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Technical Report · March 2015

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**Status and Trend of Harbor Seals (*Phoca vitulina richardii*)
at Terrestrial Sites in Glacier Bay National Park from 1992-2013
Progress Report**



Harbor seals at Spider Island Reef in Glacier Bay National Park.

Jamie N. Womble¹, Grey W. Pendleton², Elizabeth A. Mathews³, Scott M. Gende¹

¹National Park Service
3100 National Park Road
Juneau, Alaska 99801

²Alaska Department of Fish & Game
Division of Wildlife Conservation
Juneau, Alaska 99801

³1350 Yalupa Avenue, Unit B
Santa Rosa, California 95405

Corresponding author: Jamie_Womble@nps.gov

March 10, 2015

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ABSTRACT

Population monitoring studies of harbor seals in Glacier Bay have spanned five decades from the 1970's to the present, representing one of only a few sites in Alaska where such long-term monitoring effort exists. Monitoring methods for harbor seals at terrestrial sites have remained consistent since 1992 allowing for long-term trend estimates. The primary objective of this report is to summarize trends for harbor seals at terrestrial sites (including small glacial ice sites in McBride Inlet and Tarr Inlet) in Glacier Bay during the molting period in late July and August (1992-2013) and during the pupping period in June (2007-2013). The updated 22-year (1992-2013) trend estimate for harbor seals at terrestrial sites during the molting period in Glacier Bay (including glacial ice sites in McBride Inlet and Tarr Inlet) remains negative (-6.91%/year: SE=0.40, 95% CI = -7.69, -6.13). However, the most recent trend from 1992-2013 is less negative than previous estimates from 1992-2001 (-14.5%/year: SE=1.33, 95% CI = -17.07, -11.85) (Mathews & Pendleton 2006), 1992-2008 (-11.5%/year; SE=0.66, 95% CI = -13.7, -11.11) (Womble et al. 2010), and 1992-2011 (-9.27%/year; -10.22, -8.31) (*J. Womble, unpublished data*) (Table 1). Trend estimates over the more recent 10-yr period from 2004-2013 (9.64 %/yr; SE=1.66, 95% CI = 6.40, 12.89) and the 5-yr period from 2009-2013 were positive (13.25%/yr; SE= 4.37, 95% CI = 4.69, 21.82) and suggest a decrease in the rate of the declines that persisted for more than a decade. However, the number of seals at terrestrial sites in Glacier Bay has not returned to pre-decline levels that were documented in the early 1990's.

INTRODUCTION

Population monitoring studies of harbor seals in Glacier Bay have spanned five decades from the 1970's to the present (Streveler 1979; Calambokdis et al. 1987; [Mathews & Pendleton 2006](#); [Womble et al. 2010](#)), representing one of only a few sites in Alaska where such long-term monitoring effort exists ([Pitcher 1990](#); [Frost et al. 1999](#); [Jemison et al. 2006](#); [Hoover-Miller et al. 2011](#)). Monitoring of harbor seals has been justified and prioritized for a number of reasons. First, harbor seals are one of the most numerous species of marine mammal in Glacier Bay National Park, serving an important role in the marine ecosystem as both consumer and as prey, as well as being a highly sought-after viewing experience for visitors to Glacier Bay. Second, monitoring efforts in the mid-1990's revealed precipitous declines in harbor seals, with the steepest declines occurring at terrestrial sites, resulting in elevated conservation concerns ([Mathews & Pendleton 2006](#)). Third, harbor seals in the Glacier Bay and Icy Strait region were recently designated by the National Marine Fisheries Service as one of twelve stocks of harbor seals in Alaska, rather than only three, based primarily on genetics, telemetry data, and population trends, thus underscoring the importance of understanding the status and trend of seals in the Glacier Bay region (Allen & Angliss 2011).

Trend estimates for harbor seals at terrestrial sites in Glacier Bay have been previously reported in [Mathews & Pendleton \(2006\)](#) and [Womble et al. \(2010\)](#). Here we provide an updated estimate of the trends of harbor seals counted at terrestrial sites in Glacier Bay National Park during the molting period (late July-August) from 1992-2013 and during the pupping period (May-June) from 2007-2013. This summary does not include trend estimates for seals counted at the primary glacial ice site in Johns Hopkins Inlet as analysis is currently ongoing using

analytical methods that have been recently developed by the National Marine Mammal Laboratory ([Ver Hoef & Jansen 2014](#)).

METHODS

Aerial Photographic Surveys at Terrestrial Sites

Aerial survey methods for counting and photographing harbor seals at terrestrial sites in Glacier Bay (Figure 1) have generally been consistent over the 22-year period from 1992-2013 ([Mathews & Pendleton 2006](#); [Womble et al. 2010](#)). From 1992-2002, aerial surveys of harbor seals in Glacier Bay were conducted by Elizabeth Mathews and colleagues from the University of Alaska Southeast and Glacier Bay National Park & Preserve ([Mathews & Pendleton 2006](#)). From 2004 to 2013, aerial surveys were conducted by Jamie Womble (National Park Service) and colleagues from the Alaska Department of Fish & Game-Division of Wildlife Conservation ([Womble et al. 2010](#)). The aerial surveys are based on standardized methods that have been developed and implemented for counting harbor seals in several regions of Alaska ([Frost et al. 1999](#); [Boveng et al. 2003](#); [Small et al. 2003](#)).

