (Aqatsiaq 1996; Ivalu 1996; Makkik and Ipkangnak 1996).

Several different methods have been used to estimate walrus abundance in Canada (e.g., Simple Counts, Minimum Counted Population (MCP) and Bounded Counts (BC) (Stewart et al. 2013, 2014 b,c). These methods differ in what they are estimating and in the types of adjustment factors that are appropriate to adjust the counts for the proportion of animals hauled out (Doniol-Valcroze et al. 2016). Many surveys are only able to count walruses at a haulout site a single time. In cases where a haulout site is visited more than once, the average of the counts is taken (Simple Count method), the highest of the counts is retained (MCP), or a new estimate is generated, which in theory may already account for some proportion of the population that is not hauled out (BC). Since the MCP is assumed to retain a count that was supposedly obtained during more favourable conditions, and BC supposedly compensate for some unknown proportion of the population that is hauled out, it has been suggested that these estimates should be adjusted assuming that an optimum or maximum proportion (versus a simple average) of the population is hauled out when the counts were made. However, this presents a sampling challenge, since it is not clear, what maximum proportion of the haulout distribution should be used (e.g., the highest 5, 15 or 20%) (Doniol-Valcroze et al. 2016). Since it is not clear what factors are affecting walrus haulout behavior (see Doniol-Valcroze et al. 2016), it is more appropriate to take the average of multiple counts, and to adjust the counts using an average proportion of animals hauled out, preferably based on transmitters deployed during the study (Doniol-Valcroze et al. 2016).

In this study, the SC from the 2010 and 2011 aerial surveys of Foxe Basin were used and adjusted for the proportion of animals that were hauled out (P=0.37, SE=0.16) during the survey using information from 19 transmitters deployed in 2010 and 2011 (Stewart et al. 2013). In 2011, an estimate of average haulout abundance was obtained by combining two surveys and adjusting for the proportion of the population that was hauled out. It is possible to assess the relative contribution to the overall variance of the counts and the telemetry data, by comparing the CV^2 of the total mean count and the sum of proportions hauled out (Thompson et al. 1997). For the 2011 data, 79% of the variance is due to the telemetry data while only 21% of the variance is due to the count data. It is clear that estimates of walrus abundance are very sensitive to the adjustment factor and its associated uncertainty used to account for walruses that were in the water when the survey was flown. Improvements in our understanding of factors affecting haulout are needed to improve estimates of walrus abundance (Doniol-Valcroze et al. 2016).

PBR was developed in the United States to meet legislative requirements identified under the *Marine Mammal Protection Act*. Model simulations have shown PBR to respect management objectives in spite of some reasonable levels of bias (Wade 1998). Another advantage is that it only requires a single number to obtain an estimate of allowable removals. PBR estimates tend to be conservative, but since harvesting was not considered as a management objective in the simulation trials, it can impose a cost to hunters in terms of lost opportunities of harvest. When multiple estimates are available, it is not clear what values should be used or how they might be combined, consequently, there can be considerable variability in suggested removal levels. To date, Canada has used the default values for R_{max}, but the selection of the F_R has varied depending on the fishery. For narwhal, a F_R of 0.5 or 1 have been selected, while under the Atlantic Seal Management Strategy the F_R is set to 1, unless there is an obvious serious conservation concern (Stenson et al. 2012). For Atlantic walrus, Stewart et al. (2013) provided PBR estimates, using a F_R of 0.5, and if there was evidence that the stock was not depleted a value of 1 was also presented. The use of the term ‘depleted’ is unfortunate, because in the United States this term has very specific meaning within the *Marine Mammal Protection Act*, but Stewart et al (2013) considered a stock to be depleted if it showed evidence of decline. Because they found no evidence of decline in the Western Jones Sound and Penny Strait-Lancaster Sound stocks, PBR estimates using a F_R of 1.0 were also determined (Stewart et al. 2013).

