Estimating Productivity and Pup Growth Using Aerial Imagery of Harbor Seals on Ice

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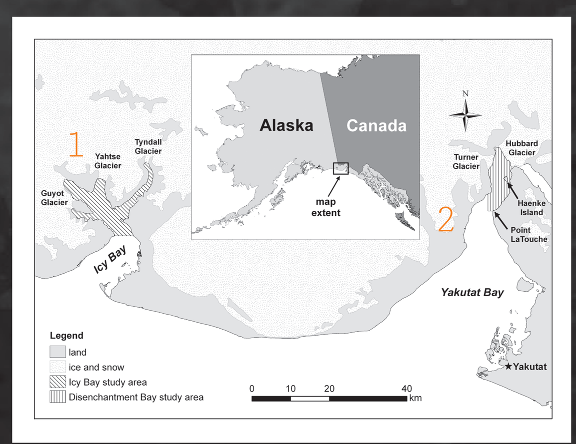
1 The Gist

Monitoring indices of productivity and pup growth would lead to more timely management and better conservation of seal populations. But estimating even basic age structure of seal populations (pups vs. non-pups) is hampered by the difficulty of getting adequate numbers of measurements, particularly for species inhabiting areas of ice. A method to measure body size and estimate pup growth - via remote sensing - would be valuable for long-term monitoring. We used vertical aerial photographs of harbor seals hauled out on glacial ice over two years (2004-2005) at two sites (Disenchantment and Icy Bays, Alaska, USA) to estimate body length of seals in a GIS (N =29,884 seals over 39 surveys). We fit a linear growth curve to length measurements from a subset of pups (i.e., small seals photographed suckling; N = 1,018 mother-pup pairs), and then used independent data from known yearlings (N = 45) and discriminant analysis to discern pups (N = 9,349) from non-pups across the entire population. Because cross-sectional data tend to underestimate actual growth rates, we derived a novel correction to simulate measures of longitudinal growth. Our estimated growth (3.34 mm/day) did not differ by site or year, and was very close to results from an actual longitudinal study (3.30 mm/day; N = 7 pups). Productivity (pups/total seals) was similar across sites and years, varying from 0.34 to 0.40, but higher than estimated at other sites (0.23 - 0.34). This new method shows promise for estimating population structure and in turn pup growth and productivity, using regular aerial surveys.

3 The Species[a], Study Areas[b], Method[c], and Dataset[d]

a Harbor seals *Phoca vitulina richardsi* haul out in fjords on ice calved from glaciers. Moms nurse their highly precocial pups on the ice over 3-4 weeks.

b Seals use glacial ice fields in Icy[1] and Disenchantment Bays[2], near Yakutat, Alaska. The latter site is visited by over 150 cruise ships during pupping and molting.



c1 GPS-linked, digital SLR camera, mounted in belly port, capturing images of 80m X 120m ground coverage at 4cm/px resolution every ~ 2 sec.

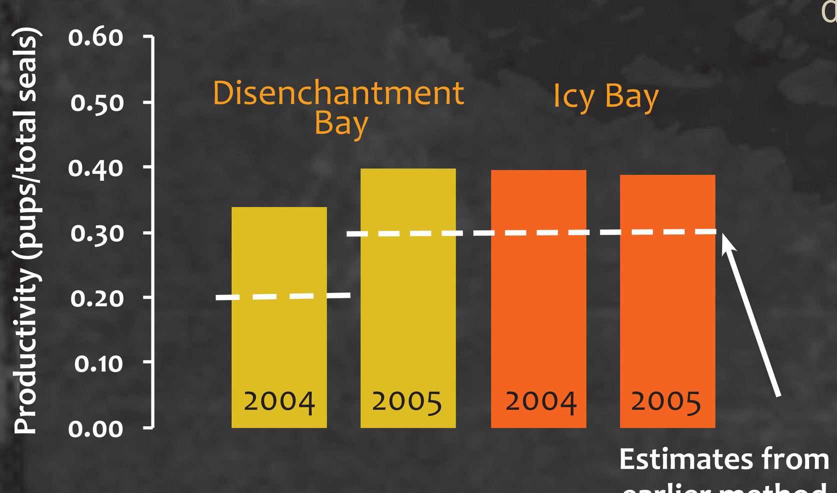
c2 DHC-Beaver flying transects 200m apart @ 1000 ft.

d N = 29,884 seals mapped over 39 surveys from May to June 2004 and 2005(13 @ Icy Bay, 26 @ Disenchantment Bay); 1,018 pups photographed suckling.

5 The Punch Line[a, b]

a Pup productivity was similar across years/ sites and higher than that from previous methods at our and other sites (0.23-0.34).

b Corrected pup growth rate (3.34 mm/day) did not vary by site (ANOVA:P=0.6) or year (P=0.13) and was comparable to published values from a longitudinal study (3.30 mm/day; Cottrell et al. 2002).