Aerial photographic surveys of harbor seals at terrestrial sites and two glacial ice sites in Tarr Inlet and McBride Inlet were conducted during the pupping period in June from 2007 to 2013 and during the molting period in late July and August from 1992-2013 (Table 1). Replicate aerial surveys (Figure 1) were conducted to increase precision in the trend estimates of harbor seals ([Adkison et al. 2003](#); [Small et al. 2003](#)). If it was not possible to complete at least 4 replicate surveys on different days during one tidal cycle, then surveys were attempted during the second low tidal cycle of the month, weather permitting.

Fixed-wing single engine aircraft were used to photograph harbor seals at terrestrial sites and at small glacial ice sites in McBride Inlet and Tarr Inlet. Aerial surveys were conducted at

an altitude of approximately 304 meters (unless weather conditions required lower altitudes) and usually ± 2 hours around the low-tide over a 4-8 day cycle of low tides (Table 1). Once seals were located at a site, the pilot circled the site repeatedly and an experienced observer photographed all seals that were present. Harbor seals were photographed using a digital single-lens reflex camera (Nikon D1X and Nikon D2X with Nikkor 80-300 mm lens). In most cases, groups of seals that were hauled out were generally small enough to fit into one photographic field, with the exception of Spider Reef, Flapjack Island, and McBride Inlet. The primary observer also visually counted or estimated the number of seals ashore.

If disturbance occurred during the survey, it was documented and the number of seals disturbed was recorded. Counts of harbor seals associated with substantial pre-count disturbance were not used in the analyses.

Beginning in 2007, a handheld GPS unit (Garmin 76 CSX) was used to record the track line of the aircraft at 2-second intervals. The GPS unit and digital SLR camera were synchronized to the second before the start of each survey. The track line by the GPS was used to geocode digital surveys photos during post-processing.

Since 2004, only two pilots, both with extensive experience surveying pinnipeds in Alaska (Jacques Norvell/Tal Air, 2004-2010; Charles Schroth, Jr./Fjord Flying Service, 2011-2013), have piloted the aircraft during the aerial surveys. All aerial surveys from 2004-2013 were conducted under NOAA-National Marine Fisheries Service Scientific Research Permits (#358-1787-01; 358-1878-02; 16094-01; 16094-02) and Glacier Bay National Park Scientific Research and Collecting Permits.

Processing Digital Imagery

After each survey was completed, the high-resolution digital images (Figure 2a) for each survey day were downloaded and geocoded using RoboGEO V5.6.17, which writes the latitude, longitude (decimal degrees, WGS 84), GPS timestamp, and altitude (meters) from the GPS track line into each image's EXIF header and permanently embeds the location data within the digital image. Digital images were reviewed and the clearest digital images for each site were selected and imported into ArcGIS for counting. A point shape file was created in ArcGIS and each seal was marked as a point feature (Figure 2b). Each image was counted twice by an experienced observer and the average of the two counts was recorded as the total count.

The aerial survey methods for harbor seals at terrestrial sites are very similar to those established in the early 1990's by E.A. Mathews, with a few exceptions. First, from 1992-2002, harbor seals were photographed using a 35-mm SLR camera with a motor drive with 400 ASA slide film which produced slides that were projected onto paper for counting ([Mathews & Pendleton 2006](#)). In 2004, we began using a digital SLR camera (Nikon D1X & D2X with 80-300 mm Nikkor Image Stabilizing lens) which produced digital images that could be imported into GIS for counting seals ([Womble et al. 2010](#)). Beginning in 2007, as mentioned, a handheld GPS unit (Garmin 76 CSX) was used to record the track line of the aircraft. Collectively, these changes made data collection in Glacier Bay consistent with methods currently used by the National Marine Mammal Laboratory for monitoring harbor seals throughout Alaska.

Statistical Analysis

Estimates of population trend based on counts should account for both the variation in counts as a function of real changes in population abundance and also for factors that influence the proportion of the population that is visible and available to be counted during aerial surveys.

Counts of harbor seals from aerial photographic surveys were modeled as a function of covariates that could affect visibility or availability (*e.g.*, time of day, tide height, survey date) and also a polynomial function of year that was assumed to reflect population change ([Small et al. 2003](#)).

