Marine Mammal Stock Assessment Review: Comments on the Use of Correction Factors in Calculations of N_{min}

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This document was written to initiate dialogue on the proposed use of correction factors for calculating N_{min} for marine mammal stock assessment reports prepared by the National Marine Fisheries Service (NMFS). Although some of the ideas presented below were discussed at meetings of the Alaska Scientific Review Group (ASRG), and several suggestions were incorporated into the document, this manuscript has not been reviewed by all members of the ASRG. Consequently, it may not reflect a consensus view on the use of correction factors. This manuscript was reviewed by Lloyd Lowry whose comments improved an earlier draft.

Direct censuses of marine mammals underestimate absolute numbers, and the use of correction factors has been proposed (Eberhardt et al. 1979) and employed (Pitcher and McAllister 1981, Thompson and Harwood 1990, Huber et al. 1992). During its October 1994 meeting the Alaska Scientific Review Group recommended the use of appropriate correction factors for estimating N_{min} where available. Because correction factors specific to a survey are rarely available, we agreed that factors from other studies might be applied to a species in other parts of its range. During this meeting we did not discuss other details of how correction factors might be applied.

While accurate correction factors are clearly desirable for improving estimates of N_{min}, we need to acknowledge that study-specific correction factors are rarely available, they are very costly to obtain, and that there are risks involved in extrapolating corrections from one study to another. In her review of the biology and management of harbor seals for the Marine Mammal Commission, Hoover-Miller (1994) comments that "[i]nformation from radio-tagging studies can be used to compute correction factors for counts to derive population estimates. Because of seasonal and annual differences in seal activity patterns and movements, it is essential to base correction factors on local knowledge and not to extrapolate from other areas or from small numbers of tagged seals (Allen-Miller 1988, Harvey 1988)."

Inappropriately applied correction factors could result in an overestimate of a population -- a breach of the requirement to maintain conservatism in all aspects of the calculation of N_{min}. If correction factors are to be used, we need to clarify specifically when and how they can be applied, we need to insure that estimates are conservatively applied, and we need to insure that there is always a scientific basis for such application.

The following sections summarize some of the problems with using correction factors and describe circumstances in which they might be used to calculate N_{min} in the MMPA stock assessments. While my discussion refers mainly to pinnipeds and specifically to harbor seals, some of my comments could also apply to the use of correction factors for other marine mammals. I encourage a dialogue with others on the Alaska Scientific Review Group on this topic and with our SRG colleagues from the other regions. While the use of correction factors is of obvious value in determining a best population estimate, we need to insure that there is a carefully designed protocol for their application, since they may result in dramatic changes in the estimates of N_{min} as well as PBR levels for many of the species under consideration.

During surveys of marine mammals some portion of the population is assumed to be unavailable for censusing. Uncorrected counts may be used to monitor trends as long as the underlying assumption that the missed proportion remains about the same from one year to another. Alternatively, marine mammals populations may be sampled and mathematical calculations may be used to estimate absolute abundance (e.g., Taylor and DeMaster 1994). For pinnipeds an estimate of the proportion of animals not at the surveyed haulouts during an aerial survey or land count can be made through the use of concurrent radio telemetry studies. Satellite telemetry systems currently available use polar-orbiting satellites. Because the satellites provide only intermittent coverage of any particular area, there are difficulties with using satellite telemetry data for developing survey correction factors (L. Lowry, pers. comm.).

Correction factors can vary widely for a species based on study timing, location, haulout substrate, age and sex of tagged animals, weather patterns, and on the specific methodology used (Hoover 1983, Thompson 1989, Huber et al. 1992, Frost and Lowry 1993), and corrections used in one area may not apply to another area or habitat (Eberhardt et al. 1979, Hoover-Miller 1994). Table 1 summarizes the range (1.5 - 5.9) of correction factors calculated from just a few telemetry studies of harbor seals. Because the PBR model used to calculate N_{min} is only robust enough to accommodate a 50% sampling bias in the correction factor (D. DeMaster, pers. comm.), the use of correction factors could result in non-conservative population estimates.

