BRISTOL BAY DATA REPORT NO. 74

Total Run Size of Bristol Bay Sockeye Salmon (Oncorhynchus nerka) as a Function of Body Size

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Anchorage, Alaska
December 1979
INTRODUCTION

The Port Moller offshore test fishery, begun in the early 1940's, has operated essentially unchanged with regard to methods and location since 1967 (Randall, 1977). The primary goal of the project has been and continues to be providing the resource managers with sockeye and chum salmon run magnitude and timing information 6 to 8 days in advance of the fishery (Mundy and Mathisen, 1977).

As Meacham (1978) notes, the inseason forecasting ability of the program has been historically poor, even since 1968 when gear mesh size and fishing locations were standardized at their present specifications. This was due to the fact that the estimator used each year, mean passage of fish past Port Moller into Bristol Bay for each index fish caught, was derived from the summed individual estimators of all previous years. In fact, the "new" estimator each year was simply the mean of the previous actual return per index ratios since 1968. The estimator then represented the average condition exhibited across all previous years of the project's operation. Unfortunately, because of the large degree of unexplained variability exhibited by the passage rates from individual years (7,200 in 1973 to 56,900 in 1972) the mean passage rate of all previous years was nearly useless in its predictive ability regarding any single subsequent year.

Identifying the inherent annual variability in this systematic sampling program was essential to realizing the full potential of the project. It subsequently led to the synthesis of a Bristol Bay-specific sockeye gillnet catchability model, where the relative ability of a sockeye to become irrevocably entangled in a 5 3/8-inch stretch measure gillnet was identified and quantitatively described as a function of the
individual fish's weight. Continuing further, this relationship between fish size, as described by weight, and return per index fish caught was considered for the entire population of sockeye entering Bristol Bay in each year. This was done using the mean size statistic (weight) of the sockeye sampled at Port Moller to estimate the catchability relative to other years, and therefore the actual return per index value for the respective year. Considering this relationship in the form of a least squares fit power curve led to the explanation of some 71% of the variability of the previous estimates based solely on mean return per index values across all years.

Later investigations revealed that mean length is a more precise estimator of sockeye catchability than mean weight (Meacham, pers. comm.). The explanation for this probably lies in our relative abilities to measure each of the two parameters afield. Whereas the length of a deceased fish is fairly easy to accurately measure under most field conditions, the weight may not be. Keeping weighing equipment dry and taking accurate weight readings aboard a tossing ship in the rain is often not possible with the weighing equipment presently used. In addition, the weight of a fish retrieved from a gillnet may vary significantly from its actual live weight due to the violent nature of its death and the subsequent loss of body fluids.

Although identifying and describing most of the variability among previous estimates of return per-index values has led to their highly accurate predictability in-season, estimating total population size of the returning sockeye depends upon the systematic sampling of each station as scheduled. Because weather in the Port Moller area and other factors rarely allow complete sampling of the peak of the run, interpo-
lations must be made for data from missed stations. Despite the fact that highly sophisticated interpolation techniques have been employed, the lack of any solid realtionships among values attained between stations within a day or between entire days prevents much confidence from being placed upon the interpolated values attained.

The basic weakness in the existing in-season forecasting program has led to the development of a simultaneous inseason total abundance estimation technique.

METHODS AND MATERIALS

All data used in the present analysis was retrieved from the Bristol Bay Data File, presently being compiled and maintained by the Alaska Department of Fish and Game, Commercial Fisheries Research Section, Anchorage, Alaska.

Proceeding from the basic, perhaps even elementary acknowledgment that each fish or population of fish is the product of the sum total of factors that have affected that fish or population throughout its life cycle has led to the identification of one parameter - mean length of the fish in the population - which indicates the sum total of effects that those factors have had upon the individual fish and population thereof. Unlike present studies which seek to identify and describe realtionships between known parameters (i.e., climatological) and subsequent population responses, this method of forecasting allows the integrated values of all factors affecting the fish whether described or not to manifest themselves in the end product, namely the individual members of
the population. It is the characteristics exhibited by the individual fish therefore which represent a measurable "condition factor" allowing quantification of the sum total of factors affecting the fish to date. And from the relationships between these condition factors (mean lengths) and the related population sizes, a simple mathematical model was created from the measurable mean attribute exhibited by the individual fish in the concerned population. A very strong negative relationship was found between the mean length of fish in a population and their numbers.

RESULTS

Listed in Table 1 are the total population size, corresponding mean weight, and mean length by year as measured at Port Moller for the years 1970 through 1978 except 1974 when the project did not operate. The best relationship (least squares fit power curve) between the mean length of the individuals measured at Port Moller and the corresponding total inshore run is shown in Figure 1 and is described by:

\[ Y = aL^b \]

Where \( Y \) = predicted population size
\( L \) = mean length of fish
\( a = 4.723 \times 10^{80} \)
\( b = -28.999 \)
Figure 1. Relationship between Port Moller mean length and sockeye inshore run
Table 1. Mean length, mean weight, and total inshore return of Bristol Bay sockeye salmon, 1970-1978.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MEAN WEIGHT (lbs)</th>
<th>MEAN LENGTH (mm)</th>
<th>TOTAL RETURN (x 10^6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>5.82</td>
<td>531.93</td>
<td>39.4</td>
</tr>
<tr>
<td>1971</td>
<td>5.84</td>
<td>549.93</td>
<td>15.83</td>
</tr>
<tr>
<td>1972</td>
<td>6.49</td>
<td>566.80</td>
<td>5.37</td>
</tr>
<tr>
<td>1973</td>
<td>7.30</td>
<td>585.19</td>
<td>2.42</td>
</tr>
<tr>
<td>1974</td>
<td>The project was not run in 1974</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>5.25</td>
<td>547.99</td>
<td>24.20</td>
</tr>
<tr>
<td>1976</td>
<td>6.13</td>
<td>552.30</td>
<td>11.47</td>
</tr>
<tr>
<td>1977</td>
<td>7.00</td>
<td>567.59</td>
<td>9.47</td>
</tr>
<tr>
<td>1978</td>
<td>6.09</td>
<td>545.43</td>
<td>19.65</td>
</tr>
</tbody>
</table>

This relationship yields a coefficient of correlation \((r) = 0.97\) and a coefficient of determination \((r^2) = 0.94\).