General linear models (McCullagh & Nelder 1989) were used to estimate the relationship between counts of harbor seals and covariates with a Poisson response and log link function for three time periods during the molting season (22-year: 1992-2013; 10-year: 2004-2013; 5-year: 2009-2013) and one time period during the pupping season (7-year: 2007-2013), following methods described by [Link & Sauer \(1997\)](#). Count data of harbor seals are often “overdispersed” with the variance typically larger than the mean, which violates the Poisson assumption ([Ver Hoef & Boveng 2007](#)). Thus, each site was modeled with its own intercept and over-dispersion parameter. The contribution of each site to the overall trend for the time period of interest is based on weighting the number of seals at each site, which gives greater weight to sites with higher numbers of seals (*e.g.*, Spider Reef) and provides a weighted average trend across sites ([Link & Sauer 1997](#)).

Covariates included in the general linear models were date, time relative to solar noon ($[(\text{sunrise} + \text{sunset})/2]$), tide height, and time relative to low tide for the time of survey for each site. Quadratic effects were included for date (*e.g.*, date^2), time relative to solar noon, time to low tide, and tide height. An interaction term was included between tide height and site, which allowed the effect of tide to vary among sites ([Small et al. 2003](#); [Mathews & Pendleton 2006](#)).

The number of seals counted during an aerial survey represents a minimal estimate of population size, as some unknown proportion of seals are in the water and not available to be counted during surveys. Estimating the proportion of seals that is not available to be counted

requires estimating the proportion of time that seals spend hauled out ([Boveng et al. 2003](#)) using radio and/or satellite telemetry during the survey period of interest (*e.g.*, [Simpkins et al. 2003](#)). Thus, the population trajectory that is estimated from aerial photographic counts of seals represents a smoothed curve that is proportional to the actual population size across years. Population trend was defined as the geometric mean rate of changes over the time period of interest as the population trajectory may not always be linear. Trend is a single-number summary of the average change in the trajectory for a specific time period ([Small et al. 2003](#); [Mathews & Pendleton 2006](#)).

Model averaged estimates of trend and standard errors were obtained for each time period as a weighted average of trend from the individual models with weights based on corrected Akaike's Information Criteria (AICc) ([Hurvich & Tasi 1989](#); [Burnham et al. 1995](#)). All combinations of covariates and both linear and quadratic population trajectories were fit for a total of 768 models for the entire series from 1992-2013. Fewer models ($n = 384$) were included for the 10- and 5-year trend periods because models with quadratic population change were not included for these shorter time periods. The model-averaging procedure ([Burnham & Anderson 2002](#)) incorporates the uncertainty regarding which model is most appropriate into the trend estimate and its variance. To assess the sensitivity of the trend estimates to covariates, models were evaluated by omitting sets of covariates.

An importance index was calculated for each covariate for each of the four trend periods. The relative importance of a covariate was estimated by summing the Akaike weights across all models in the model set where the covariate occurred ([Burnham & Anderson 2002](#)). The relative variable importance index ranges from 0 to 1, with higher values indicating more important covariates relative to other covariates in the model set. Previous analysis of similar harbor seal

count data from several locations has suggested that covariates with importance indices < 0.85 rarely have substantial influence on estimated trends (G.W. Pendleton, *unpublished*).

The statistical methods used in this most recent analysis (1992-2013) are the same as those that have been used to estimate trends in the number of seals from aerial surveys at terrestrial sites in Glacier Bay from 1992-2001 (Mathews & Pendleton 2006) and from 1992-2008 (Womble et al. 2010) and also in other regions of Alaska including Sitka, Ketchikan, Kodiak, and Bristol Bay (Small et al. 2003).

RESULTS

The 22-year (1992-2013) trend estimate for harbor seals at terrestrial sites in Glacier Bay (including two small glacial ice sites in McBride Inlet and Tarr Inlet) during the molting period is -6.91% /year (SE=0.40, 95% CI = -7.69, -6.13). Previous trend estimates for this same area but from shorter time intervals are -14.5% /year (1992-2001: SE=1.33, 95% CI = -17.07, -11.85, Mathews & Pendleton 2006), -11.5% /year (1992-2008: SE=0.66, 95% CI = -13.7, -11.11, Womble et al. 2010), and -9.27% /year (1992-2011: SE=0.49, 95% CI = -10.22, -8.31, J. Womble, *unpublished data*) (Table 1). The 10-year trend estimate from 2004-2013 was 9.64% /yr (SE=1.66, 95% CI = 6.40, 12.89) and the 5-yr estimate from 2009-2013 was 13.25% /yr (SE=4.37, 95% CI = 4.69, 21.82). The lower magnitude of the estimated annual decline highlights the non-linear pattern of the population change during the molting period (Figure 3).

The number of seals counted during the pupping period (May-June) over the 7-year period from 2007 to 2013 appears stable (4.36% /year (SE=1.79, 95% CI = 0.85, 7.86) (Table 2). Harbor seal count data from earlier time periods in the 1990's were not available for all

terrestrial haulout sites in Glacier Bay and thus precluded a comparison of trends between earlier time periods (1990's) and more recent years (2007 to 2013).

