Minimum Population Estimates for Walrus in the Penny Strait/Lancaster Sound and West Jones Sound Stocks, Canada

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Abstract

Aerial surveys to estimate the minimum number of walrus alive in the Penney Strait-Lancaster Sound (PS-LS) and West Jones Sound (WJS) stocks began in 1998. The best recent estimates derive from surveys in 2007, 2008 and 2009. Previous surveys were used to assess methods. The maximum count for PS-LS was obtained in 2009 when 22 haulouts accounted for 557 walrus. The maximum count of WJS walrus (401) was obtained in 2008 at 8 of the 9 known haulouts. These counts may be extrapolated to account for animals at sea, resulting in estimates of approximately 2200 walrus in PS-LS and 1600 in WJS. These estimates should, however, be viewed with caution until better data on the frequency, duration, and independence of hauling behaviour are available for these regions and seasons.

Introduction

Atlantic walrus (*Odobenus rosmarus rosmarus)* occur in Canada in number of largely discrete stocks (Born *et al.*1995, DFO 2000, COSEWIC 2006, Stewart 2008). Within the range of each stock, walrus are widely distributed. There are over-wintering groups at three or more locations: Coburg Island, Hell gate/Cardigan Strait, and Dundas Island (Born *et al.* 1995, Stewart 2008). In the summer they are found in western Jones Sound, and from Penny Strait into Lancaster Sound, especially the south shore of Devon Island. They are found at sea in small numbers and on ice or land in numbers from 1 to over 1000. This widely spread but clumped pattern is a challenge to quantitative survey design and may explain the dearth of recent quantitative estimates of population size. Yet knowing the numbers of animals present is a key aspect of co-management for species that sustain culturally and economically important harvests. Walrus are harvested by Inuit in Canada and Greenland, and by sports hunters in parts of Canada (Born *et al.* 1995, DFO 2000, Priest and Usher 2004).

Since 1998, DFO and various partners have been trying to enumerate walrus in this area. Here we report on studies designed to exploit the clumped behaviour of walrus to generate Minimum-Known-Alive (MKA) estimates (Krebs 1966) for walrus in the Canadian Arctic archipelago. Known or reported terrestrial haulout[1] sites, where walrus traditionally come ashore to rest, were examined systematically to obtain counts of animals and estimates of herd composition. Although surveys were conducted between 1998 and 2006 inclusive, they are not

[1] Throughout the text we use “haulout” as the noun and “haul out” as the verb.

included here because they are no longer current. These preliminary surveys did however provide data by which to assess our estimation techniques (visual estimates/ counts from photographs, Appendix 1) and create a comprehensive inventory of terrestrial haulouts in the survey area for the 2007-2009 surveys.

Methods

The scientific literature (*e.g.,* the review by Born *et al*. 1995), Inuit *qaujimaningit*, or IQ (*e.g.,* community consultations, Inuit participants) and other traditional knowledge (*e.g.,* long-time Arctic researchers) were used to identify former, current, and potential haul out sites. These sites and intervening coastlines and ice edges were examined from the air (fixed- and rotary-wing aircraft) repeatedly each year in the season when maximum numbers were expected to occur based on IQ. Seasonal timing was adjusted by early findings and subject to weather but most surveys in 2007-2009 were conducted in August.

The coastlines of the Arctic islands comprise an immense survey area of several tens of thousands of kilometres. Weather in the area is often challenging and equipment availability sometimes unpredictable. The length of coastline observed and the number of haulouts examined varied between years. When time and weather constrained surveys, emphasis was placed on examining previously known haulouts, even if there had been no walrus seen there for several seasons. New haulouts were added to the survey as they were discovered. Some of these new sites appeared where previous surveys were frequent and where they were rare. None had been identified by local people.

The survey area included the known ranges of the Penny Strait-Lancaster Sound and West Jones Sound stocks (NAMMCO 2006, Stewart 2008) (Fig. 1). In 1999, 2008 and 2009, areas on east Ellesmere Island were also surveyed (see Born *et al*. WP this meeting). The data were collected without regard to stock boundaries but have been analyzed as separate stocks (NAMMCO 2006, Stewart 2008) as the more precautionary approach (Taylor 1997, Taylor and Dizon 1999).

