On the Possibility of Using the Pink Salmon Survival Measure (R/E) in the Forecast of Chum Salmon Returns in North-East Kamchatka

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The time of downstream migration and body size of pink and chum salmon juveniles are very similar in north-east Kamchatka. The supposition that environmental factors, such as hydrometeorological conditions, predation, availability of feeding resource etc., have a similar effect on the yearlings of both species on their way downstream toward sea was examined. The ratio R/E as a measure of survival of a salmon generation during their life time was calculated for pink and chum salmon. A correlation between survival measures of both species was shown. Survival of pink salmon may be used as a good predictor for forecasting chum salmon returns in north-east Kamchatka.

INTRODUCTION

A number of ecological similarities in chum and pink salmon species have served as premises for the evaluation approach described here.

The juveniles of both species migrate to sea in the late spring of the year following spawning, and the downstream migration timing and body sizes are similar in north-eastern Kamchatka. According to Karpenko (1996, 1998), in the period from 1978 through 1992, over 80% of chum and pink salmon juveniles migrated to sea between June 10 and 30. The body length of pink salmon juveniles averaged 3.07 - 3.29 cm, while that of chum salmon was 3.58 - 3.76 cm. This allows the supposition that environmental factors such as hydrological and meteorological conditions, predation, availability of food resources (for a certain period), may have a similar effect on the yearlings of both species migrating to sea.

The mortality level is at its highest among the species in the period of downstream migration, as compared with the rest of their life cycle. Therefore, it is during this period that the environmental conditions should be considered as the most critical for survival of the generation. If that inference is true, then logically it will appear that the similarity in environmental effects during the downstream migration can be manifested in similar survival results in both species, as expressed by the survival measure (return/escapement ratio, R/E) and dynamics. If common survival results are manifested and can be expressed quantitatively, then these can be applied to forecasting the chum salmon return, as it happens 1 to 3 years following that of pink salmon. This research was dedicated to examine the above supposition.

Attempts to evaluate chum salmon returns while forecasting that of pink salmon were made earlier by Nickolayeva (1988) for the Kamchatka River, based on the idea of the possible relationships between chum and pink salmon generations. She indicated that the average age at maturity and survival measure of chum salmon generations of the Kamchatka River were related to pink salmon abundance in north-eastern Kamchatka.

MATERIALS AND METHODS

Data on landed catches and number of chum and pink salmon spawners in north-eastern Kamchatka from 1957 to 1995 (KamchatNIRO Archives), material on pink and chum salmon juveniles migrating downstream in the Khailyulya River from 1978 to 1992 (Karpenko 1996), as well as the data on age composition of the Khailyulya River parent chum salmon stock during 1973 - 1995 (E.T.Nickolayeva and L.O.Zavarina) were kindly provided by L.O.Zavarina. These were used as the initial basis for this research.

Reliable data on the abundance of 37 pink salmon broods and their respective survival measure values (K_{Pink}), are available for north-eastern Kamchatka. It is not possible to determine chum salmon survival measures, based only upon the data on returns and number of spawners, because chum salmon have a longer life cycle, as well as a more complex age composition. We used only the data on age compositions and abundance of 17 chum salmon generations, for the brood years 1973 - 1989. The reliable chum salmon survival measure, determined via consideration of the age composition, will be referred to as the true survival measure (K_{True}).

RESULTS AND DISCUSSION

The fluctuations in pink and chum salmon returns are shown in Figure 1. Pink salmon register a ten- to hundredfold higher abundance than chums, as well as greater amplitude and frequency of fluctuations, which relates to this species' life cycle. A decline in abundance of both species was observed during the late 1950s to mid 1970s. After the mid 1970s, there was a steady increase in both species, but a decline for chum salmon in the late 1980s. Pink salmon abundance remained steadily high to 1995. Figure 1 suggests there may be a certain similarity in environmental factors influencing chum and pink salmon returns, although it is also evident that direct comparison of return dynamics yields little promise for forecast adjustments.