The importance of the covariates varied with survey period (Table 3), as did the sensitivity of the trend estimates to inclusion of the covariates (Table 4). The study design attempted to eliminate the effect of covariates where possible; however, for short series of years, the specific pattern of the covariates (e.g., count dates earlier over time) could be confounded with trend, affecting both the importance and the sensitivity. Covariates with importance >0.85 often, but not always, have greater effect on trend estimates (i.e., trend estimates more sensitive). Trend estimates usually are not sensitive to inclusion of covariates with importance <0.85 , but there are exceptions, especially for short series of years (Tables 3 & 4). The quadratic year effect (1992-2013 period only), was highly important and had high sensitivity, as would be expected from the pattern of decline and then an increase in counts (Figure 3). Survey date (including date²) had an importance value > 0.85 for all periods, but the trend estimate was not usually sensitive to the covariate, except for in the pupping season analysis. Time to low tide was important and was associated with higher sensitivity for 3 of the 4 analyses (Tables 3 & 4), but the direction of the effect differed based on the specific patterns of survey times in the different data sets. Time to solar noon and tide-related covariates generally had low importance and were associated with low sensitivity (Tables 3 & 4).

DISCUSSION

The most recent trend estimates from 1992 through 2013 indicate that the rate of decline in the number of seals at terrestrial sites during the molting period in Glacier Bay has lessened. The more recent, shorter-term trends (10-yr and 5-yr) are positive and this pattern of increase in the number of seals counted is particularly apparent at Spider Island Reef, the largest terrestrial

site for harbor seals in Glacier Bay. The decline in the number of seals at terrestrial sites in Glacier Bay appears to have abated sometime between 2004 and 2007 and has been increasing since then. However, the number of harbor seals counted at terrestrial sites in Glacier Bay has not returned to pre-decline numbers. Compared to peak counts in the early 1990's, only about 30-50% of the number of seals has been counted at some haulout sites in the most recent surveys. In contrast to declines in Glacier Bay, harbor seals in the nearby regions of Sitka and Ketchikan were stable and increasing over the period coincident with the declining phase in Glacier Bay (Small et al. 2003).

Generally the trend analyses for seals at terrestrial sites in Glacier Bay were not very sensitive to the use of covariates and the relative importance of covariates differed depending upon the trend period. However for some data combinations (i.e., specific time periods and survey conditions), inclusion of covariates is essential to mitigate confounding between covariate patterns and trend. Importance values of covariates should be interpreted cautiously because the aerial surveys have been designed to count seals under optimal conditions, typically conducting surveys during the lowest tidal cycle during the pupping period in May and June or molting period in late July and August. As a result, surveys have not been conducted across a range of conditions for tidal height or other covariates. If surveys were conducted across a range of conditions then the importance of some of the covariates might be expected to be higher (Mathews & Pendleton 2006). As with the trend estimates themselves, the covariate importance and sensitivity values are location and time-period specific.

After the initial decline in harbor seals in Glacier Bay was documented ([Mathews & Pendleton 2006](#)), research was initiated to identify potential factors that may have caused the decline. A suite of studies indicated that (1) the body condition of harbor seals that were

sampled from 2004-2006 was not different from other stable or increasing populations (Blundell et al. 2011), (2) the clinical health and disease status of seals is not different than seals from other stable or increasing populations ([Hueffer et al. 2011](#)), (3) disturbance by vessels was not a primary factor driving the decline ([Young et al. 2014](#)), (4) predation by Steller sea lions was not a sole factor responsible for the declines ([Mathews & Adkison 2010](#)), and (5) harbor seals exhibit a high-degree of fidelity to Glacier Bay during the breeding season (May-June), but the majority seals traveled beyond Glacier Bay during the post-breeding season (September-April) (Womble & Gende 2013).

Potential competition with Steller sea lions and humpback whales was also suggested as a possible factor contributing to the declines (Mathews & Pendleton 2006; Herreman et al. 2009). Steller sea lions in the Glacier Bay region increased at unprecedented rates (8.8%/year) from the 1970's to 2009 (Mathews et al. 2011) and humpback whales in Glacier Bay increased at 4.4%/year from 1985 to 2009 (Saracco et al. 2014). Although competition has not been directly investigated as a potential factor in the decline, if it were a major factor contributing to the decline in the number of seals in Glacier Bay, we would not expect to see stable and increasing trends in harbor seals in more recent years given the continued growth in the number of Steller sea lions and humpback whales in the Glacier Bay and Icy Strait region.

Precipitous declines in harbor seals occurred in several regions (Tugidak Island, Prince William Sound, Aialik Bay, Aleutian Islands) of Alaska beginning as early as the 1970's ([Pitcher et al. 1990](#); [Frost et al. 1999](#); [Jemison et al. 2006](#); [Small et al. 2008](#); [Hoover-Miller et al. 2011](#)). In more recent years, there is evidence to suggest that the declines in harbor seals at some of these sites have abated. For example, in the early 1990's, the number of harbor seals at Tugidak Island in the western Gulf of Alaska and Nanvak Bay in Bristol Bay began to stabilize and

increase after periods of steep decline that began in the 1970's ([Pitcher et al. 1990](#); [Jemison et al. 2006](#)). Similarly, in Aialik Bay in the Gulf of Alaska, harbor seals declined by 93% from 1979 to 2009, but the number of harbor seals began to increase in the mid-1990's ([Hoover-Miller et al. 2011](#)). These patterns of steep decline followed by stabilization and gradual increase are similar to patterns that have been documented for harbor seals at terrestrial sites in Glacier Bay, although the abatement of the decline occurred several years later in Glacier Bay.

