ESTIMATE OF CHUM SALMON (ONCORHYNCHUS KETA) OF JAPANESE ORIGIN CAUGHT IN THE U.S. JUNE FISHERY CONDUCTED IN THE SHUMAGIN/UNIMAK WATERS

Atsushi Takei
International Affairs Division

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Fisheries Agency of Japan.

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
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Atsushi Takai
International Affairs Division
(Fisheries Agency of Japan)

ABSTRACT

Based on the results of tagging experiments conducted by the Alaska
Department of Fish and Game in 1987, we estimated the number of chum salmon of
Japanese origin caught in the U.S. June fishery conducted in the
Shumagin/Unimak waters. Because the chum salmon of Japanese origin experience
a longer period between release and capture than the North American chum
salmon, in this analysis, the time-dependent mortality and tag shedding are
taken into consideration which were not considered by Eggers and Barrett
(1988).

The results correspond fairly well with the results of scale pattern
by the U.S. fishery is estimated to be 0.9-7.9% in Unimak waters and 18.4-
35.3% in Shumagin waters.

Based on our analysis and the results obtained by Eggers and Barrett
(1988) and Conrad (1984), the average number of Japanese chum salmon caught by
the U.S. June fishery in 1980-88 is estimated to be 4,000-114,000 in Unimak
waters and 17,000-53,000 in Shumagin waters, a total of 21,000-167,000.

In this analysis, parameters such as mortality rates had to be
assumed with wide range, and it is desirable that future estimates of these
parameters have narrower confidence limits. Estimation methods in addition to
tagging are suggested. These results also suggest that a significant number
of Japanese chum salmon may be taken incidentally in the groundfish fishery in
the U.S. 200 miles zone and the necessity of further study on this subject is
pointed out.
1. Foreword

The Alaska Department of Fish and Game (ADFG) conducted a large-scale tagging experiment in 1987 to ascertain the origin of the chum and sockeye salmon caught in the waters of Shumagin/Unimak in June (Eggers and Barrett, 1988). In this research, actual tag recovery data are corrected by the proportion of tagged fish to fish caught by the Western and Central Alaska fisheries and it is possible to analyze the result quantitatively.

A total of 6,323 chum salmon were tagged and released under this program with 833 recaptures recorded, of which 36 recaptures were reported by the Japanese coastal set net fishery and 11 by the U.S.S.R. coastal fishery.

In this paper, the number of Japanese origin chum salmon intercepted by the U.S. June fishery were estimated using data collected by Eggers et al.

2. Method

Eggers and Barrett (1988) estimated the proportion of the origin of the chum salmon by the formulae below:

\[ P_i = \frac{R_i}{U_i} \left( M - M_{\text{mort}} - M_{\text{spr}} \right) \]  
\[ P^{*}_i = \frac{R_i}{U_i} \left( M - M_{\text{mort}} - M_{\text{spr}} - M_{\text{asian}} \right) \]

Here, \( P_i \) = the proportion of \( i \)th stock without consideration of the Asian origin

\( P^{*}_i \) = the ratio of the \( i \)th stock with consideration of the Asian origin

\( U_i \) = exploitation rate of the \( i \)th stock

\( R_i \) = number of tagged fish in the catch from the \( i \)th stock (reported recaptures are corrected by sampling of the catch)

\( M \) = number of tagged fish

\( M_{\text{mort}} \) = number of tagged fish that died as a result of tagging \( (M_{\text{mort}} = 0.358M, \) using the estimate from the sockeye salmon)

\( M_{\text{spr}} \) = number of the tagged fishes recaptured in the June fishery

\( M_{\text{asian}} \) = number of tagged fish of Asian origin

where,

\[ M_{\text{asian}} = M - M_{\text{mort}} - M_{\text{spr}} - \sum R_i / U_i \]  

The proportion of the fish of Asian origin were estimated to be 48.9% for Unimak, and 66.9% for Shumagin from the formula (3) above.
The proportion of the fishes of the Asian origin estimated by Eggers and Barrett (1988) is, as it were, the value after subtraction of returning fishes to North America, the catch in the June fishery and tagging mortality, hence the error in the tagging mortality estimate, for example, is straightforwardly taken as the error of the fishes of the Asian origin. Apparently, they used the above method because the main purpose of their research was to estimate the relative proportion of origin within the North American fish.

