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Growth Inefficiency of the Artificial Pink Salmon Culturing Under Providing Fish with a Supplimentary Feeding and Optimization of Terms for their Release from Southeastern Sakhalin Hatcheries

by

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Abstract

Materials characterizing the results of applying a supplementary feeding for juveniles at southeastern Sakhalin hatcheries and optimization of terms for their release are given in this paper. Data on the effective work of hatcheries from the southeastern part of Sakhalin Island during the period preceding the application of recommendation (1961-1988) and following by it (1989-1997) are analyzed. The researches have been resulted in the fact that mostly often a peak of downstream migration coincides with the warming of sea coastal part up to 7.1^0 ? . The date of time corresponding to the water warming up to this value in the coastal zone was calculated for a preliminary preparation of calculations on the optimization of terms for the fish production release annually conducted during the 1990s. Coefficient of return for hatchery pink salmon constituted 5.77% in 1989-1997, varying within 2.97-8.65%. This estimate significantly differs from the corresponding value for the period preceding the process of optimizing dates of releases, exceeding it 5.7 times.

Introduction

Artificial fish culture is one of the main ways used to recover and maintain at the high level the valuable commercial fish stocks including Pacific salmon. Sakhalin and Kuril islands are a very important region for the native salmon culturing, where 23 hatcheries are located at present. In 2002, these enterprises released 576.9 million fry. On the southeastern Sakhalin the artificial pink salmon culturing is being conducted at 6 hatcheries; they produce more than 41% of the total pink salmon release from Sakhalin and Kuril enterprises.

Effective work of salmon hatcheries is determined, first of all, by the perfection in biotechnique for fish culturing. More than a half-century history of salmon culturing at Sakhalin allowed elaborating and applying the effective scheme of eggs incubation and larval enduring (Smirnov, 1963; Kanidyev, 1984; Instruction..,1963). However, the 1990s of the last century appeared to be a new step in salmon culture development. Majority of hatcheries have been reconstructed. Simultaneously with this, recommendations on regulating the terms for juvenile release have been gradually applied. The necessity of such measures is associated with the fact that hatchery pink salmon develop faster and they appear to be ready for downstream migration earlier than wild fish (Kanidyev, 1984; Markovtsev, 1989). Delay in release for its synchronization with the favorable conditions in the coastal zone entails a necessity in additional including a process of growing out into the biotechnique cycle, during which pink salmon are being fed.

Materials characterizing the results of applying a supplementary feeding for juveniles at southeastern Sakhalin hatcheries and optimization of terms for their release are given in this paper. Data on the effective work of hatcheries from the southeastern part of Sakhalin Island during the period preceding the application of recommendation (1961-1988) and following by it (1989-1997) are analyzed.

Material and methods

To analyze the dynamics of juvenile downstream migration from natural spawning grounds, the materials collected during April-June 1971-1988 on the Bakhura River located in the southeastern part of Sakhalin Island have been used (Fig. 1). Fry migrants were counted according the method of sampling fishery (Volovik, 1967).

Based on the obtained data, we built cumulates, which were approximated with the logistic function for each year of observations. We used the estimate of x-coordinate, where an inflection of logistic function corresponding to 50 % of the number of fry migrants was observed as a date accepted to be the index of peak migration.

The dates of release were controlled by the factual data from Lesnoy, Bereznyakovsky, Sokolovsky, and Pugachevsky hatcheries (Fig. 1).

Seasonal dynamics of surface water temperature in the coastal zone was analyzed using the information on average-daily estimates in April-June 1977-1988, from the hydrometeostation “Starodubskoye” (southeastern Sakhalin).

In addition, the published data on the effective work of pink salmon Sakhalin hatcheries have been considered (Rukhlov, Lubaeva, 1977, 1980; Rukhlov, Shubin, 1986; Koryakovtsev, 2001).

Regressive and statistic analysis was done using the standard programs of Microsoft Office.