In this study, we used values for R_{max} of 0.07 and 0.08. In earlier work, it was argued that 0.08 was not appropriate because survival rates for walrus were not known, leading to possible bias in estimates of R_{max} for this species (Chivers 1999; Stewart and Hamilton 2013). However, for most species examined in the United States, R_{max} is not known so defaults are based on modeling only, consequently, their default values for R_{max} walrus were set at 0.08. Some additional studies have suggested that 0.07 may be too conservative. Finite estimates of population growth obtained by fitting an exponential curve to Soviet estimates of abundance from 1958 to 1975, when walrus were not considered to be food limited were 0.07 (Sease and Chapman 1988). However, this estimated rate of growth was negatively biased, since harvesting continued throughout this period and was not considered in their analysis. Modeling of the dynamics of Atlantic walrus populations in Greenland, resulted in an R_{max} of 7.7% (95% CI 6.7–8.9%) assuming no harvest (Witting and Born 2014). More recent modeling of Pacific walrus during a period where population growth has slowed (1974-2006) suggest that adult survival rates used by Chivers (1999) were conservative since they did not consider harvesting (Taylor and Udevitz 2015), indicating that $R_{max} = 0.08$ is a reasonable estimate for this parameter.

Our estimates of PBR for the Foxe Basin stock were as high as 385 animals, which are considerably higher than the Stewart and Hamilton (2013) estimate of 166. The differences result from using a larger estimate of abundance, a F_R of 1, and a higher R_{max} of 0.08. For walrus in Foxe Basin, there is no evidence for any trend in population abundance for close to 30 years. Although there were considerable differences between studies in methods used, consistency in neighbouring counts provides some support for these estimates. Within the context established in Canada for Atlantic walrus, the use of F_R as high as 1, as was used for the Penny Strait-Jones Sound walrus stock is an acceptable option given no evidence of a declining population trend. At the same time, some guidance is needed to identify model defaults to apply to stocks in Canada.

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Table 1. Reported harvests for the communities of Hall Beach and Igloolik from 1954-2014, based on DFO catch statistics and in Stewart and Higdon (unpublished report). Hall Beach was not founded as a community until 1957.In some years there are no reports (NR) of catches available.

	Hall Beach		Igloolik		
Year	Subsistence	Sport	Subsistence	Sport	Total
1954	NR	NR	425	0	425
1955	NR	NR	NR	NR	
1956	NR	NR	198	0	198
1957	NR	NR	79	0	79
1958	NR	NR	267	0	267
1959	NR	NR	195	0	195
1960	NR	NR	31	0	31
1961	NR	NR	58	0	58
1962	NR	NR	700	0	700
1963	NR	NR	NR	NR	
1964	NR	NR	104	0	104
1965	NR	NR	550	0	550
1966	NR	NR	100	0	100
1967	NR	NR	NR	NR	
1968	NR	NR	150	0	150
1969	NR	NR	200	0	200
1970	NR	NR	NR	NR	
1971	NR	NR	NR	NR	
1972	NR	NR	NR	NR	
1973	30	0	NR	NR	30
1974	70	0	50	0	120
1975	5	0	45	0	50
1976	55	0	75	0	130
1977	118	0	100	0	218
1978	41	0	97	0	138
1979	100	0	225	0	325
1980	73	0	114	0	187
1981	120	0	190	0	310
1982	200	0	100	0	300
1983	200	0	100	0	300
1984	110	0	100	0	210
1985	85	0	125	0	210
1986	26	0	125	0	151

Hall Beach			Igloolik		
Year	Subsistence	Sport	Subsistence	Sport	Total
1987	86	0	82	0	168
1988	61	0	124	0	185
1989	74	0	63	0	137
1990	74	0	104	0	178
1991	74	0	104	0	178
1992	70	0	225	0	295
1993	60	0	165	0	225
1994	64	0	137	0	201
1995	NR	0	42	1	43
1996	27	0	117	2	146
1997	109	0	80	4	193
1998	80		125	8	213
1999	NR	0	NR	10	10
2000	87	1	168	6	262
2001	40	0	40	12	92
2002	1	4	NR	10	15
2003	87	1	97	14	199
2004	66	NR	NR	10	76
2005	75	3	100	12	190
2006	100	4	184	2	290
2007	35	0	54	NR	89
2008	33	0	74	0	107
2009	70	0	89	0	159
2010	75	0	141	0	216
2011	33	2	95	6	136
2012	107	1	107	4	219
2013	NR	10	NR	0	10
2014	92	2	9	0	103

Table 2. Number of walrus observed in 1983 by Orr et al 1986, modified from Stewart and Higdon (unpublished report). Latitude (Lat) and Longitude (Long) are in decimal degrees

