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# INTERANNUAL VARIABILITY IN SIZE AND AGE STRUCTURE OF RUSSIAN CHUM SALMON STOCKS

by

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# Interannual variability  in size and age structure of Russian chum salmon stocks

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ABSTRACT

Data on trends in abundance,  size and age composition of chum salmon stocks from all major Russian stocks are considered for the last 40-50 years. Increase in the total abundance of chum salmon were accompanied by decrease in average size in most major reproduction areas from the 1970s to 2010s. Changes in size were accompanied by changes in age structure of chum salmon populations. The tendency of growth in average age of spawners due to an increase in the proportion of older chum salmon spawners was in most of examined areas (except Primorye chum salmon stocks) . Statistically significant correlation coefficients between average sizes and total catches hes of chum salmon. indicate that there is a close relation between chum salmon abundance and it's production features.  The reasons of the changes in the size-age structure of chum salmon stocks are discussed. Certain deficiency in food supply during marine life can negatively impact chum growth rate, but ocean food resources are not the limiting factor to the abundance of salmon.

## INTRODUCTION

A growth in number of Pacific salmon was observed in the North Pacific Ocean since the mid-1970s. The observed increase of total salmon abundance was, in part, due to chum, particularly, from Japanese hatchery stocks. The growth of the total chum salmon number in the North Pacific was accompanied by significant decrease in fish size, growth rate after the first year of life, fecundity and also  increase in age-at-maturity of fish from a number of Asian and American stocks (Ishida et al. 1993; Kaev 1994, 1999; Bigler et al. 1996; Kaeriyama 1998; Volobuev& Volobuev 2000; Kaev 2003; Sviridov et al. 2004; Helle et al. 2007; Zavolokin et al. 2009). Changes in these productive characteristics of chum salmon were concordant with the period of increase in salmon abundance, which inspired views on the lack of forage resources, decrease in fish food supply and even on critical state of many population in connection with the extremely high salmon abundance in the North Pacific Ocean (Ishida et al. 1993; Welch& Morris 1994; Bigler et al. 1996; Gritsenko et al. 2000; Klovatch 2003; Kaeriyama 2003).

An increase in total number of the Pacific salmon has been observed during the last decade (Irvine and Fukuwaka 2011). Increase in abundance of Russian pink and chum salmon stocks was especially substantial.

The present report provides comparative analysis of actual data on population dynamics and also on trends in size and age at maturity of chum salmon from all major Russian stocks for the last 40-50 years.

## MATERIALS AND METHODS

Data on dynamics of catches, average body size and age structure of Russian chum salmon stocks in the 1960-2000s provided the basis for this study. Data on catch statistics of chum salmon and their average size in the Far Eastern major fishing areas in 1971-2010 were taken from NPAFC statistical documents (Irvine et al. 2009, NPAFC Statistical Yearbook 1993–2009 (http://www.npafc.org)). Data on biological features (age structure, average length and weight of chum salmon of age groups 1+ to 6+) were examined in four rivers of the northern Sea of Okhotsk, four rivers on eastern and four rivers on western coasts of Kamchatka, the Amur and Anadyr rivers, three rivers in Primorye, five rivers on Sakhalin and south Kuril Islands. However data on biological parameters of spawners from southern Primorye (Barabashevka and Ryazanovka rivers) as well as from Sakhalin (Tym, Udarnitsa and Kalininka rivers) are mostly from hatchery chum salmon. The scheme of research areas is shown in Fig. 1.

Fishing was carried out using beach seine and stationary gill nets. Body length (AC) and weight were measured and scales were taken to determine age. The number of annually analyzed individuals was usually not less than 500 specimens, collected during the entire upstream migration of chum salmon. The analysis of interannual changes in length and body weight was made for the most abundant 3+ and 4+ age groups. Every year, males and females were sampled in approximately equal proportions. Full years were used to calculate average age.