Figure 2 shows fluctuations in pink and chum salmon survival measures. Figure 2, more distinctly than Figure 1, shows the similarity in survival trends. The K_{True} dynamics closely match with the K_{Pink} fluctuations from 1975 to 1986, excluding 1973 to 1975. The highest recorded survival for pink salmon reached its peak value in the brood year 1973 and in 1975 for chum. Possibly, either the peaks themselves or their apparent delays resulted from extremely low spawning runs during the specified periods, a mere tens of thousands for chum, and about three million for pink salmon, i.e. about tenfold below average. Also, one should bear in mind that the measurement error ratio may increase as a species' return declines dramatically. A more realistic explanation can be given only upon a closer consideration of conditions during spawning, migrating, and marine periods. Conspicuously in counterphase are the survival measures for the brood year 1988. A change in the long-term tendency of the chum salmon abundance dynamics, compared to those of pink salmon, was a possible cause for the differences. Resumption of driftnet fishing was possibly another factor, where chum salmon were landed in much greater quantity than pink salmon, and results of which were not included in the overall return evaluation in the last years. However, in general, Figure 2 demonstrates that the survival measure fluctuations are synchronous for the periods of concurring abundance fluctuations.

The short observation series for chum salmon survival measure values, covering only 17 brood years, does not allow for a statistically correct and

Fig. 1 Dynamics of pink salmon and chum salmon return.

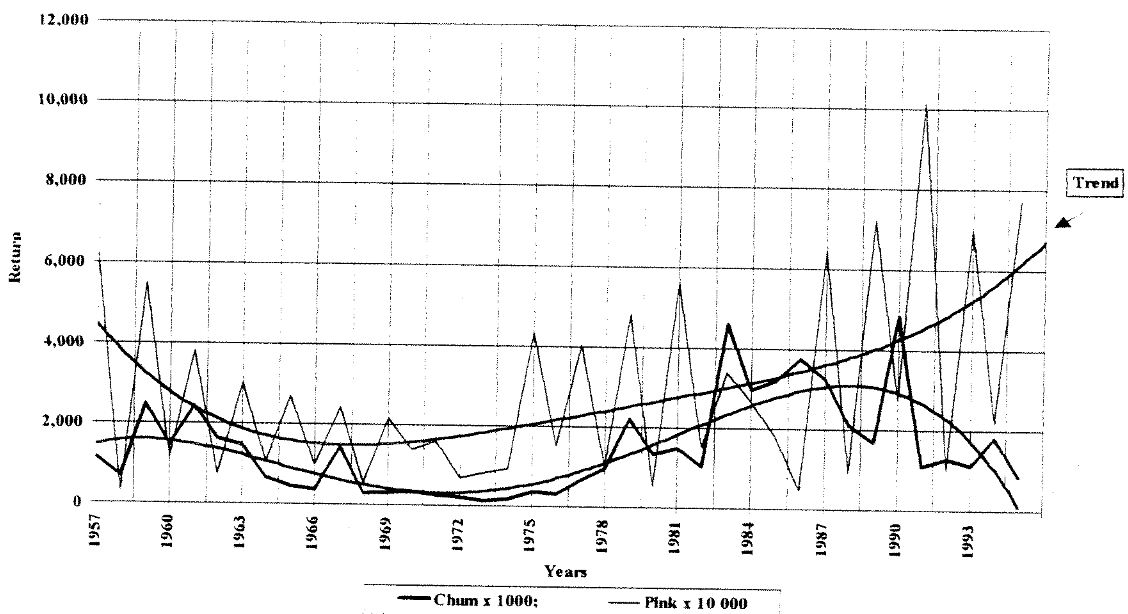
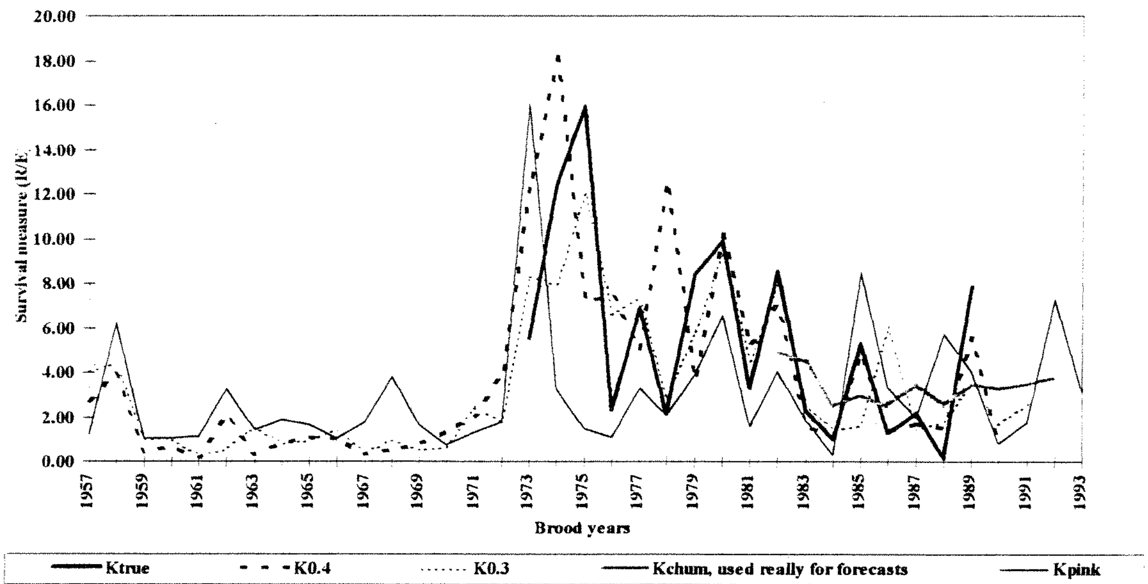