Results and discussion

The river and early sea life periods determine a success in pink salmon reproduction to a great extent. After juvenile downstream migration, the absence or lack of food in the coastal zone, low water temperatures, and predators’ pressure are the main causes of their mortality (Vernon, 1962; Birman, 1985; Karpenko, 1998; Sweeting, Beamish, 2002). As a rule, a pink salmon downstream migration is timed to the beginning of spring water warming in the coastal zone, and a connected with it one of the annual maxima in zooplankton vegetation. This provides favorable food conditions for fry migrated, and contributes to the increase in survival (Bakshtansky, 1961; Vernon, 1962; Smirnov, Kamyshnaya, 1965; Ivankov, 1984; Kaev, Chupakhin, 1986). As a rule, fry migrated from the rivers of southeastern Sakhalin do not stay in river estuaries and coastal shallows for a long time, and already in the first days migrate 6-10 nautical miles offshore, where inhabit a wide coastal line (Shubin, 1990; Shubin et al., 1990, 1996; Pushnikov, 1994; Ivankov et al., 1999). In late June, juveniles, probably, are concentrating in a zone of the external shelf front, shifting along it to the south up to the frontal zone of the Soya Current, migrating from there to the east (Radchenko et al., 2002).

Mainly, pink salmon belonging to the fall subpopulation spawn in Bakhura River and other rivers of southeastern Sakhalin (Altukhov et al., 1983). Unlike summer pink salmon, they are characterized by the latter entrance of spawners to the river and, consequently, by the latter juvenile downstream migration from spawning grounds.

Dynamics of pink salmon downstream migration from Bakhura River has a rather similar character in even and odd years. The migration peaks in even years occurred in dates from May 30 to June 15, in odd years they were from 3 to 18 of June. The average date of peak for the whole period of observations corresponded to 8 June.

The analysis of dynamics of mean daily water temperatures in the coastal zone shows that the May-June spring warming with a high level of approximation ($R^2 = 0.97$) is described by the equation of a straight line (Fig. 2). The estimate of y-coordinate of the linear trend diagram (6.8 ^{0} ?) appeared to be on 8 June. This is well illustrated by Fig. 3, where both diagrams built by the average long-term data of temperature dynamics in the coastal zone and the intensity of the downstream migration are shown simultaneously. An interannual variability of dates for the maximum intensity of downstream migration ranging from May 30 to June 18 let us to conclude that the common terms for wild juveniles migrating downstream the rivers of southeastern Sakhalin are timed to the beginning of stable warming of the coastal waters up to 6.0-8.2ºC, that corresponds to the noted dates. More often, a peak of downstream migration coincides with the warming of coastal seawaters up to 6.8 ^{0} ? . As a rule, after occurring this temperature, no cases of water sharp cooling are observed, and juveniles do not experience temperature stresses.

Such stability in downstream migration terms may be suggested to be the evolutionary adaptation of pink salmon in the northeastern part of Sakhalin Island under the realization of their strategy for a maximum survival. Undoubtedly, a decline in this value (lower than 6.8^{0} ?) can be resulted in increase in pink salmon mortality. Thus, Japanese fish farmers realize the release of production from their enterprises only after the stable water warming in the coastal zone up to 6.0? ? and more, that along with other factors allow obtaining stable high returns (Kobayashi, 1978). By the way, before the 1990s, juveniles had been released from pink salmon hatcheries of southeastern Sakhalin much earlier than the mass wild juvenile downstream migration occurred (Fig. 4). Thus, during the 1960s the juvenile release had been conducted, on average, from April 5 to May 25. The mass release occurred on 5 May, that is more than a month in advance before the beginning of optimal juvenile habitat in the coastal zone. Water temperature in this period did not exceed 3-4?? . In 1970 – 1980, the dates of mass release occurred during the period from 18 to 24 May, when mean water temperature in the coastal zone was from 3,8 to 4,6??, judging from the trend of temperature dynamics. Further, a gradual shifting of dates for release was observed, but only in 1990s they were optimized in relation to the evolutionary formed dates of downstream migration in this region.

The date of time corresponding to the water warming up to 6.8 ^{0} ? in the coastal zone was calculated for a preliminary preparation of calculations on the optimization of terms for the fish production release annually conducted during the 1990s. Correlation analysis showed that the average month water temperature in April (r =0.76) could be used as a predictor in forecasting; coefficient is significant at 0,05. Based on these calculations, the annual correction of concrete dates for pink salmon release from hatcheries of southeastern Sakhalin of 1 – 1.5 months in advance appear to be used due to the factual oceanological year conditions.