2 Background[a], Relevance[b], and Goals[c]

a In mammals, offspring growth and survival are a function of the mother's reserves at parturition and the extent to which she gathers food during the nursing period. Though poorly studied, lactation strategies in harbor seal are believed to be more consistent with that found in smaller phocids (income breeders) than that of larger phocids (capital breeders).

b We studied harbor seals that rear young on floating ice in tidewater glacial fjords, unique habitats that in Alaska are thought to support relatively high densities of nursing females that represent important source populations for disperal. Indeed, these fjords support the largest aggregations of harbor seals in the world, but the incidence of pups - or even what defines a pup observed at distance - has not been rigorously established. Previous studies, especially those enumerating pups on glacial ice, have likely underestimated productivity because a pup has been assumed to always occur with an attendant mom despite studies showing mothers will leave a pup unattended to forage. Seals at our study site are an important cultural and nutritional resource for Alaska Native people. They are also increasingly being disturbed by tour vessels with potential survival risks to pups.

c Our goal was to derive a standard method for enumerating pups - independent of mothers - by coupling specific behavioral and size criteria, which in turn would allow us to estimate productivity and possibly pup growth. We hoped our findings would shed light on two hypotheses: 1) glacial fjords are important nursery areas, and 2) glacial seals, as shown elsewhere, are income breeders requiring mothers to feed while pups are left unattended. We believe that having a cost-effective way to track measures of population health will lead to more timely and thus better conservation.

4 Three Hurdles[a, b, c]

a How to define a seal pup viewed from 1000 feet

Seals were considered known pups if they were observed in a suckling position with another larger seal, presumably its mother • The size distribution of this pool of pups was used in conjunction with that of known yearlings to discriminate non-suckling pups, with or without an attendant mom (see 4c below; yearling sizes provided by ADFG, Juneau, AK).

Examples of suckling and non-suckling pups: i) pup suckling soon after birth and another non-suckling; ii) three mother-pup pairs, one suckling; ii) two pairs both suckling; iv) a solo pup.

b How to detect and estimate growth

Minimal relief on ice floes - combined with vertical photography at a constant altitude - allowed for useful length measurements in a GIS (Fig 1) • We used a technique to correct cross-sectional growth to simulate longitudinal growth (Fig 2) • Large samples of seal body lengths was sufficient to detect growth of pups (Fig 3).

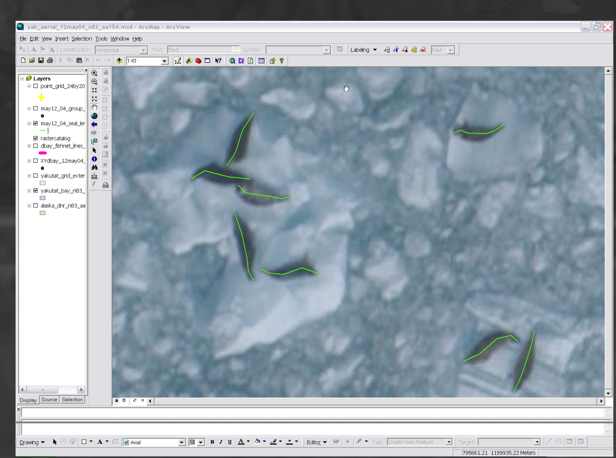


Fig 1 *Polylines* superimposed on seals to estimate body length in ArcGIS. Resolution is apx. 4 cm per pixel. Geo-JPG was drawn to scale assuming altitude was a constant 1000 ft. Distortion was assumed to be negligible.

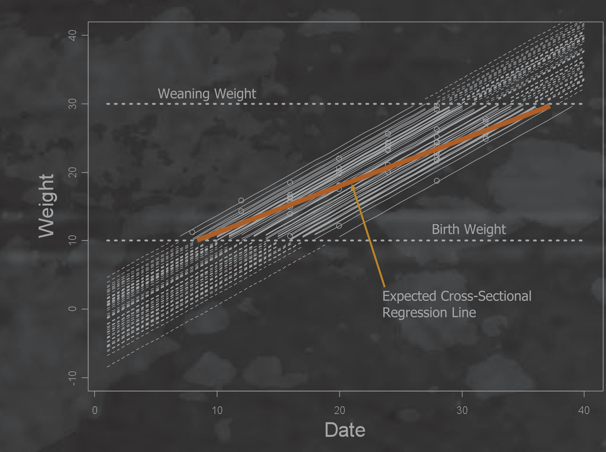


Fig 2 The expected negative bias that results from using cross-sectional measures (orange line) of body length versus longitudinal measures. Bias was corrected by fitting a hierarchical truncated normal distribution (see Fig 3).