Collectively, these similar population trajectories for harbor seals from different regions in Alaska may suggest that larger-scale factors such as changes in oceanographic climate may have been a factor that led to declines in harbor seals and other pinnipeds in several regions of Alaska. Large-scale physical and biological changes occurred in the Northeast Pacific in the 1970's with a well-documented regime shift occurring in 1976-77 ([Miller et al. 1994](#); [Trenberth & Hurrell 1994](#)). Ocean temperatures shifted from cooler to warmer and there was a subsequent reorganization in community structure and species composition in the western and central Gulf of Alaska. The reorganization was characterized by a shift from a higher-quality forage fish dominated community to communities dominated by lower-quality gadids and pleuronectids ([Piatt & Anderson 1996](#); [Anderson & Piatt 1999](#)). The pattern of warmer ocean temperatures persisted for over three decades. In 2008, there was a substantial shift from warmer to cooler ocean temperatures with some indications that there may have been a reversal of the 1977 regime shift. Recent evidence from studies of black-legged kittiwakes (*Rissa tridactyla*) in the Gulf of Alaska suggests that the most recent shift back to cooler water temperatures may provide more favorable conditions for upper-tropic level species ([Hatch 2013](#)).

Understanding mechanistic linkages between bottom-up and top-down processes, vital rates (e.g., survival and reproduction), and population trajectories of harbor seals and other

pinnipeds in Alaska are important (Trites et al. 2007); however, elucidating these complex relationships can be extremely challenging. Nonetheless, long-term population monitoring of harbor seals is an important adjunct to research that is aimed at obtaining a greater mechanistic understanding of factors influencing the population biology of species of conservation concern.

ACKNOWLEDGEMENTS

We greatly appreciate the expertise of Jacques Norvell (Tal Air) and Chuck Schroth (Fjord Flying) for safely conducting harbor seal aerial surveys in Glacier Bay. Louise Taylor-Thomas, [Kevin White](#), Gail Blundell, and [Karen Blejwas](#) assisted with conducting surveys. Louise Taylor-Thomas, Melissa Senac, and Kym Yano (National Marine Mammal Laboratory) assisted with photo processing and database entry. Funding and logistical support for aerial surveys was provided by Glacier Bay National Park & Preserve, the National Park Service, University of Alaska Southeast, Alaska Department of Fish & Game, and the Alaska Fisheries Science Center-Auke Bay Laboratory. Aerial surveys from 2004-2013 were conducted under NOAA-National Marine Fisheries Service Scientific Research Permits (#358-1787-01; 358-1878-02; 16094-01; 16094-02) and Glacier Bay National Park Scientific Research and Collecting Permits.

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Table 1. Survey effort at harbor seal terrestrial haulout sites in Glacier Bay including glacial ice sites at McBride Inlet and Tarr Inlet from 2004 to 2013 during the pupping period in June and during the molting period in late July and August.

Year	June Survey Dates	July/August Survey Dates	Total Surveys
2004	-	15, 17, 18, 19, 20	5
2005	-	4, 7, 8, 21, 24, 29	6
2006	-	8, 10, 22	3
2007	3, 10, 28	19, 12, 13, 14, 15, 16	9
2008	4, 8, 17, 23	4, 5, 6, 7	8
2009	22, 23, 24, 26	5, 6, 18, 19, 20, 21	10
2010	13, 14, 15, 16, 17	9, 12, 13, 24	9
2011	16, 17, 19, 20	1, 14	6
2012	20, 21, 22, 23	1, 16, 19, 20	8
2013	8, 9, 10, 11	7, 11, 12, 22	8

Table 2. Trend estimates and annual change (%) in the number of harbor seals counted at terrestrial sites and two glacial ice sites (Tarr Inlet and McBride Inlet) during the molting period in late July-August (1992-2013) and the pupping period in June (2007 to 2013) in Glacier Bay National Park. Previous trend estimates are from Mathews & Pendleton (2006) and Womble et al. (2010).