As a result of applying recommendations, the release begins, as a rule, from 5 to 15 June, varying due to the interannual peculiarities of spring warming the coastal waters. Along with that, the increase in duration for pink larvae and juveniles enduring, in order to release them in optimal terms, determines the necessity of managing their rate of development. As a result of Sakhalin salmon hatcheries reconstruction, a mixed water supply became to be used both from the under-channel flow s, and from the deep wells. This gave fish farmers a real possibility to realize the thermal regulation for receiving juveniles with defined parameters in terms favorable for juvenile release. A management of development rate is realized with the help of correcting a temperature regime, commonly repeating the average long-term water temperature in Sakhalin salmon rivers, but giving the possibility to avoid a significant deviation from the optimum. Two main ways for conducting thermal regulation are:

1) delay in pink salmon rate of development at the embryonic and larval stages excluding a stage of growing out, but not resulting in appearing negative physiological changes during a starvation process;

2) regulation of pink salmon rate of development in order to provide a biological reproductive cycle with juveniles' feeding for the period not less than a month, under the requirement that by the start of feeding the juvenile fish have already reached a physiological readiness for exogenous feeding, and the temperature has exceeded 5? ? .

In recent years, practically at all Sakhalin hatcheries pink salmon have been fed up before their release due to the long period of low temperatures in the coastal zone. The first type of thermal regulation has been observed only at several hatcheries, when juveniles are not ready for exogenous feeding right up to the moment of release due to the influence of low temperatures. However, in this case the small sizes of juvenile fish do not give them advantage over the wild or hatchery fed up juveniles. Body weight of such juveniles is not more than 240 mg, length 33 mm. In addition, under the unsuccessful results of thermal regulation the juvenile fish may reach a readiness for the exogenous feeding before the release and be hungry under the absence of feeding. The experimental works show that juveniles in this case begin to lose weight; in the extreme cases the weight decreases from 240 to 180 - 190 mg, after which their mortality occurs (Tarasyuk, 1994, 2001). Just this fact took place in the first half of the 1980s. Enduring juveniles up to the optimal date of release without feeding caused a loss of their biomass up to 229 mg in 1984-1988. Such juvenile fish are much undergone to the predatory press in the early sea life period, that provides a high elimination and decline in return coefficients.

When providing the second variant of thermal regulation at hatcheries being realized at embryonic and larval stages of development, the larvae are ready for feeding by the occurrence of water temperature favorable for growing out in ponds. In this case, as a rule, juvenile fish, during the period of artificial feeding, are growing effectively using a natural course of temperature changes. Realization of this variant in the industrial conditions allowed releasing juveniles with the mean weight of 266 mg in 1991-1995, and 272 mg in 1996-2000. The experimental works showed that by the beginning of release (8 June) fry from the earlier laid sets (fertilization on 1 September) could reach the weight more than 400 mg and length 40 mm (Tarasyuk, 2001).

Applying the recommendations on the optimization of terms for juvenile pink salmon release, along with providing a biotechnical cycle with a supplementary feeding, made it possible to increase a number of returns from the hatchery juvenile pink salmon. Since 1964 through 1983, return coefficients for southeastern Sakhalin hatchery pink salmon, obtained by calculations, varied from 0.03 to 2.90, averaged 1.01 % (Rukhlov, Shubin, 1986). Although the above method has some imperfection due to the accepted assumptions during its using, however, its results appeared to be well comparable with the appropriate estimates obtained by the method of marking. Thus, for the period of 1977 – 1983, return coefficients were determined within 0.1-3.2, averaged 2.3 % by the data of marking (Rukhlov, Lubaeva, 1977, 1980). In the 1990s, when the correction in terms of release and supplementary feeding of juveniles have been carried out, the return coefficients determined by the earlier applied calculation method, appeared to be higher for southeastern Sakhalin hatcheries. The return coefficient for hatchery pink salmon in total over the southeastern Sakhalin region was calculated by analogy with the materials characterizing a previous period. The required value was obtained as a weighted mean all over the hatcheries using the data on catches of the artificially cultured pink salmon (Koryakovtsev, 2001). The results of calculation showed that the return coefficient for hatchery pink salmon made up 5.77 % in 1989-1997, varying within 2.97-8.65 % (Fig. 5). This estimate significantly differs from the corresponding value for the period preceding the optimization of the time period for releases ($t = 6.20$, differences are significant under $p<0.05$), exceeding it 5.7 times. Evidently, such a significant increase in the coefficient of return for the artificially cultured pink salmon in the southeastern Sakhalin region is, to a great extent, a result of the complex favorable affect both the optimization of terms for release, and supplementary feeding of juveniles.