Date	Time	Lat	Long	No. walrus
19 Aug.	10:25	68.3667	-80.7333	73
19 Aug.	10:42	68.2167	-81.0833	113
19 Aug.	10:45	68.2000	-81.2167	61
19 Aug.	10:49	68.1667	-81.2833	310
19 Aug.	10:52	68.1500	-81.3667	11
19 Aug.	10:56	68.0667	-81.5167	9
19 Aug.	11:06	67.9000	-81.5833	1
19 Aug.	14:10	68.7500	-78.5667	37
19 Aug.	14:15	68.7667	-78.6667	113
19 Aug.	14:20	68.8500	-78.6167	327
19 Aug.	14:25	68.8667	-78.5000	166
19 Aug.	14:35	68.8500	-78.8000	190
19 Aug.	14:40	68.8167	-78.8833	140
19 Aug.	14:45	68.7833	-78.9000	23
19 Aug.	14:47	68.7833	-78.9833	27
19 Aug.	15:00	68.8167	-79.7167	422
19 Aug.	15:05	68.8000	-79.7667	3
19 Aug.	15:10	68.8000	-79.9167	59
19 Aug.	15:15	68.7167	-80.0000	6
19 Aug.	15:20	68.7333	-80.4000	42
19 Aug.	15:25	68.6333	-80.4000	79
19 Aug.	15:35	68.6167	-80.4833	56
19 Aug.	15:37	68.6167	-80.5333	46
19 Aug.	15:40	68.6167	-80.5500	46
19 Aug.	17:13	68.9167	-80.7667	6
19 Aug.	17:22	68.9167	-80.3000	95
19 Aug.	17:26	68.9333	-80.0167	43
19 Aug.	17:30	68.9333	-79.8333	40
19 Aug.	17:32	68.9333	-79.9000	66
19 Aug.	17:35	68.9667	-79.5333	96
19 Aug.	17:40	69.0000	-79.4833	1
19 Aug.	17:54	69.2500	-79.1333	5
19 Aug.	18:02	69.4167	-78.9167	1
19 Aug.	18:04	69.4167	-78.9000	2
19 Aug.	18:06	69.4667	-78.9667	1
20 Aug.	11:45	68.9333	-78.4667	1
20 Aug.	11:52	69.1333	-78.3500	5
				2722

Table 3. Number of walrus observed and estimated from strip transect surveys flown in July-August 1988-89, from Richard (unpublished report). Line a is a 0 sighting line added to facilitate calculations.

1988 survey				
Transect	Weighting	walrus	Expanded	Transect
a	11.575	0	0	4
7	11.575	4	46.3	5
8	11.575	397	4595.3	6
9	11.575	0	0	7
10	11.575	37	428.3	8
11	11.575	0	0	9
12	11.575	0	0	10
13	11.575	0	0	11
14	11.575	0	0	12
15	11.575	5	57.9	
16	11.575	0	0	
Total		443	5,128	Total
SE (CV)			4,390 (0.86)	

Table 4. Walrus counts obtained on days surveys were flown in the Foxe Basin area during September 2011. Data from Stewart et al. 2014. Cells in red represent photographs from water level (boat).

Location	**1**	**2**	**3**	**7**	**8**	**12**	**13**	**18**	**19**	**21**
Bushnan Rock	35					3603			8	
South Ooglit Island		108	1640	405	483	995	1327		2504	67
Manning Island			49	1068		1009	834	253	1108	
Jens Munk Island						94				
South Ooglit Island South Tip	0	0	0	0	0		0		864	
North Ooglit Island									1	
Totals by date	35	108	1689	1473	483	5701	2161	253	4484	67

Table 5. Survey year, count/estimate, proportion of animals hauled out, and adjusted counts for walrus in Foxe Basin. In the 1983 survey, approximately 15% of the animals recorded were in the water. Numbers in brackets reflect haulout counts only. [1] Walrus counts at two haulout sites during period when transmitters were deployed. [2] MCP estimates but using lower haulout proportion from Foxe Basins data

Year	Number (N)	SE (N)	Var (N)	Proportion hauled out	SE (P)	Var(P)	Adjusted Number	Var	SE	Source
1983	2722 (2314)			0.37	0.16	0.026	7,357 (6,253)	10,125,306 (7,316,124)	3,182 (2,705)	Orr et al 1986
1988	5,128	4390	19272100	0.37	0.16	0.026	13,859	176,703,152	13,293	Richard unpubl. Rep.
1989	5,510	1644	2702736	0.37	0.16	0.026	14,892	61,222,005	7,824	Richard unpubl. Rep.
2010	3,861			0.74	0.015	0.0002	5,200	12,467	112	Stewart et al. 2013
2010[1]	2,409			0.37	0.015	0.0002	6,480	73,114	270	Stewart et al. 2013
2011[2]	6,043			0.74	0.016	0.0002	8,153	33,198	182	Stewart et al. 2013
2011	4,484			0.36	0.15	0.022	10,472	19,046,649	4,364	Stewart et al. 2013 adjusted for adding error

Table 6. Survey year, count/estimate, proportion of animals hauled out, and adjusted counts for walrus in Foxe Basin.