Fig. 2 Dynamics of survival measures of pink salmon and chum salmon.



well-grounded conclusion. In order to mitigate this basic data deficiency, we made a number of assumptions.

According to the data on parent salmon age composition it is known that the core of the returning chum salmon stock, 90%, is made up of 0.3 and 0.4 year-olds in north-eastern Kamchatka. The share of each age group can vary between 10% and 90%, however through 17 years the 0.3 year-olds averaged 48% and 0.4 year-olds 44% of the total. The remainder is split approximately equally among the 2+ and 5+ year-olds. The 6+ year-olds account for less than 1% of the total run in each year. Based on the above figures, one can assume that should one divide, for example the 1990 return figure by the 1985 spawner. A definite value should be attained statistically related to K_{True}. It will characterize the share of the 0.4 year-olds in 1985 contributing to the return in 1990. This value will be referred to as the conditional survival measure (K0.4). The K0.3 conditional survival measure is defined the same way. Quite naturally, this type of approach is not applicable to 2+ and 5+ year-olds, which do not belong with the core age groups. The legitimacy of this approach can be judged by examining Figure 2, that shows the proximity of K0.4 and K0.3 values and dynamics with those of K_{True}. The correlation coefficient between K0.4 and K_{True} equals 0.53 ($P<0.05$), and between K0.3 and K_{True} equals 0.77.

Table 1. Statistical characteristics of K_{True}, K0.4, K0.3, and K_{Pink}

	K_{True}	K0.4	K0.3	K_{Pink}
Average	5.62	3.85	3.36	3.37
Minimum	0.17	0.22	0.27	0.29
Maximum	15.94	18.14	12.01	22.7
Standard deviation	4.59	4.28	3.11	3.87

According to Table 1, the average K_{True} is slightly higher than K0.4 and K0.3. However, based on Figures 1 and 2, one can assume that this is because the observation period when the average K_{True} was produced coincided with the highest survival period of chum salmon during the return increase, and, incidentally, the real average for a period since 1957 cannot be adequately expressed by K_{true}. The statistical data on K0.4, K0.3, and K_{Pink} are very close. This is a formal proof that these can be applied for juxtaposition purposes, in respect to the conditions affecting the survival and dynamics of pink and chum salmon populations.

Attention was also paid to density dependencies between spawners and progeny of pink and chum salmon, as well as interdependence of spawners in both species. Figures 3 and 4 show the spawner-to-progeny density dependencies, founded on the true survival measures for pink and chum salmon. These are approximated via exponential functions shown on Figures 3 and 4. It is clear that the exponents are practically the same for pink and chum salmon. It can be seen from Figures 5 and 6, that similar dependencies, produced for K0.4 and K0.3, are close to those for K_{True}. Figures 3 to 6 show the decline in survival measure with the increase in spawners while Figure 7 shows no dependence of the chum salmon survival measure upon the abundance of pink salmon spawners simultaneously returning to the spawning grounds.

The ultimate output of the calculation is presented in Figure 8. It can be seen therefrom that the curve for the better part corresponds to actual abundance

Fig. 3 Dependence of survival measures of chum salmon on the number of spawners.