Years	Annual Change (%)	SE	Lower 95% CI	Upper 95% CI	Trend Period (yr)	Season	Source
1992-2002	-14.46	1.33	-17.07	-11.85	10	Molting	Mathews & Pendleton 2006
1992-2008	-12.41	0.66	-13.70	-11.11	17	Molting	Womble et al. 2010
1992-2011	-9.27	0.49	-10.22	-8.31	20	Molting	this report
1992-2013	-6.91	0.40	-7.69	-6.13	22	Molting	this report
2004-2013	9.64	1.66	6.40	12.89	10	Molting	this report
2009-2013	13.25	4.37	4.69	21.82	5	Molting	this report
2007-2013	4.36	1.79	0.85	7.86	7	Pupping	this report

Table 3. The relative importance of each covariate in the estimation of harbor seal trends at terrestrial sites in Glacier Bay over three different time periods (1992-2013; 2004-2013; 2009-2013) during the molting season (late July-August) and from 2007 to 2013 during pupping season (June). An importance index of 1.0 indicates maximum importance and 0 is not important. Year was not included in the 10-yr (2004-2013) and 5-yr (2009-2013) molting period model sets or in the 2007-2013 pupping period model sets.

Covariate	Trend Period Molting (August)			Trend Period Pupping (June)
	1992-2013	2004-2013	2009-2013	2007-2013
Year ²	1.000	~	~	~
Date	0.000	0.942	0.815	0.000
Date ²	0.985	0.311	0.308	1.000
Time to solar noon	0.001	0.902	0.268	0.000
Time to solar noon ²	0.000	0.994	0.208	0.000
Time to low tide	0.392	0.998	0.893	0.000
Time to low tide ²	0.421	0.292	0.378	0.999
Tide height	0.025	0.080	0.284	0.000
Tide height ²	0.003	0.965	0.420	0.000
Site X Tide height	0.000	0.717	0.000	0.000

Table 4. Sensitivity of trend estimates for harbor seals to inclusion of covariates. The values in the Full Model row are the estimated period-specific trends. All other values are the % change in the estimated trend if the specific covariate is not included in the model. Covariates omitted include both linear and quadratic terms for date, time relative to solar noon, and time relative to low tide.

	Molting Period (August)		Pupping Period (June)	
Variables	1992-2013	2004-2013	2009-2013	2007-2013
Full Model (Trend)	-6.91	9.64	13.25	4.36
Year ²	22.6	~	~	~
Date	-1.6	0.2	3.2	6.9
Time relative to solar noon	0	-2.4	5.4	0
Time relative to low tide	-0.6	-10.5	22.4	-16.1
Site X tide height	0	0.1	0	0
Tide height, Site X tide height	0	2.8	-4.2	0
No covariates used	23.4	-0.8	1.3	-2.8