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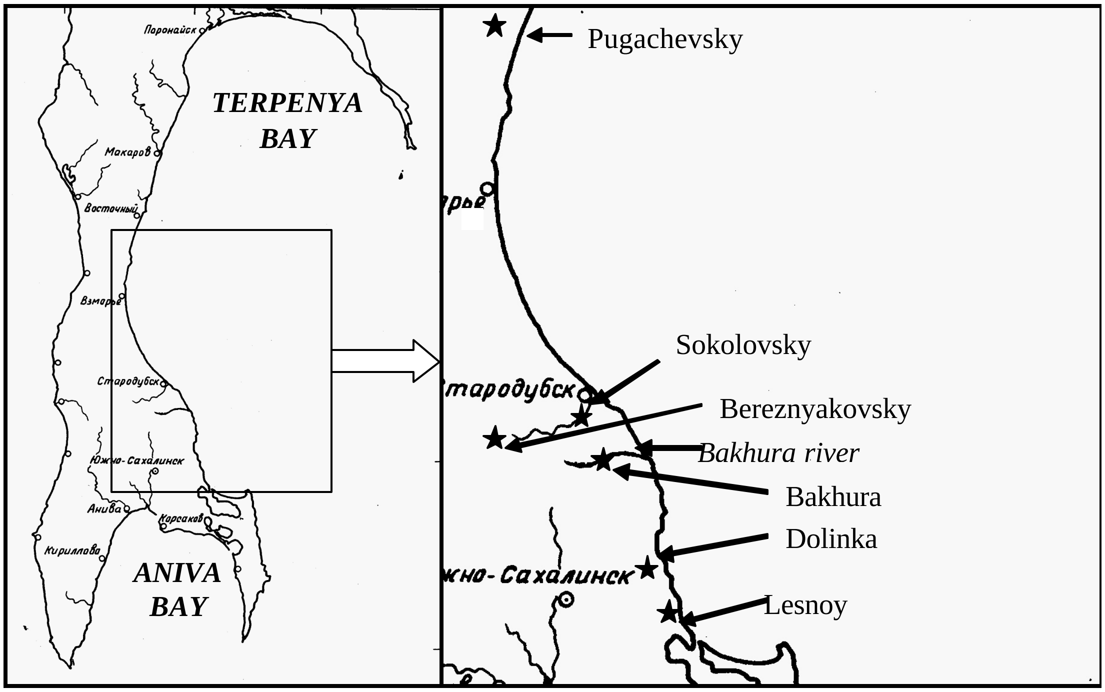