The helicopter survey (2007) was conducted in a Bell 206L with a target altitude ~150 m ASL and variable speeds, approximately 500 m from the shoreline. Searching speed was ~185 kph but speed was reduced to facilitate counting at haulouts. The observers sat in the front left position; the pilot also reported sightings. The fixed-wing aircraft used in 2008 and 2009 was a de Havilland Canada DHC-6 Twin Otter flying at a target altitude of about 300 m ASL, surveying at about 210 kph, about 750 m from the shoreline. Three to four observers sat on opposite sides of the aircraft (Fig 2). A GPS linked to a lap-top computer was used to record the survey tracks and enter sighting data; watches and digital cameras were synchronized to the GPS time. It was not possible to enter all sightings in real-time (too many concurrent sightings, pauses in equipment function, etc) but observers also recorded their sightings in notebooks with accurate times. These observations were included in tallies based on the times and track logs.

When walrus were seen, the numbers were estimated independently by each observer and oblique aerial photographs were taken whenever possible. Photographs from each encounter were examined in Adobe PhotoShop® CS2 version. Each photograph was modified in size, contrast and brightness to produce the clearest image for counting. Coloured dots were super-imposed on each enumerated walrus and the modified image re-examined for missed animals. Between-observer and between-methods comparisons (Appendix 1) indicated that a single examination of photographs produced reliable counts and that photographic counts were more reliable than visual estimates. Therefore, all photo-counts were a single enumeration by one observer (REAS) and, when more than one type of data were available for a site, the photo-count took precedence over the visual estimate. The best data for each observation were summed for each day.

Some haul out sites were visited twice in one day and the larger estimate of the day was used on the assumption that the walrus were unlikely to have been counted at a nearby haulout the same day because sites were examined on a linear flight path. For example, haulouts examined in the order A-B-C, in the morning on an out-bound flight were re-examined as C-B-A on the return flight. The relative travelling speeds of walrus and aircraft make it unlikely a higher count at A as a result of movement of counted walrus from B would go undetected.

Surveys of adjacent areas were often separated by a few days due to flying restrictions and the movements of walrus among haulouts are not well known. We assumed sequential surveys do not produce double counts if the distance between areas is great or if local knowledge indicated a gap in distribution. Data from satellite tags deployed between 1998 and 2004 in the survey area (Stewart 2008) were used to test this assumption. We examined location data of quality 1 or better when locations were 24 $\pm$ 1 h apart to explore the probability of double counting within a 24 h period. We limited tag-data to August and September to avoid complications associated with freeze-up and established a distance criterion (40 km/24 h, see **Results**) after which we considered significant exchange of walrus improbable. When there was potential for movement between adjacent areas between surveys, we measured sea distance between the haulouts using MapSource®, rounded to the nearest 5 km, and rejected any count that violated the distance criterion.

Haulout sites previously identified by IQ or the literature but not occupied when surveyed were inspected for recent walrus activity. Discolouration and disturbance of the substrate was taken as evidence of use in the current season.

The direct enumeration of populations using the minimum known alive approach sums the number of animals caught at time *t* plus the number of marked animals captured after, but not at, time *t* (Krebs 1966). That is, it sums the number enumerated in one sample with those that must have been alive at the same time but were not included in the first sample. In the current application, walrus at one haulout were “caught” in a count at time *t* and that number was subsequently augmented by animals at other sites when we were confident they had not been included in the previous counts. Maximum daily MKA estimates were summed across days for a season only when the distance criterion was met.

