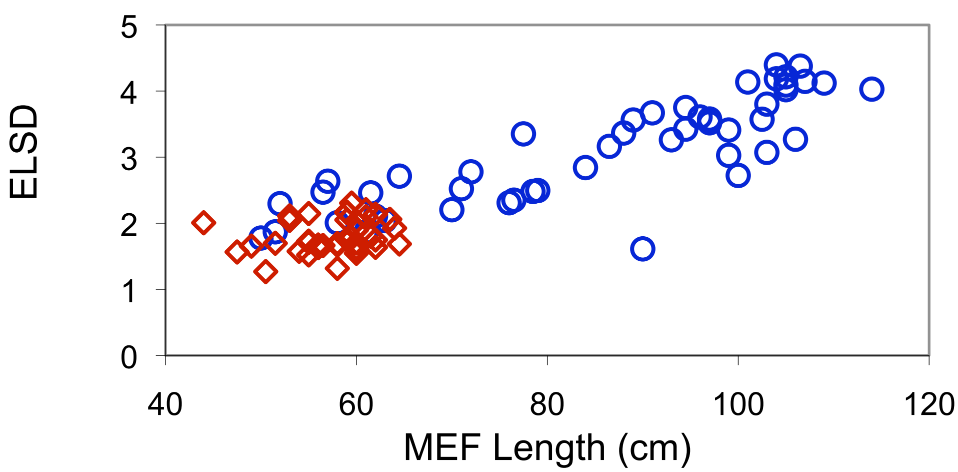
# Understanding Echo Length Standard Deviation (ELSD) as it is used to produce sonar estimates for Kenai River king salmon—FAQ

## What is ELSD, and how are ELSD data used to estimate the number of king salmon?

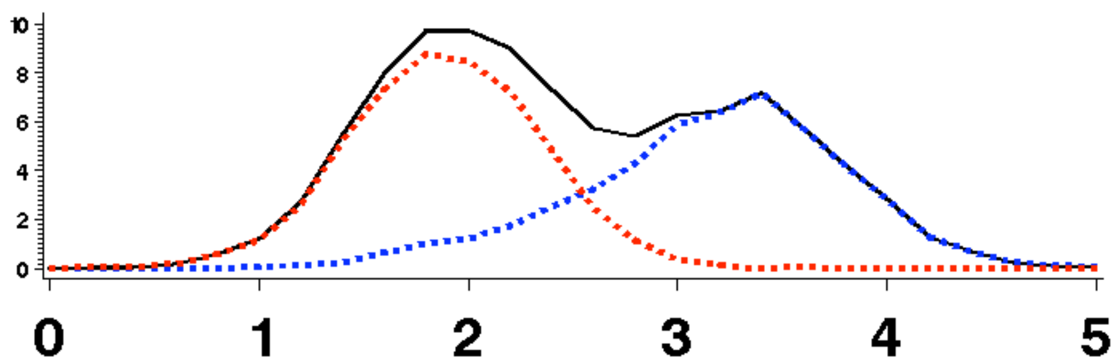
ELSD stands for echo length standard deviation. Echo length is the duration of the sound reflected from the fish. Standard deviation is a statistical measure of how variable something is. As it turns out, echo length is more variable (from one echo to the next) for large fish than it is for small fish. We first discovered this by tying fish of known size in front of the sonar and measuring characteristics of their echoes ("tethered fish" experiments). A "scatter" plot of ELSD versus fish length from those experiments is below. Measurements of ELSD range between 1 and 5 for fish between 40 and 120 cm long.




ELSD measurements can be used to help separate small from large species of fish, e.g., sockeye from king salmon. One way to do this is to use what is called a threshold; e.g., all fish with ELSD measurements less than a certain value, say 2.5, are assumed to be the sockeye and all fish with ELSD greater than 2.5 are assumed to be kings. Thresholds work well if the measurements are an accurate reflection of fish size and if the two species don't overlap in size. However ELSD is not a perfect predictor of fish size. There is some "measurement error", i.e., a 100 cm fish might have an average ELSD of 3 but the values could range between 2 and 4. Also, some king salmon can be as small, or smaller, than most sockeye salmon. So we use a different method, involving a statistical "mixture model", that allows us to take these things into account.