Fig. 1. Locations of southeastern Sakhalin pink salmon hatcheries

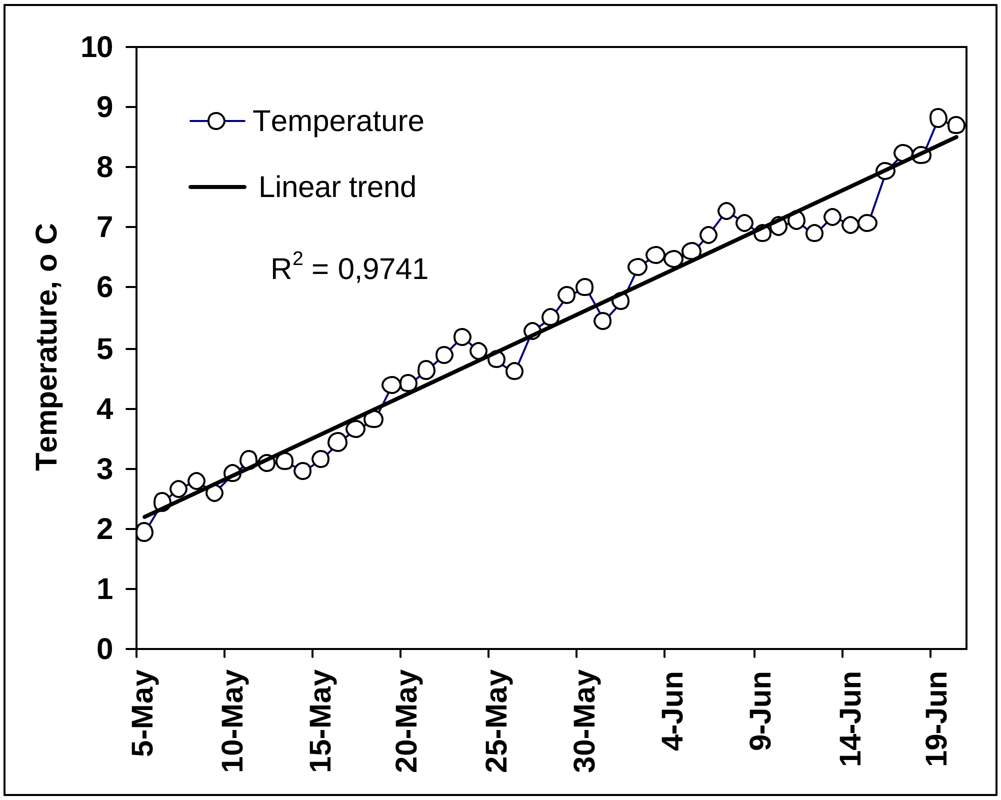

Fig. 2. Average long-term dynamics of daily temperatures in the coastal zone of southeastern Sakhalin (hydrometeostation “Starodubskoye”)