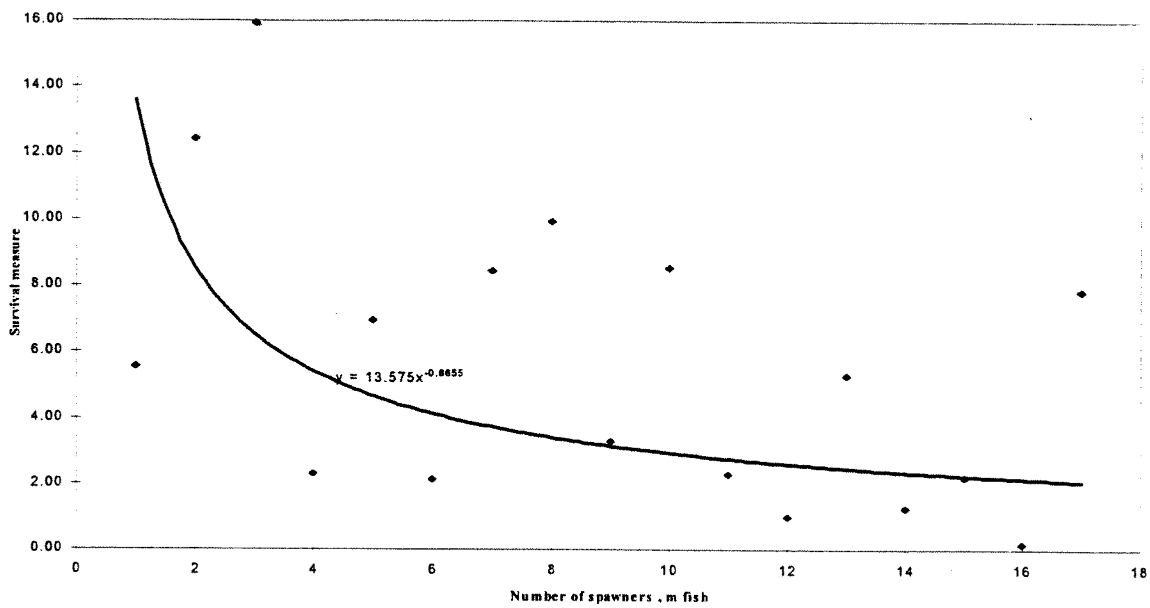


Fig. 4 Dependence of survival measure of pink salmon on number of spawners.

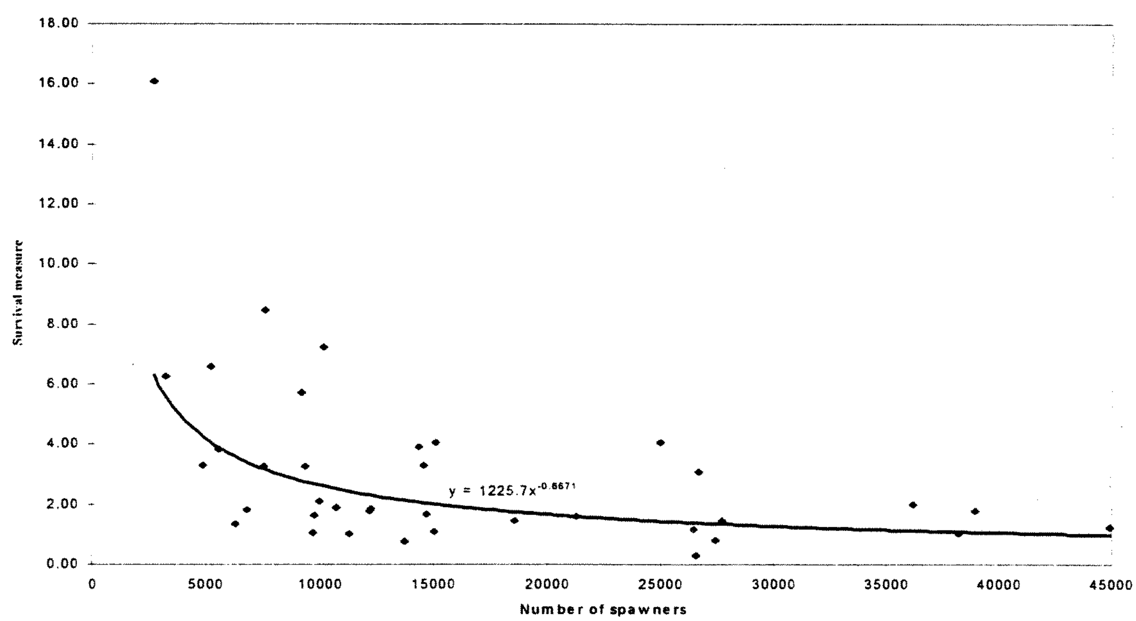


Fig. 5 Dependence of conditional survival measure (K0.4) of chum salmon on the number of spawners.