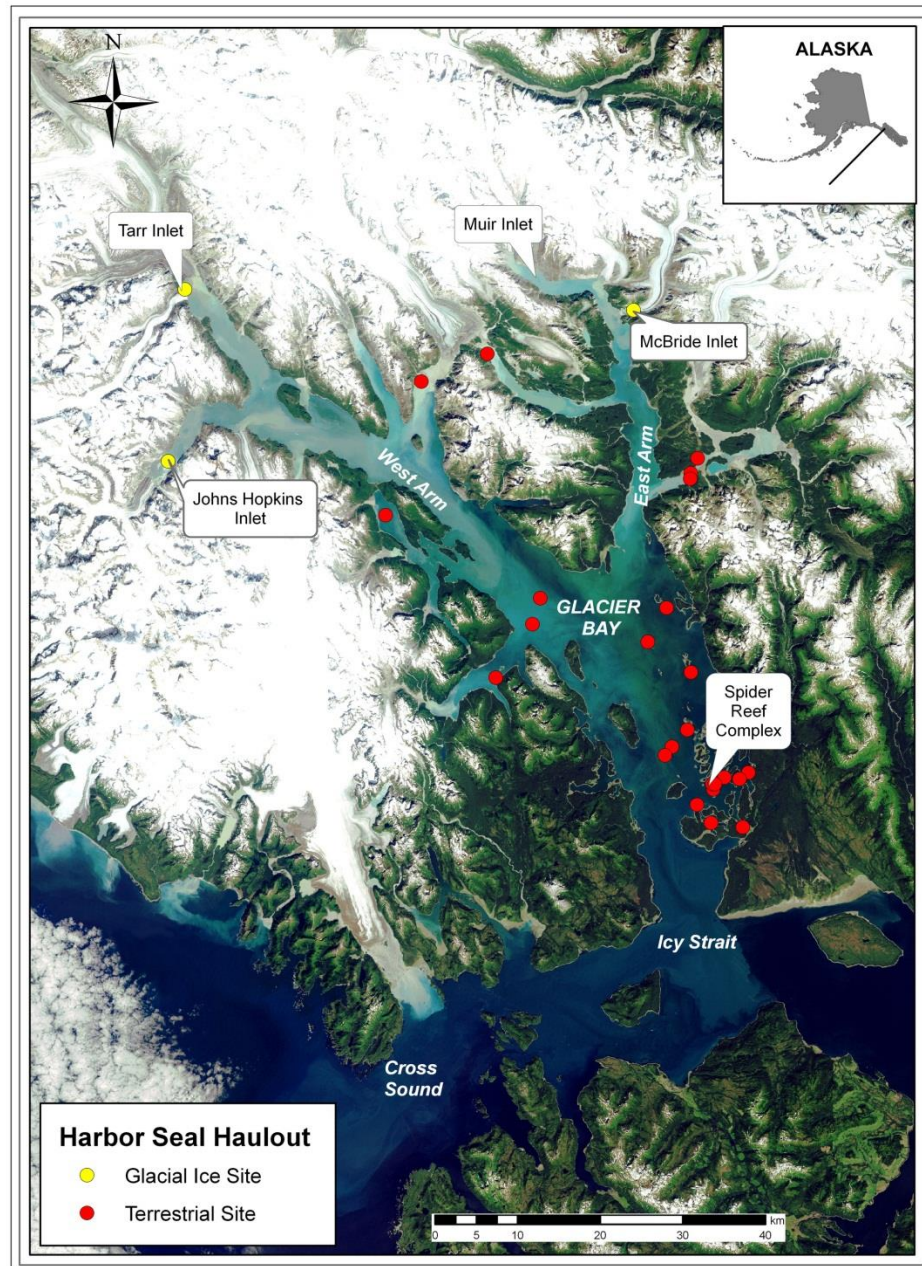


Figure 1. Harbor seal haulout sites in Glacier Bay. Red circles indicate terrestrial sites and yellow circles indicate glacial ice sites.

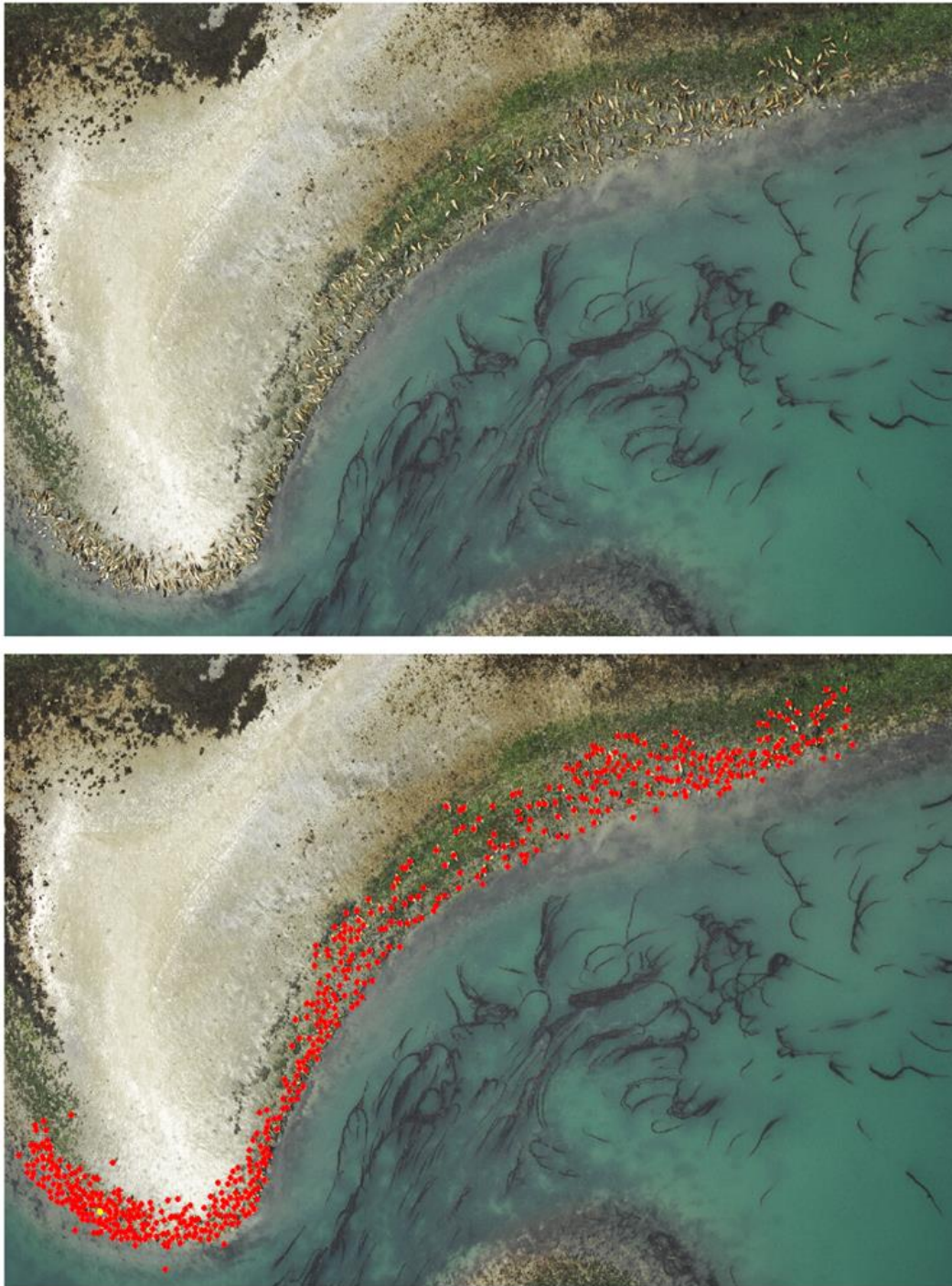


Figure 2a & 2b. Digital image of harbor seals at Spider Reef on 4 August 2008 (upper panel). Digital image of harbor seals overlaid with point shapefile in GIS for mapping and counting seals (lower panel). The total number of harbor seals counted in this image is 603.