Year	Number (N)	SE (N)	Var (N)	Proportion hauled out	SE (P)	Var(P)	Adjusted Number	Var	SE	Source
2010	3,861			0.37	0.16	0.0256	10,435	20,369,148	4,513	
2011	5,945			0.37	0.16	0.0256	16,068	482,867,359	6,949	
2011	4,484			0.37	0.16	0.0256	12,119	27,471,666	5,241	

Table 7. Estimates of population size (SE), PBR estimates obtained using different values for the maximum rate of increase (R_{max}) and Recovery factor (F_R).

Year	Population (SE)	R_{max}=0.07			R_{max}=0.08		
		F_r=0.5	F_r=0.75	F_R=1	F_R=0.5	F_R=0.75	F_R=1
2010	10,435 (4,513)	129	193.4	258	147	221	295
2011	14,093 (6,704)	169	253	337	193	284	385

Figure 1. Location of Atlantic walrus stocks in the eastern Canadian Arctic. The stocks are Baffin Bay (BB), West Jones Sound (WJS), Penny Strait-Lancaster Sound (PS-LS), Hudson Bay-Davis Strait (HBDS) and South and East Hudson Bay (SEHB). The North and Central Foxe Basin stocks are surveyed together and are referred to as Foxe Basin (FB).

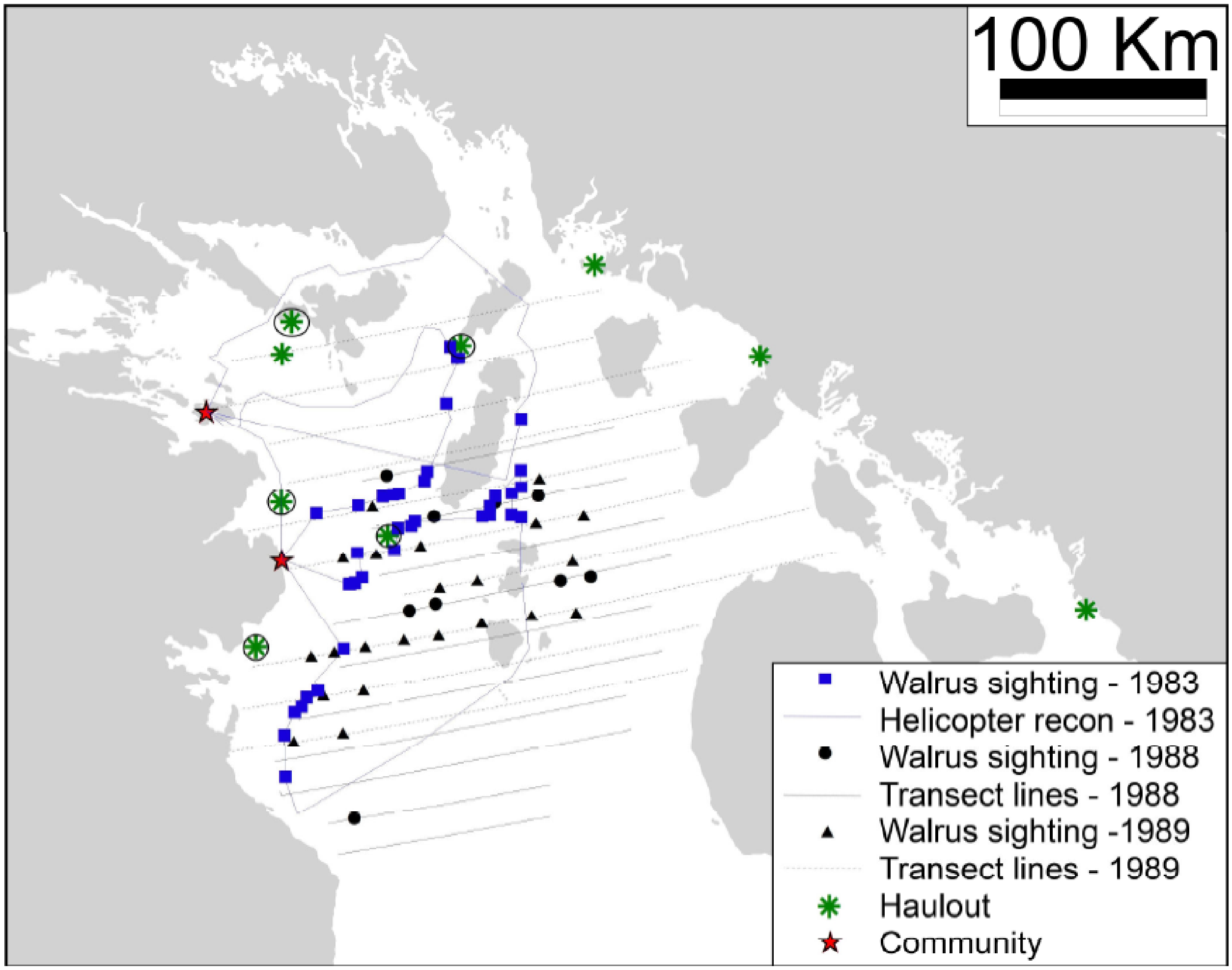

Figure 2. Comparison of survey coverage for the three Foxe Basin walrus surveys conducted by DFO in 1983 (Orr et al. 1986), 1988 and 1989 (Richard 1994 unpublished report (edit 2015)), and 2010 and 2011 (Stewart et al. 2013). The haulouts covered in the 2010-2011 surveys are identified by circles. Figure is from Stewart and Higdon (unpublished report).

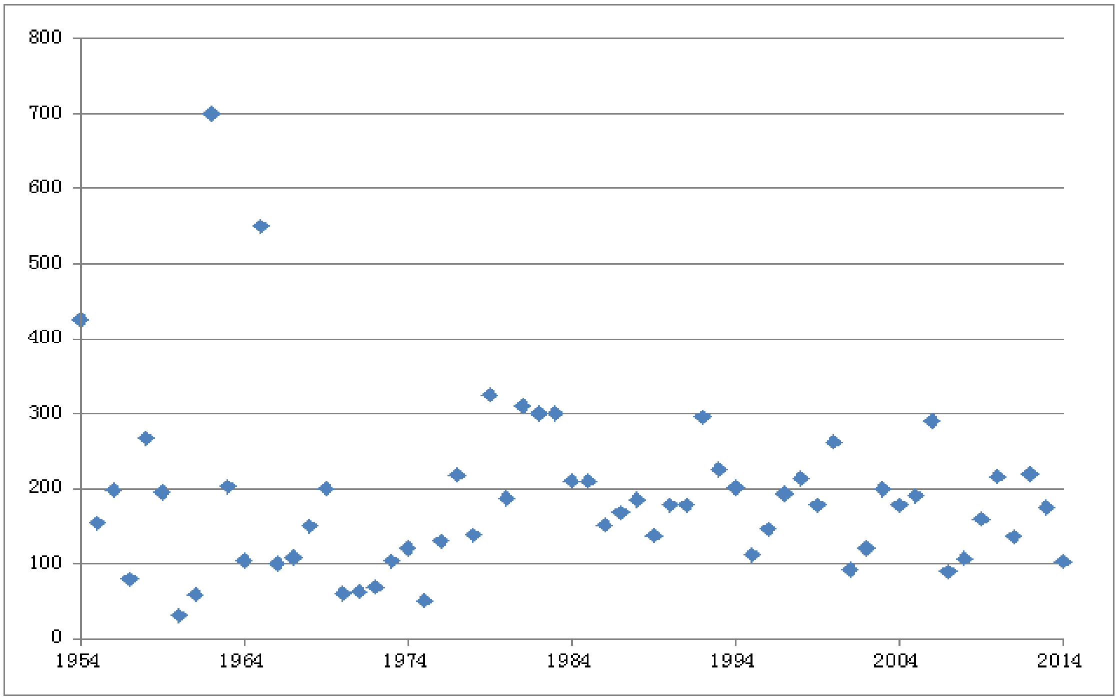

Figure 3. Reported harvests from Foxe Basin communities of Hall Beach and Igloolik. In years where no harvests are reported in a community, the 5-year average from adjoining years is used to fill in the missing value (see Table 1).