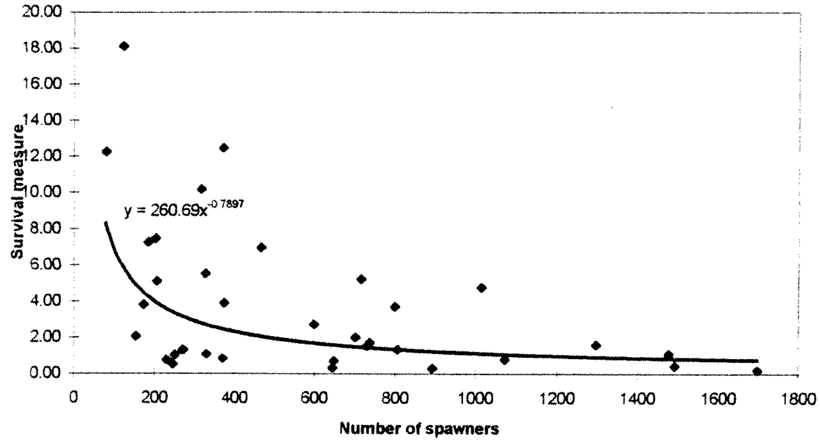


Fig. 6 Dependence of conditional survival measure (K0.3) of chum salmon on number of spawners.

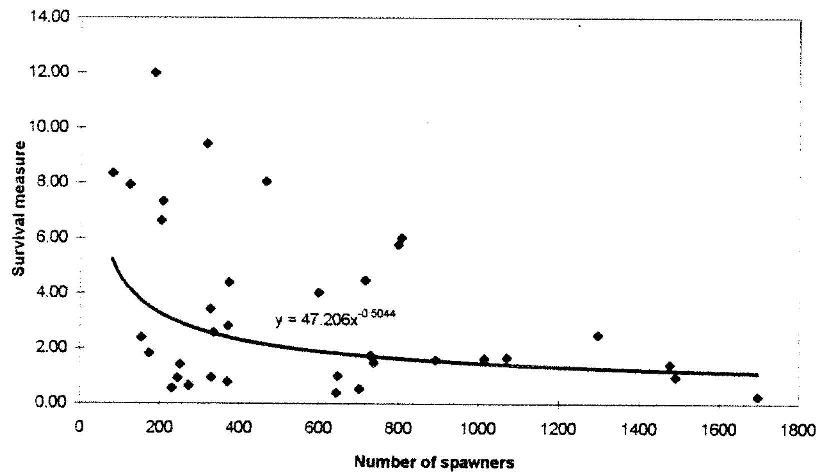


Fig. 7 Dependence of K_{True} of chum salmon on number of pink salmon spawners.