Results

Distance criterion - There were 16 pairs (7 walrus in 5 years) of tag locations of LQ $\geq$ 1, approximately 24 h (23.8 $\pm$ 0.6, $\bar{x}$ $\pm$ 1 SE) apart. The average distance these tags moved, adjusted to 24 h, was 10.8 $\pm$ 10.7 km/24 h. However, the maximum distance moved was 37.8 km in 24 h. Another tagged walrus left a haulout and moved 32.4 km in 14 h, 4.7 km the next day, then 31.0 km to an occupied haulout the third day. Based on this animal and the maximum movement recorded in 24 h, we used 40 km sea distance as the minimum distance between haulouts to assume no significant exchange between haulouts in 24 hours, and multiplied by the number of days for longer inter-survey periods.

Stock size

Nine surveys were conducted between 1998 and 2008. Coverage and estimates were variable before 2008, however there was no correlation between the numbers counted in the Penny Strait - Lancaster Sound area compared to the West Jones Sound area (PSLS = 258.1 ($\pm$ SE 141.8) + 0.05 ($\pm$ 0.68) WJS, n = 9, R^2 = 0.0006). Survey effort in terms of kilometres-on-effort and total kilometres flown varied among recent years as well (Table 1).

Penny Strait - Lancaster Sound.

By 2007, the preliminary surveys had identified 21 terrestrial haulout sites currently used in the Penny Strait/Lancaster Sound stock area (Fig 1). Two historic sites, Marshall Penn and Stratton Inlet (Born *et al.* 1995) were not occupied during any survey and showed no signs of recent use. One walrus was seen on ice near Marshall and two were seen together swimming near Stratton but we consider these sites to be not currently in use.

A haulout on Houston-Stewart Island was first seen to be occupied in 2007. This island is adjacent to usual survey flight patterns but was not scrutinized closely in a systematic manner until 2007. It may represent either new walrus use or expanded survey effort. In 2009, walrus were hauled out on Cape Hornby, Devon Island. This cape is over-flown by every survey in the area and represents a newly occupied haulout.

Counts in preliminary surveys were significantly related to the number of haulout sites included in PSLS (P= 0.04) but only weakly so (R^2 = 0.43). The maximum count in 2007-2009 was 557 over 2 days in 2009 at all known haulouts in the area. No higher count was recorded during our preliminary surveys.

West Jones Sound

By 2007, the preliminary surveys had identified 8 primary terrestrial haulout sites currently used in the West Jones Sound stock area (Fig. 1). One historic site identified by *IQ*, Nookap and Saukuse Islands was not occupied during any survey nor has it shown any signs of recent use. While much of the site is rocky, generally it has been snow covered or ice encircled during surveys. However, in 2008 and 2009 a few walrus were seen swimming within 5 km of these islands and they are not yet considered abandoned.

Haulouts in Baad, MuskOx and Goose Fiords had been previously identified (IQ, Born *et al.* 1995) but in Baad Fiord and MuskOx Fiord there are two sites each where walrus repeatedly haul out. In Baad Fiord, the two sites are only about 4 km apart on the same shoreline and both places have not been occupied simultaneously. We consider that one site. In MuskOx Fiord the two sites are about 5 km apart, on opposite sides of the fiord and have been both occupied at the same time. We consider them as two sites. The two sites in Goose Fiord (Borgen and Clement) are approximately 20 km apart and are routinely occupied at the same time. They are counted as two haulouts.

In 2006, walrus were seen for the first time hauled out on a small rock in West Fiord. This island is adjacent to usual survey flight patterns but was not closely scrutinized in a systematic manner until 2006. It may represent either new walrus use or expanded survey effort.

Sverdrup (1903) commented on walrus at Blubber Point (76 39 N/ 89 50 W). This site was examined in 1999, 2003, ,2006, and 2007 but no sign of walrus was seen. It is a difficult site to access and has not been included in the list of haulouts to be routinely examined.

Counts in preliminary surveys were not significantly related to the number of haulouts sites included (P= 0.94, R^2 = 0.31). The maximum count in 2007-2009 was 401 on one day in 2008 at all known haulouts in the area except West Fiord. No higher count was recorded during our preliminary surveys. Complete coverage in 2009 yielded a count of 388.

