Post-Stratification and the Illusion of Certainty in the Management of Red King Crab in Bristol Bay, Alaska

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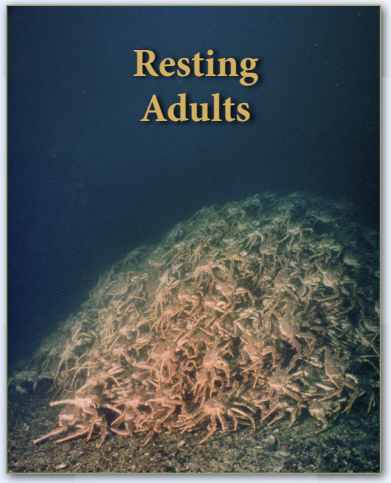


The highly aggregative podding behavior of red king crab results in catch distributions characterized by long runs of low or zero catches punctuated by rare, very large catches. Typically, such catch distributions result in poor precision of abundance estimates. For years, however, NMFS has published mean density and abundance estimates for which precision, in the form of 95% confidence intervals, is better than might be expected for extremely contagious spatial distributions.

In an effort to reduce the effect of a single large catch on the magnitude and variance of the arithmetic mean, NMFS has used since 1991 a pseudo-adaptive "hot-spot" method, whereby investigators conduct four extra tows in the vicinity of a station where the standard-survey catch of legal male red king crab is 100 or more. The data are then poststratified, with each hot spot forming a stratum and the remainder of the survey area forming another, larger stratum. The analysis proceeds as if the samples had been collected under a conventional stratified design.

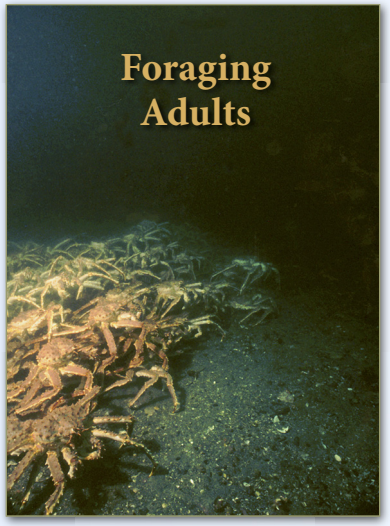
The equation for stratified mean density is

$$\overline{x}_{wtd} = \frac{a_1\overline{x}_1 + a_2\overline{x}_2 + \ldots + a_i\overline{x}_i}{\sum a_i}$$

where $\overline{x}_i$ = the arithmetic mean density (crab/km^2) in stratum i and a_i = the area in stratum i. The equation for the variance of the weighted mean is

$$Var(\overline{x}_{wtd}) = \frac{a_1^2\left(\frac{s_1^2}{n_1}\right) + a_2^2\left(\frac{s_2^2}{n_2}\right) + \ldots + a_i^2\left(\frac{s_i^2}{n_i}\right)}{(\sum a_i)^2}$$

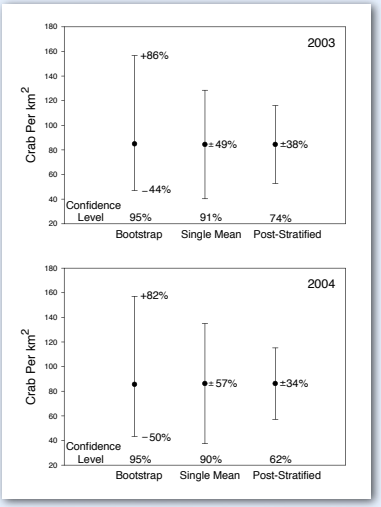
where s_i^2 = the variance in stratum i and n_i = the sample size in stratum i. The effect of isolating the largest variance to the stratum with the least area results in an area-weighted variance that is smaller than the unweighted (unstratified) variance.



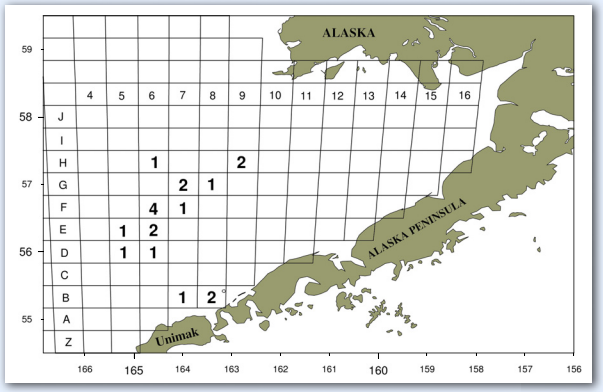
Hot-spot poststratification, done after the results of the survey are known, ensures that high-density, high-variance catches from extra sampling are confined to an area that is small relative to the remainder of the sampling area. In conventional stratification, strata are formed without knowledge of the results of the current survey. If investigators guess wrong and stratify in a way that fails to isolate the highest variance to the smallest stratum, the penalty is that precision decreases, perhaps to a level lower than that achieved with an unstratified design. The risk that investigators guess wrong (e.g., the high-density, high-variance crab aggregations move to another, larger stratum) increases as investigators reduce the size of the suspected high-variance stratum. Hot-spot poststratification, because it incurs no such risk, distorts the risk-reward structure of the stratified model and leads to an estimate of variance that is biased low.

Some investigators have avoided poststratification by averaging multiple tows at a single station and using the mean as the estimate of red king crab abundance at that station. This method also causes the estimate of total survey variance to be biased low due to the loss of the variance associated with the now-combined intra-station multiple tows.

The recommendations and general content presented in this poster do not necessarily represent the views or official position of the Department of Commerce, the National Oceanic and Atmospheric Administration, or the National Marine Fisheries Service.



Comparison of three methods of estimating precision for the 2003 and 2004 Bristol Bay king crab survey: 1) bootstrap confidence intervals (no post-stratification and no grouping of multiple tows into station means); 2) single-mean intervals; and 3) post-stratified intervals. The low confidence levels (1 - α) for the post-stratified intervals (nominally 95%) indicate that they fail to cover the mean 26-38% of the time (vs. the expected 5%). Therefore the post-stratified intervals are sufficiently misleading to be of little use in the management of Bristol Bay red king crab.



The map shows the 1975-2008 distribution of 19 hot spots among grid-square stations in Bristol Bay. Because strata must be selected on a basis independent of the current survey, this 34 year hot-spot history can help investigators set up a 12-station hot-spot stratum for future surveys. However, if a hot spot were to be found at any of the other 80-90 stations forming the larger stratum, the area-weighted variance calculated from the stratified design would likely exceed that from an unstratified design.