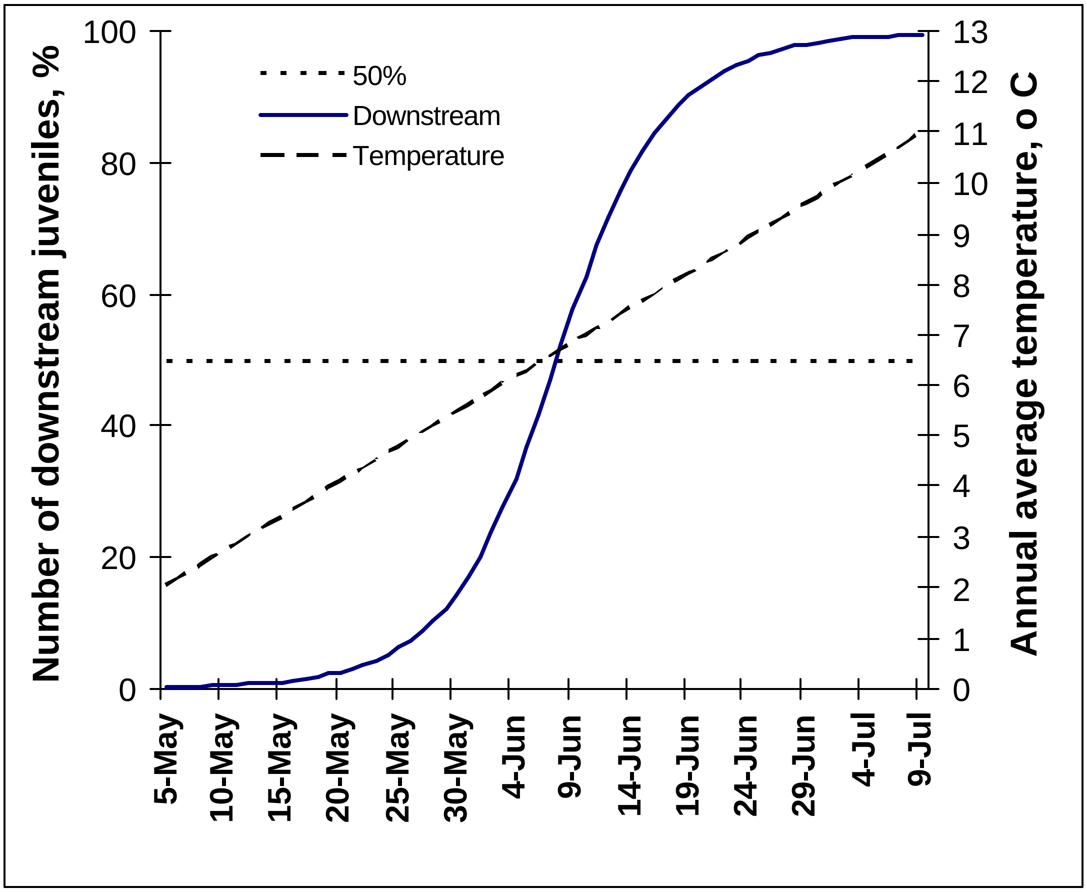

Fig. 3. Average annual dynamics of juvenile pink salmon downstream migration from the Bakhura River, and temperature in the coastal zone