In comparison, the best relationship between the mean weight (lbs.) of individuals measured at Port Moller and the corresponding total inshore run is described by:

\[
Y = aW^b
\]

\(W\) = mean weight of fish
\(a = 767547\)
\(b = -6.124\)

The coefficient of correlation \((r)\) and coefficient of determination \((r^2)\) are 0.85 and 0.78 respectively.
The relationship between mean length (mm) and mean weight (lbs.) of sockeye measured at Port Moller is described by:

\[ w = aL^b \]

Where \( w \) = predicted mean weight from a given length
\( L \) = length
\( a = 2.849 \times 10^{10} \)
\( b = 3.764 \)

This relationship yields an \( (r) \) and \( (r^2) \) of 0.87 and 0.75 respectively.

It is significant that the mean length performed better as an estimator in both return per index relationships and total return relationships. Therefore, it is assumed that the greater part of the variability in the mean length to mean weight relationship established stems from our relative inability to accurately measure weight afield as previously discussed.

As previously mentioned, the Port Moller test fishery has been conducted in its present form since 1968. The data from the years 1968 and 1969 are not presently retrievable because of the lack of a reliable relationship between mid-eye to fork of tail lengths presently used and snout to fork lengths used in the test fisheries prior to 1970. From a group of data received from Mathisen (personal communication) a linear relationship between snout to fork length and the associated percentage, that is, mid-eye to fork length was developed and described by \( Y = a + bx \), where: \( a = 103.239 \); and \( b = 0.19432 \). The Coefficient of Determination \( (r^2) \) = 0.29 which, although significant at \( p = 0.01 \) for \( n = 200 \) pairs of
variates, is not a sufficiently cohesive group of data to allow its use in predictive capacity.

DISCUSSION

Perhaps the most powerful attribute of the presented estimation model of sockeye abundance is that it allows the integrated quantification of all factors affecting the fish, including those factors not yet identified. This ability did manifest itself during the actual development of the model. The original hypothesis suggested that the relationship between the condition of the fish and their subsequent population size would be positive; the better the conditions that the fish had encountered (as measured by the condition factor - mean length) the greater their survival rate would be. On the contrary, it appears that as more severe environmental conditions are encountered, survival rate drops, decreasing intraspecific competition for the available resources in situ and in the future when conditions again improve.

Two implications are derived from this relationship. First is the indication that the marine environment and not its lacustrine counterpart may at times be limiting to a schooling group of organisms such as the sockeye salmon. And, this limiting nature of the ocean environment upon the sockeye salmon population of issue can be expressed in the form of the density-dependent body size function developed. This density-dependance is implied by the inverse nature of the strong relationship between population size and average fish condition ($r = -0.97$), suggesting that competition between cohorts may be limiting their potential growth because of a limited requirement in the marine environment. Further
support comes from the knowledge that the majority of the body growth in
the life cycle of the sockeye occurs in the ocean (Foerster, 1968).

Also implied is the possibility that this population and perhaps
other biological populations are regulated by extremes rather than by
means. For example, if the juvenile sockeye encounter a single period
of extremely poor conditions in the lacustrine environment, the resultant
outmigrating population may not be limited by conditions encountered
later. That is, once a substantial portion of the population has been
lost, the perhaps tremendously productive conditions encountered later
can have little effect on producing a relatively large population of
returning adults. In the same sense, a large population of immature
salmon encountering a perhaps brief period of strongly adverse conditions
in the ocean may be limited there in terms of potentially returning
adults.

It must be noted here that this model was developed in time for use
in the 1979 sockeye run to Bristol Bay. As opposed to the systematic
return per index sampling scheme, it quickly ascertained the magnitude
of the run. However, with the preliminary results nearly finalized, it
is apparent that the model predicted a much lower run size than was
realized. With mean length of fish at Port Moller finally stabilizing
at roughly 542 mm, the predicted total run size indicated a return of
24.6 million sockeye, roughly 15.4 million short of the actual.

The low prediction for the year 1979 reveals one inherent weakness
in the mathematical model described; as the mean length approaches the
lower asymptotic value, a very small change in mean length yields a very
large change in predicted return. There may be a point where the genetically
determined minimum fish size masks the effects of the communal marine
environment upon fish size. If so, the predictive ability of this model will be severely restricted at the lowest values of mean length for a given population.

Another possible explanation of the forecast error of the model in 1979 might be an increase in the early spring productivity of the sockeye-inhabited marine environment over the last two to three years (Goering, pers. comm.). The winters of 1977-78 and 1978-79 were two of the warmest winters ever recorded in the Bering Sea, perhaps setting the stage for very productive summers in this the summer range of the Bristol Bay sockeye (Straty, 1974). Further studies will be necessary to elucidate the answers to these questions.

In sum, mean length is probably not the final or even most representative condition factor expressed by Bristol Bay sockeye. It was only the most reliable estimator with enough data readily available for scrutiny. Other measurable attributes must now be found and perhaps combined with the presently identified factor to produce a composite condition factor capable of providing an extremely accurate index of the sum of conditions affecting the population of fish and its resulting size.
LITERATURE CITED