Consider an idealized pile, or mound, of ELSD measurements, sorted from small to large (0 to 5) below. The statistical term for such a mound is a "frequency distribution". Think of the individual measurements as coming from either sockeye salmon (red dashed line), or king salmon (blue dashed line). Most of the small measurements are from sockeye salmon, in red; whereas most of the large measurements are from king salmon, in blue. However ELSD measurements that are intermediate in value, say between 1.5 and 3, could come from either species of fish.

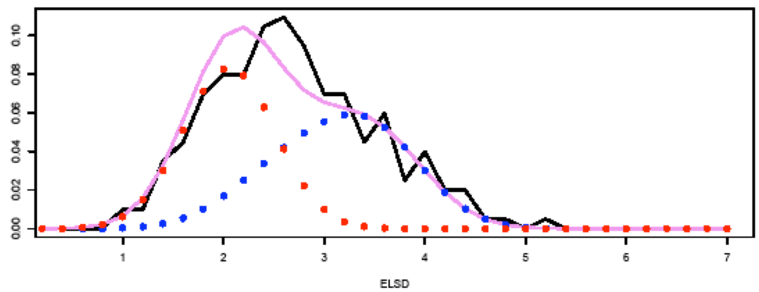
The mixture model considers the shape of the ELSD distribution and provides mathematical estimates of the relative proportions of the two species. To do this accurately, it needs information about the number of small kings, plus the relationship between ELSD and fish length. These two factors are important for determining how much the ELSD values overlap for the 2 species- the fewer small kings and the better the relationship, the smaller the overlap. Knowledge about the number of small kings comes from gillnet catches at the sonar site. Until recently, the only source of information we had about the ELSD-length relationship was from the tethered fish experiments.



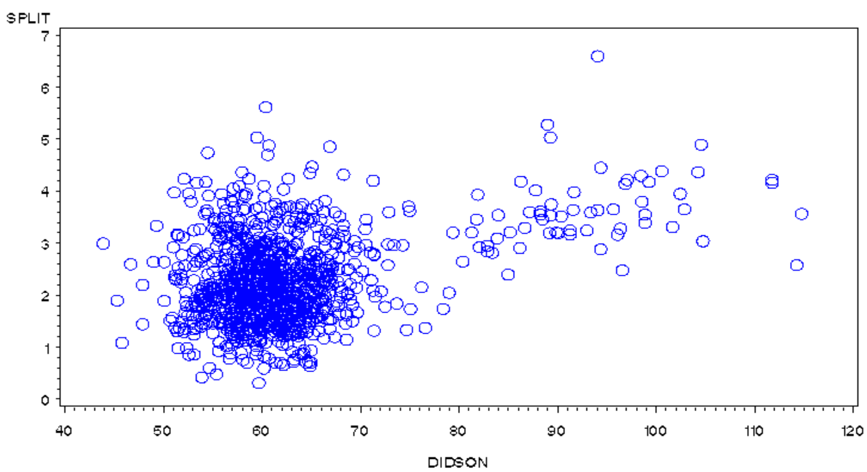

**Why would the ELSD sonar estimate be off?**

When the pile has two "humps", as above, it is relatively easy to estimate the relative proportions of the two species. The left-hand hump is mostly sockeye and the right hand hump mostly king salmon. Sometimes, however, there is only one hump, and then things get more difficult. Under these conditions it becomes especially important to understand how much measurement error, or "scatter", there is in the relationship between fish size and ELSD.

Below are some actual ELSD data from June 9$^{th}$ 2011. There is only one hump, in the middle, and there are multiple ways to explain how these data originated. The tethered fish experiments indicated that there was only a modest amount of measurement error. If that is the case, then the two component distributions (red = sockeye, blue = king) are relatively narrow, and the best explanation for the shape of the pile is that king salmon make up about 40%, and sockeye 60%, of the fish. If 1000 fish passed on that day, the estimated number of king salmon would be 400.




Very recently (June 2011), we devised a way to check our previous assumptions about the ELSD- fish length relationship. DIDSON imaging sonar, now being field tested at the site, can provide approximate length measurements of passing fish. By matching the DIDSON lengths with ELSD measurements for individual fish, we can get another look at the ELSD / length relationship. The relationship turned out to be not as good as the tethered fish had indicated- there was more scatter (see below). ELSD is apparently not as good at predicting fish size as we had first thought.




This new information affects how we view distributions like the one from June 9th. If the individual component distributions can be wider, then the best explanation for the data involves only 20% king salmon and 80% sockeye. In this case, the king salmon estimate is reduced by one half, to 200 fish. More to the point, in this case the original estimate was 2 times too big.