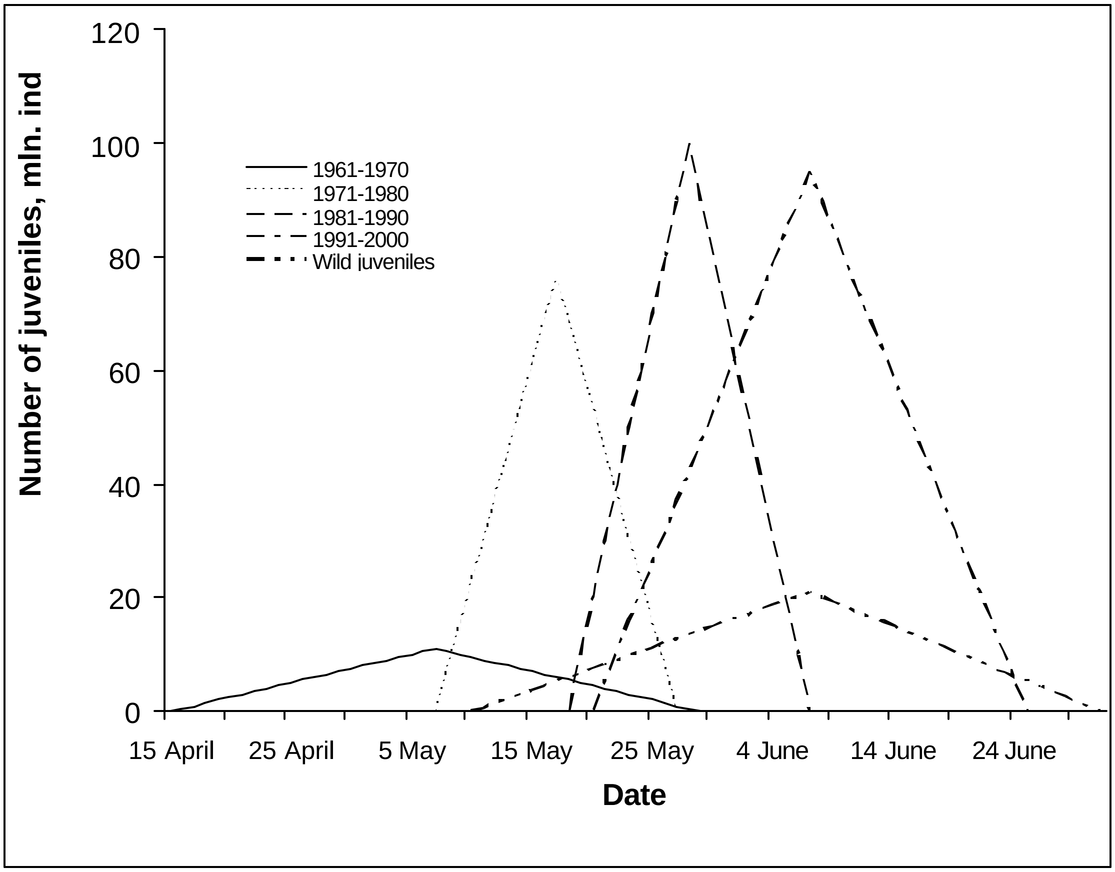

Fig. 4. Juvenile pink salmon release from southeastern Sakhalin hatcheries

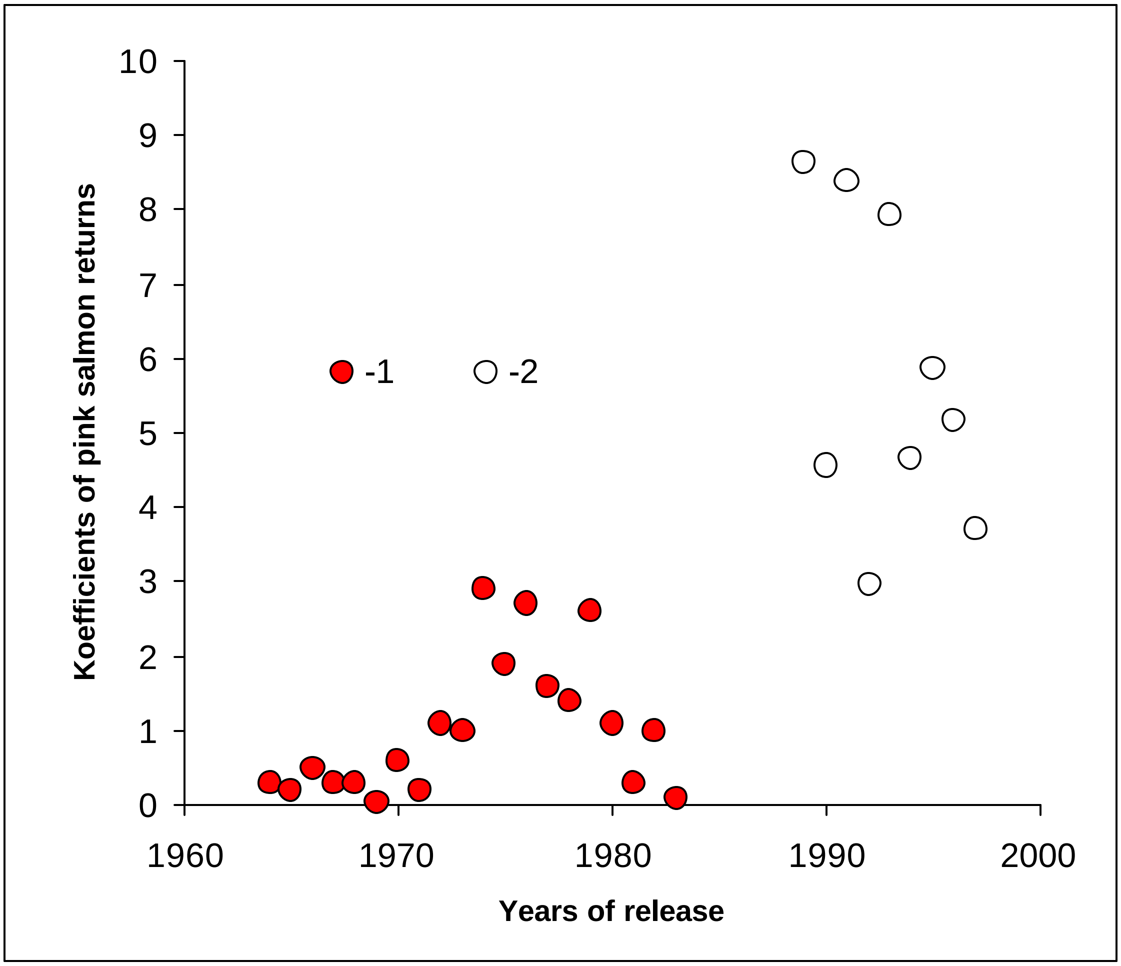

Fig. 5. Coefficients of pink salmon returns for southeastern Sakhalin hatcheries obtained by the calculation method for the 1964-1983 (1 – Rukhlov, Shubin, 1986) and for the 1989-1997 (2 – by the data of Koryakovtsev, 2001) releases