Discussion

Direct counts of pinnipeds that haul out at known locations is a common method for determining the minimum number alive (Mathews *et al.* 2006, Lydersen *et al.* 2008). While it is acknowledged to be negatively biased, hence the "minimum" in its definition, the direct counts themselves may be underestimates of the true number on the haulout at enumeration time. Surface-level counts tended to underestimate those derived from aerial surveys, as previous reported for harbour seal surveys (Mathews 1995). Similarly, visual estimates from aircraft (this study) or surface level (Udevitz *et al.* 2005) tend to diverge at larger group sizes. High resolution photographs produced precise and repeatable counts (Lydersen *et al.* 2008) but both aerial estimates and photographs can miss small animals within the herd.

None of the counts pretends to be an estimate of the total number of walrus in the area at the time of the survey. While some effort was made to count individuals in the ocean between haulout sites, only a small fraction of the water's surface was seen. There may be undetected existing or newly occupied haulouts. On south Devon, reconnaissance in 1993, 1998 and 1999 included the whole coast and emphasis was placed on surveying known haulouts. But in 2006 new haulouts were found both within the routinely searched area and beyond it.

Our preliminary surveys showed high between-year and within-year variation. For example, counts at the four main WJS sites contributed 0 to over 100 animals to various annual totals (Table 4). Similarly, within a year the counts at any site varied among days. At Clement Ugli 22 August 1998 the maximum count of 42 occurred ½ h after a count of 36. Walrus behaviour may be contagious – the presence of some animals on a haulout seems to encourage others to haul out. Lydersen *et al.* (2005) reported that animals tagged together were likely to remain associated with each other and haulout together. Conversely, a disturbance, such as an approaching bear will not just reduce the numbers on walrus ashore but reduce it to zero. These sources of extreme variation make estimating walrus populations size problematic. Haulout sites vary in spatial and temporal stability. Some of the sites appeared to have been used every year they were observed, others, such as Baillie-Hamilton and Cape Hornby are known to be new sites. The site in Ryder Inlet apparently changed from the east side to the west side of the inlet sometime after the 1980s.

For these reasons, the long time-series of our preliminary surveys informs current assessment. Replicates within and between years are merited. In 2007-

09 coverage was extensive and comprehensive. In 2009 especially we were able to replicate all survey areas within a few days.

Penny Strait-Lancaster Sound Stock

There were 565 walrus counted on four days over a 6-day period in 1977 at 11 haulout sites (Davis *et al.* 1978). The recent maximum count was 557 (2009) at 22 sites. Coverage in 1997 extended only as far east on south Devon Island as Ryder Inlet. Most of ours extended approximately 100 km farther east and, in 2006 we found 3 haulouts where none had been observed previously. Other new sites appeared throughout the range as well and it is impossible to relate walrus numbers to haulout coverage in a manner that allows population trend analysis.

West Jones Sound

There were about 300 walrus counted on one day in 1977 at four haulout sites (Davis *et al.* 1978). The recent maximum count was 401 in 2008 (388 in 2009). Again additional sites were included in recent surveys and changes in walrus numbers cannot be separated from changes in coverage.

The estimates presented above do not include animals at and submerged. For the Penny Strait-Lancaster Sound estimate from 2009 (557) only 11 (<2%) were counted in the water away from a haulout. There are no tag data concurrent and congruent with these surveys. Using the estimate from Born *et al.* (WP this meeting) of 25% of the walrus' time is spent hauled out, the 546 hauled out animals would represent 2184 walrus present in the area. Similarly, 72 (18%) of the 401 walrus counted in West Jones Sound in 2008 were in the water. The 392 hauled out therefore represent 1568 walrus.