Eggers and Barrett (1988) assumed that the tagging mortality only occurs immediately after the release without stock dependent variation, and adopted a constant mortality rate over all stocks. However, in the case of the salmon of Japanese origin, where longer time period lapes between the time of release and the time of recapture than the case of North American salmon, it is necessary to take into account the time dependent natural mortality and tag shedding.

In consideration of the above, the following formulae have been made by assuming two separate components that exist in the mortality and tag shedding, i.e. those occurring immediately after release which is time-independent, and those occurring during the elapse of time after release which is time-dependent.

\[ R_i = M (1-I) U_i P'_i e^{-mT_i} \] .......................... (4)

\[ \sum_{i=1}^{n} P'_i = 1 \] .......................... (5)

where,

- \( R_i \) = estimated number of recaptured tagged fish in the \( i \)th stock
- \( M \) = number of tagged fish
- \( I \) = time-independent mortality and tag shedding rate
- \( m \) = time-dependent mortality and tag shedding coefficient (per day)
- \( U_i \) = exploitation rate of the \( i \)th stock
- \( P'_i \) = mixing rate of the \( i \)th stock
- \( T_i \) = mean length of time between the release and recapture of the tagged fish of the \( i \)th stock

from (4) ... \( P'_i = R_i / \{ M(1-I) U_i e^{-mT_i} \} \) .......................... (6)

from (6)(5) ... \( \sum \{ R_i / M(1-I) U_i e^{-mT_i} \} = 1 \) .......................... (7)

In formula (7), \( R_i, U_i \) of the Asian fisheries, \( I \) and \( m \) are unknown, of which \( U_i \) of the Japanese fishery may be appropriately considered to be 1.0, while \( R_i \) is difficult to obtain precisely since no sampling is conducted in the catch of the Asian fishery, unlike the case of the Western and Central
Alaskan fisheries. However, it would be reasonable to consider that the rate of recapture reporting is lower in the Asian fisheries than in the Western and Central Alaskan fisheries, since in the latter case considerable effort was made to encourage reporting of recaptures by radio announcement, etc. in conjunction with the tagging research program. Therefore, the value of the \( R_i \) for the Asian fisheries is obtained by the following formula, adopting the actual number of recapture reported and the lowest value (53.5\%) of the reporting rate of Western and Central Alaska fisheries estimated by Eggers and Barrett (1988).

\[
R_i = \frac{r_i}{0.535}
\]

where, \( r_i = \) actual number of recapture reporting in the \( i \)th stock, 
\( \text{(Asian origin)} \)

Because of the difficulty in obtaining \( I \) and \( U_i \) of the Soviet fishery \( (U_{USSR}) \), a set of values taken at each 0.05th from 0 to 0.75 for \( I \) and a set of values taken at each 0.1st from 0.1 to 0.9 for \( U_{USSR} \) have been adopted (total 16 x 9 = 144 sets). \( R_i, U_i \) for the salmon of North American origin were determined from Table 17 and 18 by Eggers and Barrett (1988); \( T_i \) was determined from their Appendix F. Table 1a, b show the data used.

\( m \) and \( P_i \) are obtained by formulae (6) and (7) using these data (in the actual calculation, the computer iteration process was conducted to obtain the value of \( m \) that satisfies \( \sum (R_i/M(1-I) U_i e^{-\eta}) - 1 < 0.001 \).

Analyses for 30 categories in total have been conducted for all the North American fisheries adopted from the Table 17 by Eggers and Barrett (1988) plus five Asian fisheries (July and November fisheries of Hokkaido, September and December fisheries of Honshu, and the U.S.S.R. fishery). At this stage, the catches by the June fishery were treated in the same manner as the return in other fisheries.

Then, the following formula was used to obtain the proportion of origin after subtraction of the catches of the June fishery.

\[
P_i = \frac{P'_i}{(1-P'_{\text{June}})}
\]

However, \( P_i = \) proportion of origin in \( i \)th stock
\( P'_{\text{June}} = \) mixing rate of the June fishery obtained by formula (6).

3. Results

Table 2a, b show estimated "m" by each \( I \) and \( U_{USSR} \). The values of \( m \), within the ranges of 0.01-0.75 of \( I \) and 0.1-0.9 of \( U_{USSR} \), was 0-0.0282 for Unimak release, and 0-0.0230 for Shumagin release.