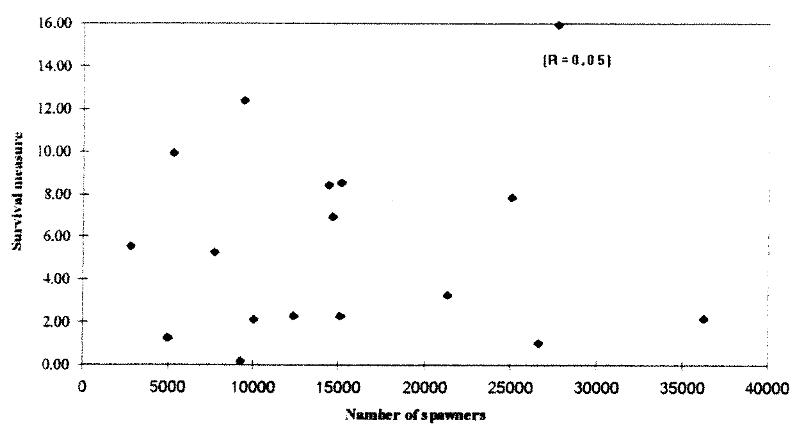
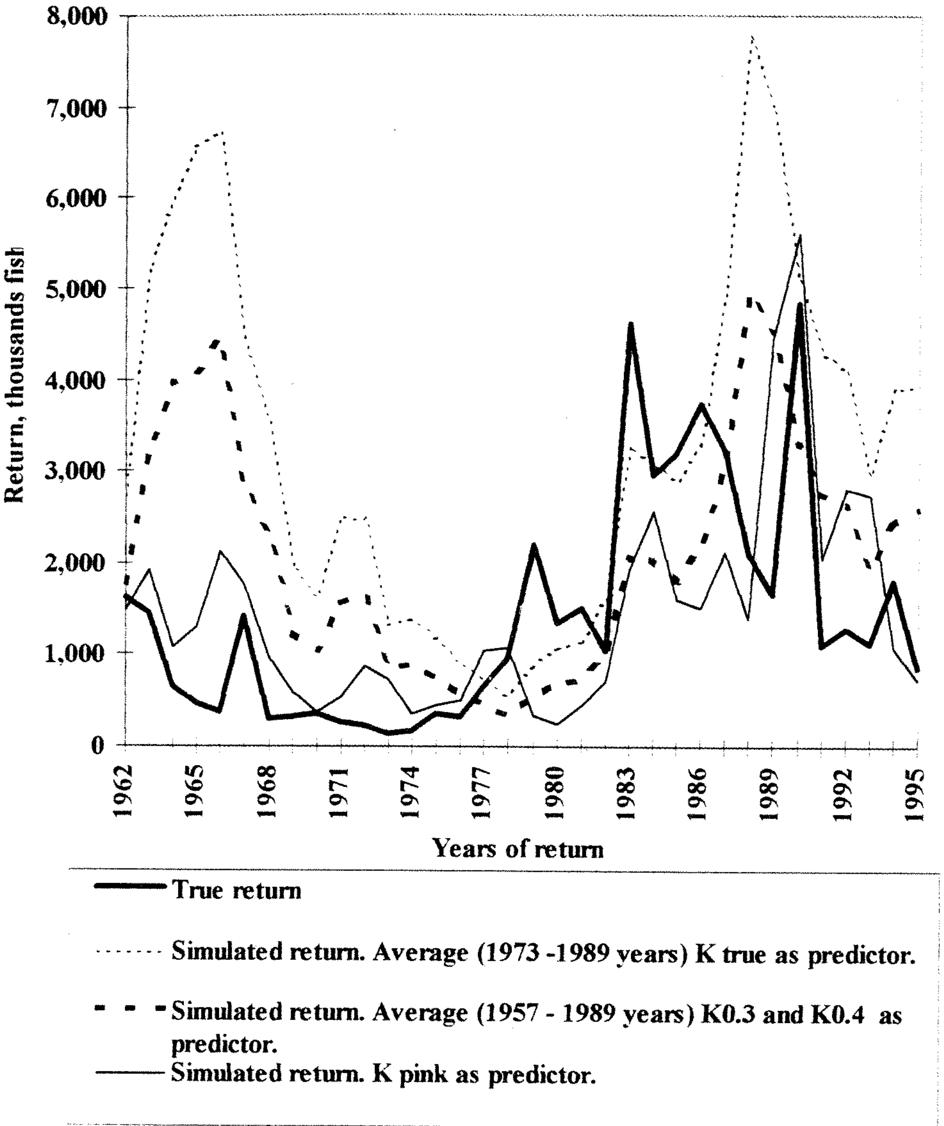


Fig. 8 Dynamics of true and simulated return of chum salmon in northeast Kamchatka.



dynamics. The maximum error did not exceed the one present in the real forecasts.

Comparing Figures 3 - 6 with Figure 7 one can conclude that, in respect to pink and chum salmon in north-eastern Kamchatka, interspecific density regulation is manifested to a much lower degree than is intraspecific regulation. Small ($r=0.44$; $r=0.37$) but significant ($P<0.05$) correlation coefficients between K0.4 and K_{Pink}, and K0.3 and K_{Pink}, accordingly, can be treated as additional support of this conclusion.