Such calculations are, however sensitive to the assumptions made about the independence of hauling behaviour and the definitions used to parse the tag data into hauled out vs. at sea. Born *et al.* (WP this meeting) used a sample period with >70% of the time “dry” to derive the adjustment factor of 25%. A lower threshold would increase the estimated time ashore. A change from 25 to 30% would change these adjusted values from 2184 and 1568 to 1820 and 1306 respectively. This assumes that the hauling behaviour of each animal is independent of all others but direct observation and evidence from Svalbard (Lydersen *et al.* 2008) indicate otherwise. Until there is a better understanding of the contagious nature of hauling behaviour and time- and site specific estimates of time-ashore are available, it is perhaps imprudent to consider adjusting a count by a largely unsubstantiated factor a “correction”. The haulout criterion used by Born *et al.* (WP this meeting) might best serve as an upper boundary. Ideally, many tags could be deployed immediately preceding a survey and the proportion of tags that are “dry” during the survey used to adjust for animals at sea (e.g., Huber *et al.* 2001).

Conclusions

Since 1998, the largest count in the PS-LS stock area indicated there were at least 600 walrus present in 2009, based almost entirely on counts at haulouts. In the same period, the maximum count of at least 400 in WJS, based largely on counts at haulouts occurred in 2008. Both counts are minima. Until better data are available, using Born *et al.*'s (WP this meeting) definition of a haul out period as an upper boundary, these populations could be as high as 2200 and 1600 respectively.

Acknowledgements

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Figure 1. Haulout sites surveyed in the Canadian Archipelago

(a) WJS

(b) PS-LS

Figure 2. Twin Otter schematic. Most surveys were flown with the data-logger/navigator in seat 4 and primary observers in seats 17 and 18.

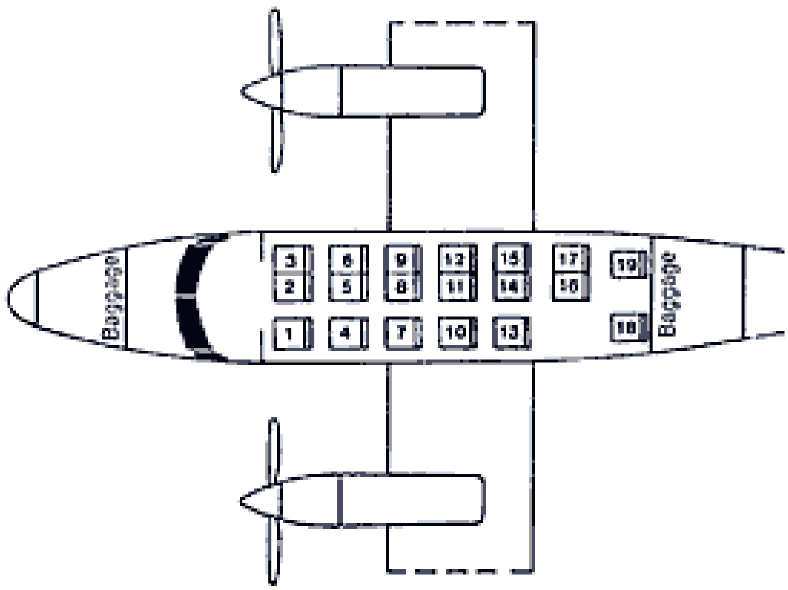

Table 1. Stock-specific survey effort and total flying effort for the PS-LS and WJS stocks.

Year	**PS-LS "on-effort" (km)**	**WJS "on-effort" (km)**	**Total Flying* (km)**
2007	2498	603	5568
2008	3300	596	4426
2009	2217	1099	5564

*transit flights were not partitioned by stock.

Table 2. Penny Strait- Lancaster Sound - maximum yearly counts and the sites contributing to those maxima. "At sea" indicates walrus that were in the water far enough away from a haulout that they could not have been scared into the water by the aircraft.