The longest time series were obtained for fish from Kamchatka (Bolshaya, Kamchatka and Khaylyulya rivers), continental coast of the Sea of Okhotsk (Kuhtuy, Tauy and Gizhiga rivers), and Amur and Anadyr rivers. To study the long-term variability in size and average age of chum salmon from the South Kuril Islands, 1974-1996 data from Iturup Island (Kurilka and Rybatskaya rivers) and 1993-2009 data from Kunashir Island (Ilyushin River) were considered together. To do that, dimensions of smaller chum salmon from Ilyushin River were adjusted to the dimensions of chum salmon from Kurilka and Rybatskaya rivers by multiplying by a coefficient obtained from comparison of length and body weight of fish in overlapping period (1993-1996). These are marked as KRI on the graphs. Unadjusted data on size and average age of Ilyushin River chum salmon are shown separately.

## Results and discussion

The total abundance of the Pacific salmon grew more than twice in the early 2000s, compared to the low abundant 1960-1970s, and reached its historical maximum in 2009. The total catch of the Pacific salmon amounted 1141 tones in the American and Asian coasts in that year (NPAFC Statistical Yearbook 2009). The pink salmon made up a major portion of the total world catch of salmon (608 thousand tons (the Russian catch is equal 425 thousand tons of it)) in 2009. The catch of chum salmon reached 359 thousand tons (the third highest value since 1925). Higher catches of chum salmon were observed earlier in 1995 and 1996: 361 and 403 thousand tons, respectively.

In the first decade of the 21st century, the North American chum salmon catch grew twice averaging 72 thousand tons (fig. 2) compared to the 1960-1980s. However, chum salmon catch on the Asian coast has increased more than three time, which was associated mainly with an increase hatchery chum production in Japan. In the last decade, annual chum catches on the Asian coast averaged 257 thousand tons, of which about 200 thousand tons were taken by Japan.

After catch declining in the late 1960s –early 1970s, chum salmon catch has increased in Russia in the early 1980s, and persisted at about 25 thousand tons (fig. 3) up to the early 2000s. The sharp increase in chum salmon catch (three times exceeding the level of the1970s) occurred in the middle of the first decade of the 2000s. In 2010, the All-Russian catch was the second highest in history, of 88.7 thousand tons, and appeared practically close to the historic peak of 102 thousand tons in 1939 (Makoedov et al. 2009). Particularly sharp increase in catches was recorded in the Amur River. It reached 15 thousand tons in 2011. The trends of chum salmon abundance increasing was typical for most regions of the Far East in the last decade (except the Anadyr River, rivers in Primorye)(fig. 4).

Changes in the total number of chum salmon were accompanied by changes in their average size in different regions. A decrease in average weight of all age groups of chum salmon was evident from the 1970s to 2010s in most major reproduction areas (fig. 5). The smallest average weights of chum salmon were observed in the 1990s in most examined areas. On eastern Kamchatka and southwestern Sakhalin, average weight of chum salmon progressively decreased from 1970 to the first decade of 2000s.

Data on body length of chum salmon spawners for two dominant age groups 3+ and 4+ are given in the figures 6 and 7, and body weight is shown in table 1. The average length of chum salmon decreased from 65.4±0.4 down to 63.2±0.2 cm, and from 68.2±0.5 down to

66.5±0.3 cm from the 1970s to 1990-2000s. The average weight decreased from 3.9±0.1 down to 3.2±0.1 kg. and from 4.4±0.1 down to 3.8±0.1 kg. for fish aged 3+ and 4+, respectively. The largest fish were observed in the 1970s. In two subsequent decades, the sizes of chum salmon of two examined size groups decreased significantly and reached a minimum in the 1990-2000s.

The size of chum salmon spawners of two examined age groups increased slightly in the early 2000s, following the 1990s, when fish were smaller and lighter. Such a trend was noticed in 15 of 22 examined rivers. In the last 5-6 years, body length of chum salmon again was decreasing in most of the rivers.