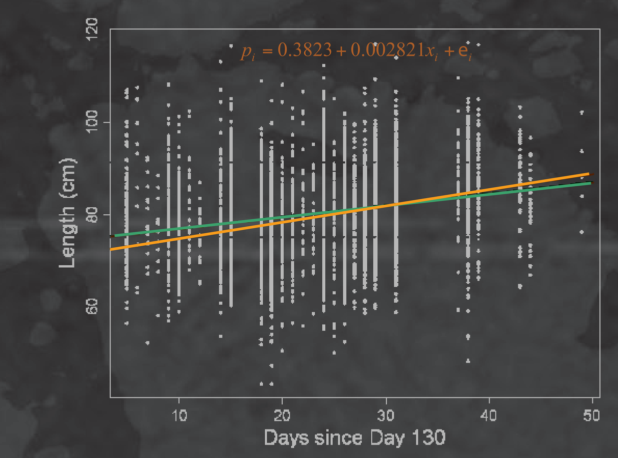


Fig 3 Comparison of corrected (orange) and uncorrected (green) linear growth models of pups observed suckling (N = 1,018); equation of corrected growth shown above where p_i is seal length, x_i is day of year, and e_i is the random error with mean zero.

c How to distinguish pups from yearlings, quantitatively

Modeling the size distributions of known pups and yearlings produced probabilty densities that were used to classify pups vs non-pups based on body length (Fig 4) • The mean length of pups reflected growth over the weaning period, while yearling size had no trend so was kept constant at the mean (Fig 5) • The final classification allowed for a positive trend in pup size (Fig 6). We identified 8,674 non-suckling pups, of which 1,750 were newly classified as pups (compared to earlier methods), and 630 were solo on the ice.

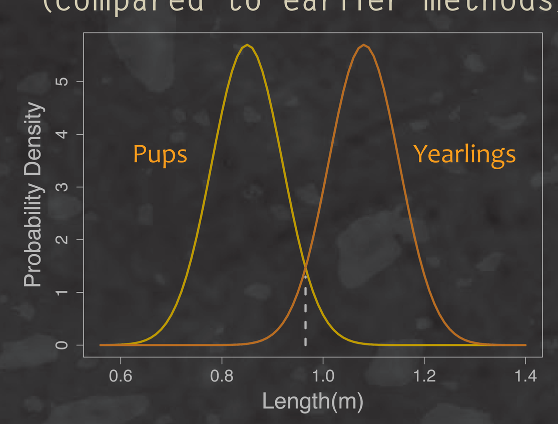


Fig 4 Probability density from linear growth model for pups (see Fig 3), and linear non- growth model for yearlings: $y_i = 1.0807 + \delta_i$, where y_i is seal length and δ_i is the random error with mean zero.

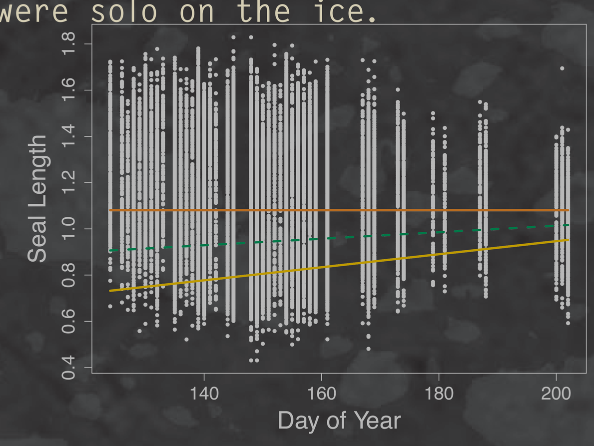


Fig 5 Mean length of pups (May/June; yellow line) and yearlings (April/May; orange line) by day of year. The green line marks the classification line, which is the halfway point between pups (trending) and yearlings (non-trending). Data points represent all seals.

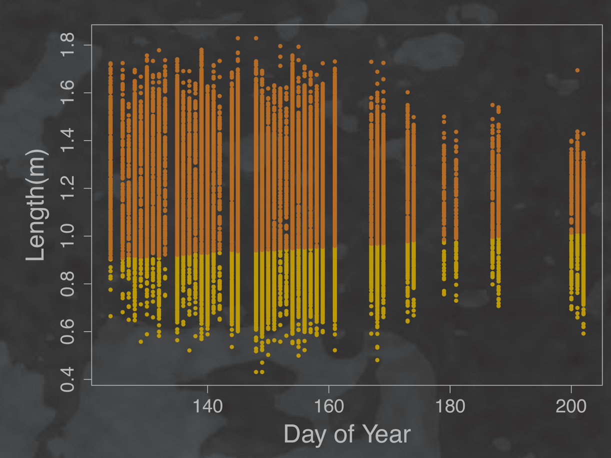


Fig 6 Classifcation of pups (yellow; N=9,349) and non-pups (orange; N=20,018). Pups were discriminated based on the sample of those suckling (N = 1,018) in conjunction with independent data on yearling size (N=48; provided by ADFG)

6 The Take Home[a, b, c]

a Seals hauled out on ice can be photographed, mapped, and measured to derive large datasets for tracking population measures that previously were attainable only through long-term and capture-recapture studies.

b It is likely that 10-20% of the pups identified were without a mother in attendance. We believe our findings support an income breeding strategy for harbor seals in glacial fjords.

c Our findings support the "nursery" hypothesis (high productivity) in glacial fjords, but standard methods need to be univerally applied for better comparisons across sites.

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