Year	Maximum count	Haulouts included in counts	Dates	Notes and assumptions
2007	493	1. Baillie Hamilton Is. 2. Barrow Harbour 3. Blanely Bay 4. (Cape Hornby)* 5. Cumming Inlet 6. Custance Inlet 7. Inglis Bay/Dyer Is. 8. Houston Stewart Is.[2] 9. Kearney Cove 10. Margaret Is. 11. Markham Point 12. No Name Bay# 13. Powell Inlet 14. Ryder Inlet	Aug 17, 21	• Nearest proximity of walrus between 17th and 21st > 200 km • 7 of the 493 walrus were at sea
2008	304	1. Baillie Hamilton Is. 2. Barrow Harbour 3. Blanley Bay 4. Brooman Point 5. Burnett Inlet 6. (Cape Hornby)* 7. Cuming Inlet 8. Custance Inlet 9. Graham Inlet 10. Inglis Bay/Dyer Is. 11. Kearney Cove 12. Margaret Is. 13. Markham Point 14. Marshall Peninsula 15. No Name Bay 16. Powell Inlet 17. Radstock Bay SE 18. Ryder Inlet 19. Stratton Inlet	Aug 22,25	• Nearest proximity of walrus between 22nd and 25th > 200 km • 15 of the 304 were at sea
2009	557	1. Arthur Fiord 2. Baillie Hamilton 3. Barrow Harbour 4. Blanley Bay 5. Brooman Point 6. Burnett Inlet 7. Cape Hornby[1] 8. Cuming Inlet 9. Custance Inlet	Aug 11,14	• Nearest proximity of walrus between 11th and 14th ~400 km • 10 of the 557 were at sea

		10. Gascoyne Inlet 11. Graham Inlet 12. Houston Stewart Is. 13. Inglis Bay/Dyer Is. 14. Kearney Cove 15. Margaret Is. 16. Markham Point 17. No Name Bay 18. Powell Inlet 19. Radstock Bay SE 20. Ryder Inlet 21. Stratton Inlet 22. Village Bay		

* Cape Hornby was first occupied in 2009 but was observed in all years, and has been added retroactively to 2007 and 2008 as contributing 0 walrus to the annual count.

[1] a haulout routinely observed that was seen to be occupied by walrus for the first time in the year indicated and represents a recent change in walrus haulout distribution.

[2] a haulout visited rarely or not at all in previous years, representing an increase in survey coverage or a change in walrus distribution or both.

No Name Bay really has no name, according to both local Inuit (I. Kalluk, Chair, Resolute Bay HTA, pers. Comm.) and the Canadian Hydrographic Service (T. Janzen, Hydrographer, CHS).

Table 3. West Jones Sound - maximum yearly counts and the sites contributing to those maxima "At sea" indicates walrus that were in the water far enough away from a haulout that they could not have been scared into the water by the aircraft.

Year	Maximum count	Haulouts included in counts	Dates	Notes and assumptions
2007	90	1. Clement Ugli 2. Norfolk Inlet	Aug 18	• No walrus were recorded at sea
2008	401	1. Baad Fiord 2. Borgen Mtn 3. Clement Ugli 4. Musk Ox Fiord - spit 5. Musk Ox Fiord - west 6. Nookap/Saukuse Is. 7. Norfolk Inlet 8. Walrus Fiord	Aug 26	• 43 of the 401 were at sea, but 34 of those were within ~3 km of a haulout site
2009	388	1. Baad Fiord 2. Borgen Mtn. 3. Clement Ugli 4. Musk Ox Fiord - spit 5. Musk Ox Fiord - west 6. Nookap/Saukuse Is. 7. Norfolk Inlet 8. West Fiord 9. Walrus Fiord	Aug 14	• 40 of the 388 were at sea

Table 4 a. Examples of between variation in haulout occupancy.

	Borgen	Clement	Walrus	Norfolk	Yearly sum
1998	3	6	68	15	92
1999	78			29	107
2000	75	60			135
2001	115	0	0	0	115
2003	45	0	0	11	56
2004		125		26	151
2006	38	12			50
2007		7		90	97
2008	0	154	90	7	251
2009	49	71	0	81	201

Table 4 b. Selected examples of within- year variation in site occupancy. All dates in August.