As for the average monthly mortality rate of the chum salmon at its final oceanic life stage, Parker (1962) estimated 0.011 to 0.016 for the final two years and Taguchi (1961) estimated 0.381 for the final one hundred days.
The value of 0.381 by Taguchi (1961) seems to be an overestimate in comparison with other estimates of the mortality rate for the oceanic life stage of the salmon.

Since the value of m estimated in this paper includes time-dependent tag shedding and tagging mortality in addition to the natural mortality coefficient under the normal circumstances without tag, using the value by Taguchi as the upper limit of m value seems to present no problems. Therefore, the lower limit of m is set at the lowest of the estimates for the final two years (0.011: coefficient at 0.00037 when converted by coefficient per day), and the upper limit is set at the estimate for the final hundred days (0.381: coefficient at 0.0160 when converted by coefficient per day). In Table 2 a, b, I and USSR giving this range of m (0.00037-0.0160) are shown in brackets. Furthermore, since no differences by the area of tagging seems to exist in I and USSR, the range where estimates of I and USSR overlap between the two release areas (shown in Table 2 a, b in double brackets) are considered to be the final values of I and USSR.

Table 3 a, b show the proportion of origin calculated by formulae (6) and (8) for each I and USSR above. A total of eleven stocks are shown in Table 3 a, b which consist of the nine stocks of North American origin divided by Eggers et al. (1988) in their Table 19 with addition of the stocks of the Japanese and the Soviet origin.

The mixing rate of the chum salmon of Japanese origin is estimated to be 0.9%-7.9% in the case of the Unimak fishery, and 18.4%-35.3% in the case of the Shumagin fishery.

4. Discussion

(1) Parameters

In quantitative analyses of tagging research, we often experience that the estimation of the recapture reporting rate is a big problem. In the case of the Central-Western Alaskan fishery, however, the estimate obtained by the sampling of the catch can be utilized. In the case of the values used for the fish of Asian origin, some doubts remain as to the appropriateness of such values in this analysis.

Dissemination for the need of recapture reporting by posters and other means has been conducted in Japan; but in comparison with the rigorous efforts made in Central and Western Alaska offering lottery-type rewards and the use of radio announcements to encourage the reporting, the incentive for reporting in Japan is judged to be much weaker. Therefore, the reporting rate for Japan could be lower than the value used in this analysis. If that is the case, the proportion of the salmon of Japanese origin in the catch would have been underestimated. Reference is made to the case of the large-scale tagging research on red sea-bream conducted in the area around Japan, in which the reporting rate was estimated to be 0.25 (Kanagawa Prefectural Fisheries
The set net fishery is used for most of the harvests of the red sea-bream on the tagging area, this reporting rate may be reasonable for the set net fishery on the Japanese coastal waters.

The reporting rate of the Soviet recaptures is also uncertain, and it is difficult to know whether the value of 0.535 used in this analysis was appropriate. On the other hand, it is possible to revise formula (6) as follows:

\[ P'_t = \frac{r_t}{U_t} \left( \frac{1}{M} \right) (1-I)e^{-m_t} \]

Furthermore, if the reporting rate is \( \lambda_t \),

\[ P'_t = \frac{r_t}{U_t \lambda_t} \left( \frac{1}{M} \right) (1-I)e^{-m_t} \]

In our analysis, \( U_t \) of the salmon of the Soviet origin are given a wide range values from 0.1-0.9, and accordingly wide range is applied to \( U_t \lambda_t \). On the other hand, the low values such as 0.1 or 0.2 and the high values such as 0.8 or 0.9 applied to the \( U_t \) for the Soviet origin do not seem to be realistic. With these in mind, even if the actual reporting rate of the Soviet origin was inconsistent with the values used in our analysis, \( U_t \lambda_t \) would fit within the range of the data given in the analysis. Therefore, it is reasonable to believe that the effect of the reporting rate estimate of the Soviet origin in the result is not significant.

(2) Fish returning in the following year and later

This analysis assumes that all released fish fall into one of the following four categories:

1) being caught in the June fishery with tag
2) mortality (due to tagging or other factors)
3) tag shedding
4) returning with the tag

At first, the number of fish included in categories 1) and 4) was estimated from recapture data. Then the difference between the number estimated above and total number of released fish is regarded to be the number of fish included in categories 2) and 3). Therefore, if the number of fish under categories 1) and 4) was underestimated, I and m would be overestimated.