It is important to recognize that accurate correction factors for pinnipeds are a reflection of the feeding ecology and behavior of the animal. We know that habitat richness can vary from area to area, from season to season, and from year to year, so correction factors are not likely to be uniform or static. In a pinniped population which was declining due to reduced availability of food, we'd predict that individuals would spend more time foraging. This could then appear as a decline, if a static correction factor for animals in the water was applied.

Small sample sizes, biases in the age or sex of tagged animals, or errors in extrapolating the timing of one study to that of another, are as likely to result in a *liberal (i.e., large)* correction factor as they are to yield a conservative multiplier. In fact, correction factors derived from a study which does not occur at both the diurnal and seasonal peaks will tend to overestimate numbers for another survey, if the second study is conducted close to the daily and seasonal peaks (and all other factors are similar). For example, an aerial survey conducted in early July in Southeast Alaska would require a significantly higher correction factor than one flown in mid August, when molting seals spend more time resting and visible at haulouts. If a July correction factor were applied to an August count, the population could be overestimated.

Within study areas in Alaska (e.g., Glacier Bay) harbor seals rest on glacial ice where peak numbers in summer months are observed around midday (Calambokidis et al. 1987), while the haulout patterns of seals only 100 km away track tidal fluctuations (Mathews 1995). Therefore it could be necessary to use different correction factors in these two haulout/habitat types even for counts made during the same aerial survey.

Because there is no uniform conservatism inherent in methods of deriving correction factors, and because correction factors will be biased high whenever they are based on concurrent telemetry assessment which was not at or near peak haulout periods, we need to insure that we build conservatism into the stock assessment methodology if corrections are to be optional additions to the calculation of N_{min} for some stocks.

Because there are several situations in which a correction factor may be derived, it may be useful to label and clarify what circumstances we want to consider for incorporation into the calculation of N_{min}. Correction factors for bias in abundance estimates include:

1) **'at sea corrections':**
   Some proportion of the animals are not visible for counting during a survey because they are at sea and telemetry data are available to estimate the proportion of animals missed at the time of a count (e.g., Huber et al. 1992).
2) **'diurnal corrections':**
   Surveys are conducted at a non-peak time of day and data are available for calculating what proportion of animals were missed from by monitoring diurnal haulout patterns in the survey areas (e.g., Stewart 1981).
3) **'seasonal corrections':**
   Surveys are conducted outside of known peaks in seasonal haulout patterns (such as the molt in harbor seals in some areas) and a correction factor is applied to adjust counts accordingly (e.g., Olesiuk et al. [1990] applied a sliding correction factor from 1.0 to 1.25 to make counts conducted during pupping and breeding comparable to those conducted during post-breeding periods).
4) **'environmental corrections'**:
   Weather conditions typically vary from one survey to another and tidal height can affect the proportion of pinnipeds we observe at tidally-influenced haulout.

Corrections for environmental conditions would need to be specific to each survey area, or site if there were substrate differences which influenced access or use.

5) **'subsample corrections':**
A survey which does not encompass the full range of a population is designed to sample the habitat such that extrapolation to the full range can be made.

(*Note:* The labels used for these five types of correction factors are provisional. Please let me know if you are aware of existing terminology in the literature that we should apply in place of any of these proposed descriptions.)

Because of the inherent uncertainty of applying correction factors, every effort should first be made to design surveys to eliminate the need for all but the 'at sea' correction, since this is an inherent bias in sampling pinnipeds given current censusing methodologies. Because 'subsample' corrections require prior knowledge of the animal's likely distribution and they could result in very large correction factors (with high variance), I recommend that they not be applied by the SRGs. A point of discussion appropriate for the SRGs is whether or not 'diurnal' and 'seasonal' correction factors should be applied. Ideally, a correction factor's variance needs to be incorporated into the equation.