	Site	Count 1 (date)	Count 2/date
1998	Borgen	67 (19th)	0 (21st)
1999	Borgen	35 (12th)	78 (19th)
2000	Clement	30 (24th)	60 (30th)
2001	Norfolk	71 (20th)	0 (25th)
2003	Borgen Norfolk	45 (11th) 58 (11th)	0 (15th) 0 (15th)
2004	Clement	125 (24th)	4 (25th)
2009	Clement Borgen	71 (14th) 49 (14th)	104 (15th) 72 (15th)

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Appendix 1 Validation of estimates

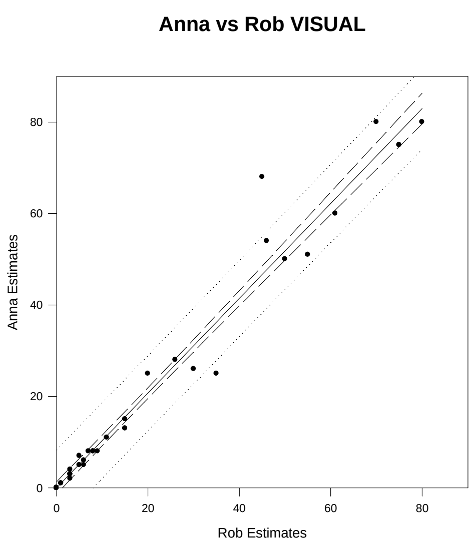
Data from 1998-2008 aerial surveys provided

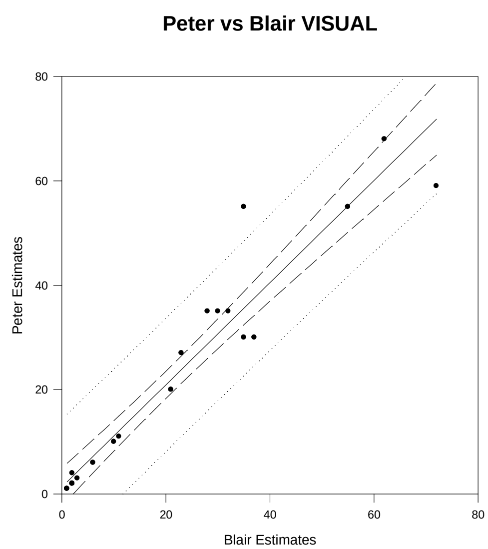
1. simultaneous visual estimates from multiple observers
2. a subset of photographs that were assessed by multiple observers
3. blind replicate counts by one observer (REAS).
4. simultaneous photographs and visual estimates for a number of haulouts.

Regression analysis (Sigma Stat® 3.11) was used to assess between-observer visual estimates, between-observer photographic counts, and between methods (visual/photographic).

1) Between Observer - Visual estimates

Two pairs of visual observation data were available for aerial observers. Neither of the between-observer comparisons of aerial visual estimates differed significantly from a 1:1 correspondence.