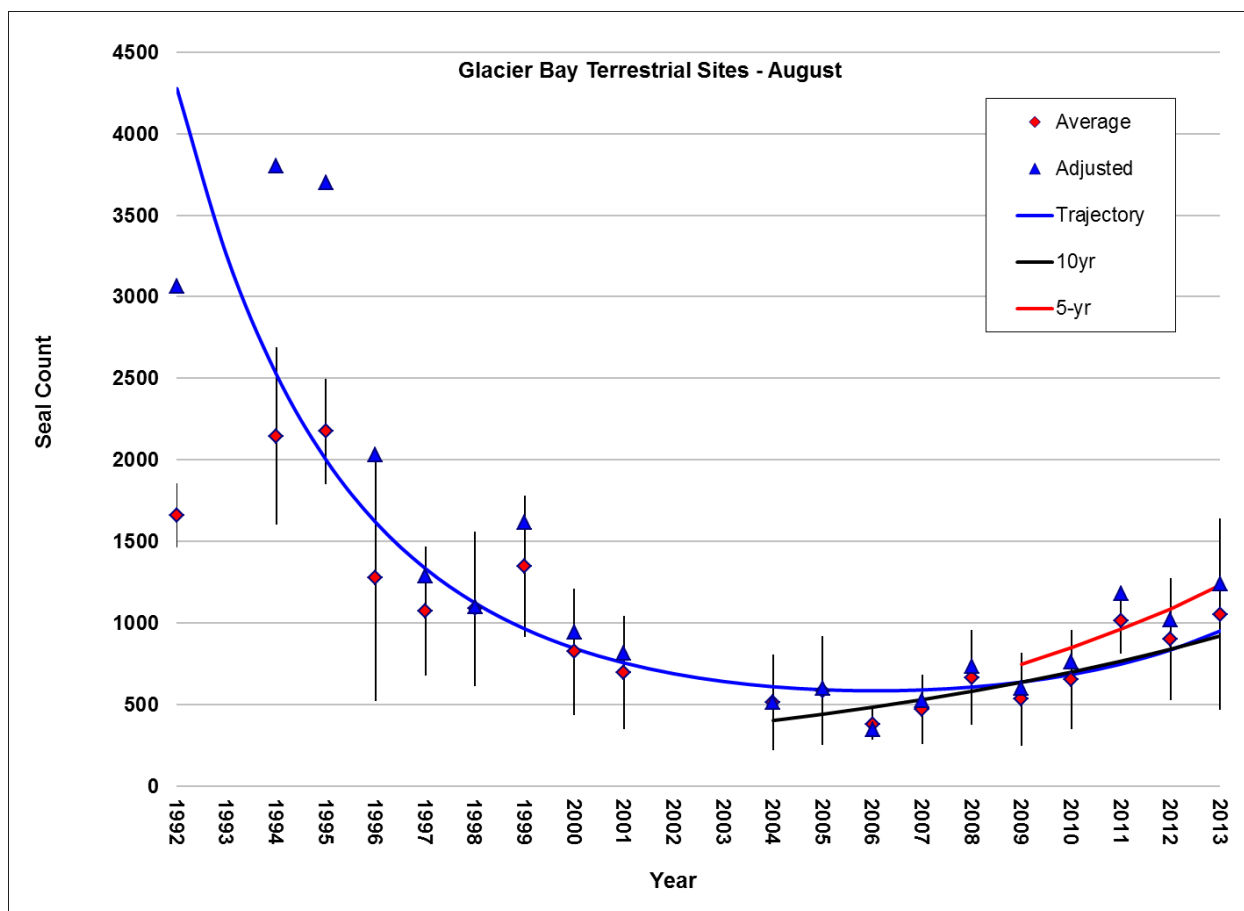


Figure 3. Trajectory (*i.e.*, smoothed pattern of population change over time) of the number of seals counted at terrestrial sites and two glacial ice sites in McBride and Tarr Inlet in Glacier Bay during the molting period in late July and August from 1992-2013 (blue line), 2004-2013 (black line), and 2009-2013 (red line). Average counts (red diamonds) were from field counts of seals conducted during aerial photographic surveys and adjusted counts (blue triangles) were functions of the field counts adjusted for the effects of covariates in the model (*e.g.*, survey date, time, tide height). Aerial surveys were not conducted in 1993 or 2003. Aerial surveys were conducted in 2002; however, data were not included in this analysis as the surveys were conducted outside of the optimal survey window. Data from 1992-2001 are from Mathews & Pendleton (2006) and data from 2004-2013 are from Womble et al. 2010, and Womble *unpublished*.