Of the first three factors listed above, the need for the second and third corrections can be eliminated by scheduling surveys to coincide with peaks in both diurnal and annual cycles. The range in the proportion of seals hauled out during a day within a season is often extreme. For example, in a study of diel haul-out patterns of harbor seals in California in autumn, Yochem et al. (1987) found that on average 41% of 18 tagged seals hauled out each day, yet the average number hauled out at the peak of daily haulouts was only 19%. Correction factors determined from these two circumstances would differ by more than a factor of two (2.4 compared to 5.3).

Problems can also arise if seasonal correction factors are applied incorrectly. For harbor seals, maximal numbers have been observed during the molt at some haulouts (i.e., Johnson and Johnson 1979, Calambokidis et al. 1987), and metabolic rates are lower in molting seals than at other times of the year, suggesting that seals would spend more time resting on land during the molt (Ashwell-Erickson et al. 1986). However, peak counts do not occur during the molt at all sites. Frost and Lowry (1994 unpublished data) found no difference in maximal numbers during pupping and molting periods during six survey years, and mean counts of harbor seals in Bristol Bay in 1991 during pupping (8,994, C.V. = 4%) and molting (8,597, C.V.=5%) were similar (Loughlin 1992). Thus, correction factors from areas where peak counts do not occur during the molt should not be applied to areas where they do, since different factors appear to be involved and a population could be overestimated.

Thompson et al.(1989) monitored ten tagged harbor seals during summer months and another four during winter. Correction factors for these two seasons would be 2.9 (CV=19%) for the summer months and 5.2 (CV=5%) for the winter (i.e., a higher proportion of time was spent hauled out during the summer than during the winter, so the correction factor is lower). If a correction factor from an area were derived later in the season than the count to which it was applied, numbers would be overestimated. Because counts during pupping are typically (but not exclusively) lower than those during the molt, correction factors derived during pupping and applied to a count during the molt could overestimate numbers.

In addition to the problems associated with differences in haulout behavior by day and by season, the timing of breeding and other life history parameters vary to some extent by latitude (Bigg 1969). While regional differences in the timing of breeding and molting among harbor seals can complicate analysis, Huber et al. (1992) dealt with this problem effectively in a region-wide survey of harbor seals in Washington and Oregon by applying correction factors specific for each of the eight areas in the study. These investigators also monitored a large number of seals (92) and attempted to tag a representative sample of ages and sexes, thus eliminating other potential biases in the derivation of correction factors. The use of study-specific corrections is clearly the preferred approach to the use of correction factors.

There are several fundamental problems with applying a correction factor from one study to another location or time. Corrections derived for one area may be inappropriate for another area due to differences in the age/sex composition of haulout groups (Thompson 1987), or differences in habitat characteristics which could alter haulout patterns from one area to another, as well as from one year to the next. In addition, there are several different ways that the proportion of time spent at a haulout can be derived (Table 1). For example, in some radio telemetry studies certain haulouts are monitored continuously using automatic recording equipment. Sampling for tagged animals may occur continuously, or a sampling period of several minutes per hour may be used (e.g., Thompson et al. 1989). In this situation, we can calculate a mean proportion of tagged animals present at the monitored haulouts for a specific time of day (including the exact time of an aerial survey), or we might determine how or if haulout patterns were influenced by tidal cycles. A limitation of this approach for the purposes of deriving correction factors is that for large aerial coverage, not all of the haulouts can be monitored. Extrapolating haulout patterns from a few to many haulouts could introduce biases if different substrates are involved, if some haulout cycles are tidally driven while others are not, or if haulout groups differ by age or sex.

Another approach is to fly the study area with the telemetry receiving equipment mounted on the airplane. Results from this approach yield haulout use estimates in terms of the proportion of days on which tagged animals were found at monitored haulouts, and these might be considered instantaneous group scan samples (Altman 1974). The advantage -- and this is a substantial advantage -- to this approach is that if visual or photographic counts are conducted at the same time as the tracking, then the correction factor is specific to the survey (e.g., Huber et al. 1992). However, if a pinniped species (i.e., walruses) exhibits synchronous haulout behavior, this method would not be aappropriate (S. Hills, pers. comm.).