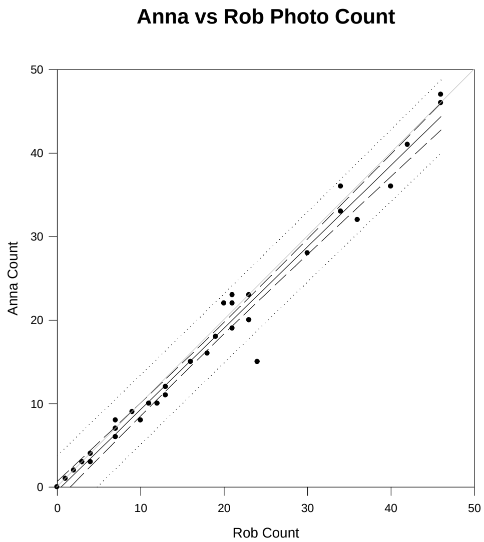


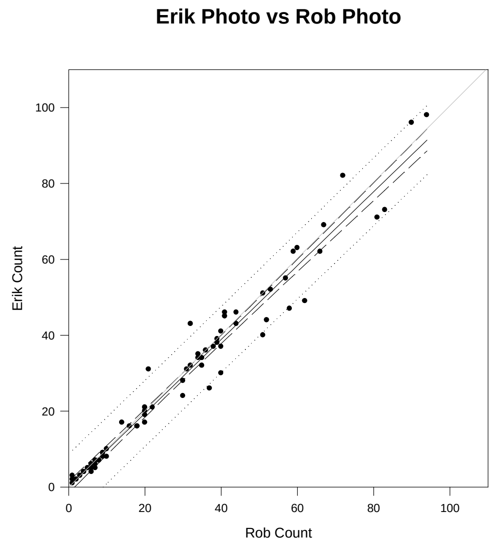
AR = 0.02 + 1.04(RS)
n = 51, R^2 = 0.97,
Intercept not significantly different than zero (P >0.05);
Slope not significantly different than 1, P > 0.05,

PO = 1.35 + 0.98(BD)
n = 23, R^2 = 0.93,
Intercept not significantly different than zero (P >0.05);
Slope not significantly different than 1, P > 0.05,

2) *Between Observer - Photographic Counts*

Two subsets of photographs were examined independently by three observers. Each observer independently examined photographs from each encounter and adjusted image size, contrast and brightness produce the subjectively clearest image for counting.



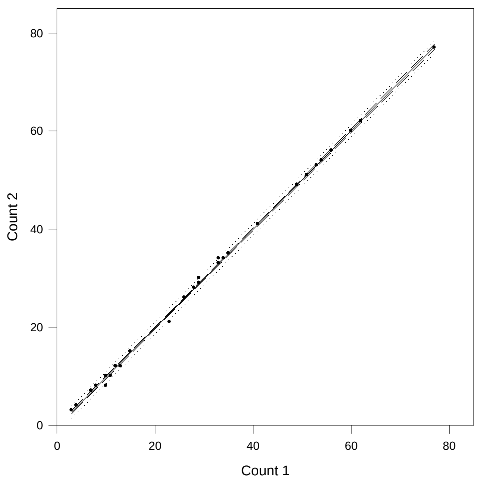


AR = -0.44 + 0.97(RS)
n = 36, R^2 = 0.98,
Intercept not significantly different than zero (P >0.05);
Slope not significantly different than 1, P > 0.05,

EB = 0.01+ 0.97(RS)
n = 76, R^2 = 0.97,
Intercept not significantly different than zero (P >0.05);
Slope not significantly different than 1, P > 0.05,

3) Within Observer - photo-counts

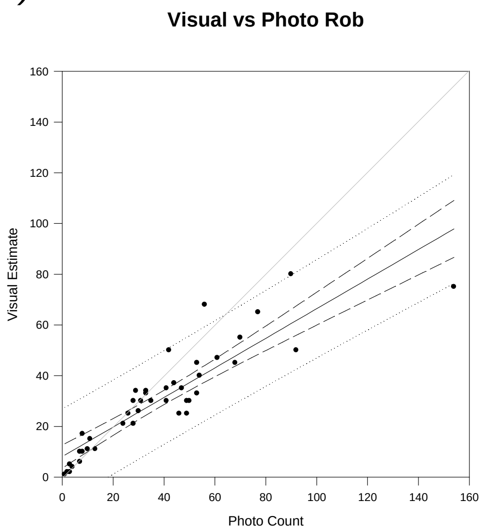
REAS conducted a blind replicate on selected photos. All images were examined in without reference to the previous count. Only 6 observations differed.



Count 1 = -0.34 (± SE 0.19) =1.00 (± 0.005) Count 2
n = 33, R^2 = 0.99,
Intercept not significantly different than zero (P >0.05);
Slope not significantly different than 1, P > 0.05,

It was concluded that counts and visual estimates of RS could be replicated by others and these were the data used whenever possible.

4) Within Observer - Visual Estimates vs Photographic Counts



visual estimate = 8.06 + 0.58 photo-count

n = 42, R^2 = 0.80,
Intercept significantly different than zero (P <0.001);
Slope significantly different than 1, (P <0.001)

Divergence was pronounced at groups sizes over 40.

Conclusion

As a consequence of these analyses, only photographic counts from REAS were used and photo counts always took precedent over visual estimates.