Since the recapture data only contains the recaptures of the tagging year, if the fish that return in the following year and later are included within the tagged fish, the values of 2) mortality and 3) tag shedding would be overestimated. In this tagging research such data as the age and length of the tagged fish were not available. Therefore the possibility of inclusion of fish that return in the following year and later can not be denied. In this analysis mortality and the tag shedding rate immediately after the release are estimated to be 45-65% which is higher than the value (35.8%) used by Eggers and Barrett (1988). This may be due to the effect of the fishes returning in the following year and later. However, in cases where the proportion of the tagged fish returning in the following year and later is small, or where there
is no significant variation of this proportion among stocks, the estimate itself of the mixing rate in each stock would not be seriously affected. In any case, if a substantial number of recaptures occur in 1988 of the fish tagged in 1987, reanalysis including this data will be needed.

(3) Comparison with the past estimates

Table 4a, b and Fig. 1a, b show the comparison of the result of this analysis with the result by Eggers and Barrett (1988) and the results of scale pattern analysis of chum salmon in the June fishery in 1983 (Conrad 1984). In the scale pattern analysis by Conrad, due to absence of sufficient samples available for the age 0.3 fish of Soviet origin, two standard samples of Western Alaskan origin and Japanese origin were used for the analysis of 0.3 years old fish. Therefore, the values appear in table 4a, b and Fig. 1a, b are the weighted mean value of results on age 0.4 fish, for which three standard samples of Western Alaskan, Japanese and Soviet origin were available, by 1987 catch by fishing period. The use of 1987 catch data by fishing period was due to the unavailability of the 1983 catch data. Table 5 shows the procedure for the weighted average.

As for the mixing rate of the fish of North American origin for both Unimak and Shumagin release, the result of this analysis falls between the two proportions estimated by Eggers and Barrett (1988) one with the consideration of Asian origin (P, in formula (1)), another without consideration of Asian origin (P*, in formula (2)). The only exception is the mixing rate of the fall fishery in the Yukon River that substantially exceeds the estimate by them. This Yukon River case is because of the inclusion of the time dependent mortality and tag shedding in this analysis: the mixing rate thus obtained for stocks with longer lapse of time between the release and the catch shows greater value than the estimation which does not evaluate these factors.

The mixing rate of the fish of Asian origin in this analysis shows smaller estimates (3.6-17.8% for Unimak, and 22.0-43.2% for Shumagin) than the estimates made by Eggers and Barrett (1988) (48.9% for Unimak, and 66.9% for Shumagin). As already stated in this paper, this may be due to the error of tag mortality estimated by them. Moreover, in their method, the proportion of fish returning in the following year and later are apportioned to be the fish of Asian origin, therefore, their method would overestimate the proportion of Asian origin, if the fish returning in the following year and later are included in the liberated fish.

In comparing the result of the scale pattern analysis by Conrad (1984) with the result of this analysis, the former falls within the estimated ranges of this analysis in the cases of fishes of Alaskan origin and of Soviet origin in Unimak waters, and Soviet origin in Shumagin waters, while in the cases of the fish of Japanese origin in Unimak waters and those of Alaskan origin in Shumagin waters, the scale pattern analysis shows higher values than the estimated ranges of this analysis. In the case of fish of Japanese origin in Shumagin, the scale pattern analysis results show the lower value than the estimation range of this analysis. These differences may be attributed to the methodological inaccuracies inherent to the scale pattern analysis as well as to the error created by the weighting on the result of the 1983 analysis with
the 1987 catch data. These differences in the results of the two analyses, however, are not so great: they fall within 4% and, as a whole, the two analyses have produced relatively consistent results.

(4) Estimate of interception of chum salmon of Japanese origin by the U.S. June fishery

Based on the estimation made by this analysis, estimates are made for the interception of chum salmon of Japanese origin by the U.S. June fishery from 1980 to 1987. Although the mixing rate of the salmon of Japanese origin is estimated to be 0.9-7.9% in Unimak, 10% had been estimated by the scale pattern analysis. Therefore, we have set its lower limit at 0.9% and its upper limit at 10%. In Shumagin, our estimates were 18.4-35.3% while the scale pattern analysis estimated it to be 17.7%. Therefore, we adopted the lower limit at 17.7% and upper limit at 35.3% in the same manner as we did in the case of Unimak.