Generally, the data shown above lead to the conclusion that the environmental factors during the spawning, downstream migration, and marine periods affect pink and chum salmon yearlings in much the same fashion. This influence is much stronger than that of the interspecific regulation. To prove the above, the assessment of chum salmon returns was undertaken during an observation period, using the abundance of chum salmon 0.4 and 0.3 year-old spawners as predictors, assuming that the contributions of 0.3 and 0.4 year-old spawners were equal. The other predictor was during that period K_{Pink}. The return was calculated using the following formula:

$$N=0.5*(E_{0.3})*K_{Pink}(3) + 0.5*(E_{0.4})*K_{Pink}(4)$$

where N - chum salmon return;

$E_{0.3}$ and $E_{0.4}$ - chum salmon 0.3 and 0.4 year-old spawners;

$K_{Pink}(3)$ and $K_{Pink}(4)$ - pink salmon survival measures for corresponding broods.

For juxtaposition purposes, a similar calculation was made, where pink salmon survival measure dynamics were not presented. Instead, the average K_{True}, in one case, and the average K0.4 and K0.3, in the other, were used as applied to the whole observation period. As seen from Figure 8, the calculation output is much less reflective of the real chum salmon abundance dynamics, than is the case with K_{Pink}. The average standard deviation of the assessed chum salmon return against the actual value (for the series presented on Fig. 8) is as follows: 1133 - when using K_{Pink} as predictor, 2782 - when using the average K_{True} for a period from 1973 through 1989, and 1714 - when using the average K0.3 and K0.4 for a period from 1957 through 1995.

Based on Figure 8, one can conclude that using the average K_{True} for the period from 1973 to 1989 as predictor in a return forecast could yield good results only if applied to a narrow time span (1976 - 1987), when chum salmon return experienced a considerable upsurge. If applied to the period from 1962 through 1975 this given survival measure will appear quite exaggerated.

The major elements of the chum salmon return forecast include the estimation of the survival measure per brood year, and evaluation of which part of each brood matures at age 0.3 or 0.4, respectively. As predictors, the data on abundance dynamics, qualitative fish indicators, as well as hydrological and meteorological information for the period between spawning and migrating to sea were used. Each of these influences expresses itself indirectly and cannot be exactly measured. The calculations are mostly of a statistical character, and are based on a relatively short observation series. We can compare chum salmon survival measures used for forecasts ($K_{forecast}$) and K_{True}, evaluated for forecasting, beginning from 1982 (Fig. 2). $K_{Forecast}$ appears, in a number of cases, at great variance with K_{True}. The average standard deviation of $K_{Forecast}$ from K_{True} equals 3.24 (the average standard deviation of K_{Pink} from K_{True} in respective years equals 3.04).

The official forecast of chum salmon returns is prepared 2 years in advance. i.e., the forecast for 1998 is made in 1996. The core of the 1998 return will be made of 0.3 and 0.4 year-olds, i.e. the brood year 1993 and 1994. Survival measures for pink salmon broods 1993 and 1994 were already known in 1996. As indicated above, survival measures for pink and chum salmon are statistically interconnected. Therefore, if the spawning and migrating conditions had been favorable for pink salmon broods of 1993 and 1994, they would have been as much so for chum salmon. Of importance is that 2 to 3 years prior to chum salmon returns there is the possibility to evaluate more accurately than by any other method (except for direct enumeration) the conditions in the most critical period for salmon stock development.

CONCLUSIONS

The environmental factors have similar effects on chum and pink salmon during spawning and downstream migration periods. This similarity is strong enough in the majority of cases that possible differences in the rearing conditions during the ocean life do not smooth over those effects. This confirms that the downstream migration and coastal periods are crucial for salmon stock development.

The similarity in chum and pink salmon return/escapement dynamics can be expressed quantitatively and applied to chum salmon return forecasting. For example, it is absolutely true that the lower than forecast chum salmon return in 1995 resulted not from the erroneous age composition prediction, but from the high mortality rate during the spawning, migrating, and coastal periods, and, consequently, from the low return/escapement ratio. The low return/escapement ratio for pink salmon brood year 1990 is a testimony to the aforesaid and its consideration was instrumental in producing a more accurate chum salmon forecast.

Of course, the similarity of survival dynamics can hardly be idealized. It does not insure against errors, and is not suggested as an alternative to already existing forecasting methods, although it can be employed as an additional predictor. Thus, in some cases, considerable forecast refinements may be attained. This suggested approach should be further proved for its applicability for other regions, with priority given to western Kamchatka, and possibly for other salmon species.

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