While we will be tempted to apply correction factors from one to another survey, we will run into problems if both surveys aren't conducted at the same time relative to peak haulout periods (both diurnal and seasonal). If surveys are not matched in this way, and a correction factor from one survey is used for another, then the magnitude and direction of the resultant bias will not be known. Most surveys are timed to occur at periods of peak haulout. Yet, if our goal is to collect trend data with maximal sensitivity for detecting change, then we should determine when the variance in mean numbers between replicate counts is lowest (i.e., During molting or pupping? At daily maxima or minima?), and this is when surveys should be conducted.

Olesiuk and co-authors (1990) extrapolated density estimates of a surveyed subset of the coastline to the entire British Columbia coast. However, the areas surveyed were selected for historic and convenience reasons, rather than randomly as necessary for statistically correct extrapolation. Surveys which encompass a population's entire range are often costly, yet caution needs to be exercised in extrapolating density estimates to large (or distant) unsampled areas. These authors also used a mathematically derived correction factor for estimating absolute abundance. This method uses the bounded count estimate which "is based on the premise that each animal in the population has some finite probability of being counted, such that it is theoretically possible, albeit highly unlikely, that all individuals would be counted during a census." The approach uses adjustments derived from the variability in replicated censuses. As I understand it, replicated surveys with higher variance produce larger correction factors than counts with low variance. The approach described in this paper needs further review, mathematical scrutiny, and independent verification, and it is not recommended for application in these stock assessments at this time.

I recommend that if correction factors are used, that they be conservative and that only one correction factor be applied to any one population estimate. The extrapolated use of correction factors should not precede sufficient research which compares correction values from different parts of a species' range and life cycle.

In summary, there are three circumstances in which a correction factor might be reasonably applied to improve the accuracy of pinniped abundance:

1) Correction factors are clearly usable when they are based on concurrent telemetry data specific to a survey.
2) Correction factors derived from a study with a sufficient sample size and cross section of ages and sexes may be applied to another study only when a scientifically defensible argument can be presented for the equivalency in timing, behavior, habitat, study design, and other pertinent factors to warrant the extrapolation.
3) Correction factors from one study which do not meet all of the criteria designated in category 2) may be applied if it can be unambiguously demonstrated that other bias(es) in the data will clearly result in a conservative value for N_{min}. If this third category is applied, it should involve careful review and consensus of appropriately qualified investigators familiar with the data and both survey areas.

In conclusion, the use of correction factors in the marine mammal stock assessments needs to be explicitly outlined and standardized, and when they are used the justification for their application needs to be explicitly stated in each stock assessment. Otherwise correction factors could bias estimates of N_{min} and reduce the sensitivity of population trend estimates.

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Table 1. Range of correction factors from several studies of harbor seals. (Table is incomplete.)

Correction Factors									
Low	**High**		**Season**	**Year(s)**	**Area**	**N**	**Sex**	**Age Groups**	**Source**
1.5	1.8		pupping	1991,92	Washington & Oregon	92	M & F (#?)	adults, juveniles and pups	Huber et al. 1992
					British Columbia				Olesiuk et al. 1990
	5.3		Nov & Dec	1982	California	18	13 M 5 F	13 young males	Yochem et al. 1987
						70			Pitcher and McAllister 1981

Radio-tagging studies which measured proportion of time hauled out (versus proportion of tagged seals detected by aerial survey)

Correction Factors*									
Low	**High**	**Mean**	**Season**	**Year(s)**	**Area**	**N**	**Sex**	**Age Groups**	**Source**
		2.016	pupping (2)		Gulf of Alaska	7	?	?	Pitcher and McAllister 1979
		2.421	molting (2)		" "	12	?	?	
2.3	3.8	2.9	summer (1)			10	5 M 5 F	(all adults except) one female	Thompson et al. 1989
4.8	5.9	5.2	winter (1)			4	3 M 1 F		

*: Based on proportion of time hauled out (1) or proportion of days hauled out (2).