The result of the calculation is shown in Table 6. The estimates of the interceptions are:

- In Unimak on average between 4-46 thousand fish
- In Shumagin on average between 17-33 thousand fish
- In both waters, the total is estimated to be between 21-77 thousand fish

Table 7 shows the number of fish of Japanese origin as the result of a preliminary calculation based on the proportion estimated by Eggers and Barrett (1988) (0.489 for Unimak and 0.669 for Shumagin). It was necessary to divide the fish of the Asian origin into those of Japanese origin and Soviet origin in this calculation. The division was made on the basis of the number of tag recovery reported (7 fish of Japanese origin and 5 of Soviet origin from the Unimak releases, and 29 of Japanese origin and 5 of Soviet origin from the Shumagin releases). The following method was used by adopting the exploitation rate at 1.0 for Japanese origin and 0.1-0.9 for Soviet origin.

In Unimak

Lower limit of Japanese origin ... 0.489 x 7/(7 + 6/0.1) = 0.0511
Upper limit of Japanese origin ... 0.489 x 7/(7 + 6/0.9) = 0.250

In Shumagin

Lower limit of Japanese origin ... 0.669 x 29/(29 + 5/0.1) = 0.246
Upper limit of Japanese origin ... 0.669 x 29/(29 + 5/0.4) = 0.561

In this preliminary calculation the estimated interceptions are:

- Unimak ... 23-114 thousand fish
- Shumagin ... 23-53 thousand fish
- Both areas Total ... 46-167 thousand fish
5. Future research

The tagging research conducted by ADFG, unlike other tagging research, makes it possible to analyze the result quantitatively. However, no accurate data is available for mortality, tag shedding and the exploitation rate of the fish of Soviet origin. Our analysis in this paper had to use wide ranges for those uncertain data. Subsequently, the number of interceptions of the fish of Japanese origin had to be estimated with wide ranges. It is desirable that future research estimates these parameters within narrower confidence limits.

Simultaneously, study for stock identification using scale pattern, parasite and isozyme would be needed.

Our analysis has demonstrated that the chum salmon of Japanese origin are migrating to the coastal waters of Alaska and suggests that a considerable number of the salmon of Japanese origin may be included in the chum salmon by-catch in the groundfish fishery within the U.S. 200 nautical miles zone. In this regard, additional research is necessary to ascertain the extent of such inclusion.

References


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- **I=0.45**

- **I=0.50**

- **I=0.55**

- **I=0.60**
Table 3a  Estimated proportion of each fishery group, Unimak release. (continued)

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Table 3b Estimated proportion of each fishery group, Shumagin release.
(continued)

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# Proportion with Asian stock.
## Proportion without Asian stock.
### Proportion of 0.4 age
Table 4b Comparison of estimated stock proportion (Shumagin)

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<td>(Without)‡</td>
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† Proportion with Asian stock.

‡ Proportion without Asian stock.

### Proportion of 0.4 age
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<th>Catch (1987)</th>
<th>Weighted Proportion (%)</th>
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Table 6  Estimated Interception of Japanese Chum Salmon by June Fisheies.

(1,000 fish)

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<th>Year</th>
<th>Unimak Catch</th>
<th>Japanese Salmon Catch</th>
<th>Shumagin Catch</th>
<th>Japanese Salmon</th>
<th>Total</th>
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<td>e=d<em>0.177 f=d</em>0.3528 b+e</td>
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<tr>
<td>1980</td>
<td>457</td>
<td>4</td>
<td>46</td>
<td>71</td>
<td>13</td>
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<td>46</td>
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Table 7  Estimated Interception of Japanese Chum Salmon
June Fisheies from Eggers et al. 1988.

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<th>Unimak Catch</th>
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<th>Shumagin Catch</th>
<th>Japanese Salmon</th>
<th>Total</th>
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<td>Lower limit e=d*0.24</td>
<td>Upper limit f=d*0.56</td>
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<td>71</td>
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<td>114</td>
<td>94</td>
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Fig. 1a Comparison of estimated stock proportion (Unimak)

- Present study
- Eggers and Barret (1988)
- Conrad (1984)
Fig. 1b Comparison of estimated stock proportion (Shumagin)

--- Prescent study

○○ Eggers and Barret(1988)

△ Conrad(1984)
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