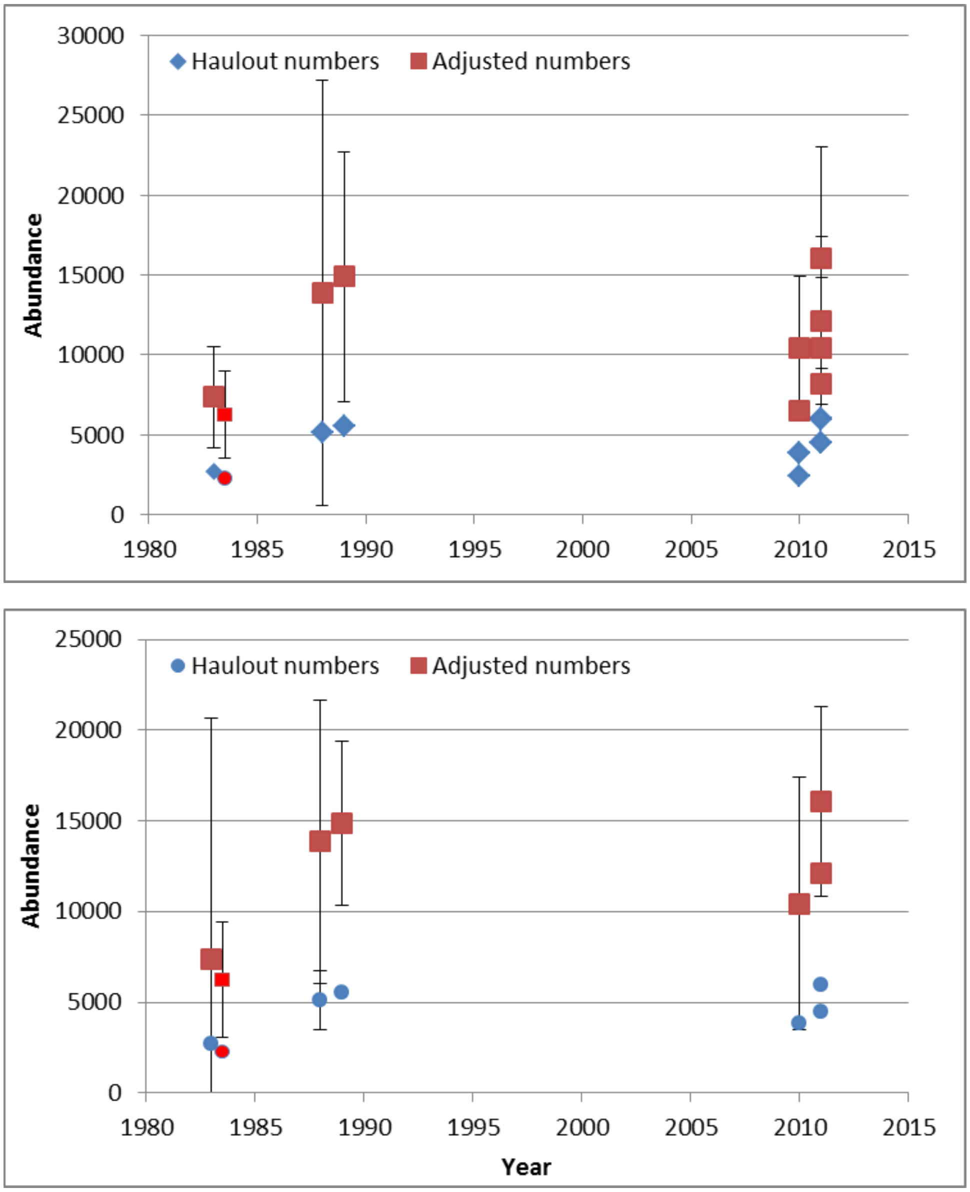

Figure 4. Estimated hauled out population and adjusted abundance of Foxe Basin walrus between 1983 and 2011. (Top panel) In the 1983 surveys, approximately 15% of the sightings were of animals in the water. The red points, which are slightly lower, reflect counts corrected only for animals hauled out. The haulout counts and estimates from 1983, 1988 and 1989 were adjusted using a haulout proportion of 0.37. The 2010 and 2011 estimates were adjusted using haulout proportions of 0.37 and 0.74 as presented by Stewart et al. (2013). The higher squares in years 2010 and 2011 show the impact of using an adjustment factor of 0.37 instead of 0.74.(Table 5). (Bottom panel) Haulout counts and estimates from 1983, 1988 and 1989 were adjusted using a haulout proportion of 0.37. Simple counts from the 2010 and 2011 surveys were adjusted assuming a haulout proportion of 0.37 (Tables 5, 6).