It is worth noting that, in the early 1960s, average sizes of chum salmon were also small. Fish length was similar to that in the 1990s in the Gizhiga, Tauy, Kukhtuy and Amur rivers, and, in some cases, it was even lower (the Amur River, 3+ and 4+; Gizhiga River, 4+) (fig. 6, 7).

The results of correlation analysis indicate the coincidence of trends in changing of chum salmon average size from rivers running into the Far East seas. Table 2 shows that size indices of chum salmon are weakly related for different stocks, especially in younger-aged group 3+. Correlations of average size of chum salmon aged 3+ are statistically insignificant in more than half of the cases, and in others cases, though correlations are significant, correlation coefficients are small in most cases, except for chum salmon from the Anadyr and Gizhiga rivers. Changes in the average size of chum salmon in the Amur River should be highlighted. Low and statistically insignificant correlation coefficients indicate a lack of relations between average length of chum salmon spawners aged 3+ and 4+ in the Amur Rivers and those in others areas (except Kukhtuy and Gizhiga chum salmon stocks).

Trends in dynamics of chum salmon weight are more synchronous in the different areas. Table 3 shows that there exist statistically significant correlations of chum salmon average body weight in major reproduction areas in almost all cases for group 3+ and in all cases for group 4+.

Changes in size were accompanied by changes in age structure of chum salmon populations. Figure 8 shows data on the dynamics of average age of chum salmon for different rivers of the Far Eastern coast, and Table 1 shows the same indices for major reproduction areas calculated for 10-year periods within time range 1960-2010. These data indicate that there is a tendency of growth in average age due to an increase in the proportion of older chum salmon spawners in most of examined areas.

At the same time, a number of features in annual dynamics of the fish average age in certain regions should be noted. A tendency towards progressive increase in average age of spawners is typical for fish from all rivers of the coasts of Eastern Kamchatka and western Bering Sea, beginning from the 1960-1970s, and to 2000s. The highest proportion of individuals aged 5+ was present in this region during 2000-2009. In the Haylyulya and Avacha rivers, the number of 5+ fish averaged 12.3% and 18.0% of the total number, respectively, in the last decade. The opposite tendency was observed in chum salmon stocks in the Sea of Japan. Since the late 1990s, a tendency towards gradual decrease in average age of chum salmon spawners was observed mainly due to a decrease in proportion of five-year old individuals (Table 1, fig. 8), which was accompanied by a decrease in abundance of chum populations in Primorye in the Avvakumovka, Barabashevka and Ryazanovka rivers (Goryainov et al. 2007). The minimum average age of chum salmon was observed in the 1970-1980s in rivers of northern coast of the Sea of Okhotsk (Volobuev 2000) and in the Amur River, and there was a tendency to an increase in age in the 2000s. There was an increase in average age of spawners due to an increase in the number of individuals aged 5+ and 6+ in the mid-1990s in northern coast of the Sea of Okhotsk (and in several rivers in western Kamchatka, Sakhalin and Primorye). For example, the proportion of chum salmon aged 5+ was about 50% in the Tauy River in 1996. At the same time it is worth noting that the average chum salmon age was higher in the rivers of the northern Sea of Okhotsk during the 1960-1970s, compared to the subsequent decade, and was similar to that in the 2000s (fig. 8).

Results of correlation analysis indicate that only few statistically significant Pearson's correlation coefficients between average age of chum from different stocks are greater than 0.5 (table 4). The strongest chum salmon average age correlations (r=0.57) were observed among fish from neighboring regions (the Tauy and Kukhtuy rivers).

Therefore, our data showed that body size and age structure in chum salmon of major Russian stocks varied significantly over the last 50 years. Similarity of annual dynamics in size and age for chum salmon of Russian stocks as well as similar trends for chum salmon from other rivers of Asia and North America (Ishida et al. 1993; Bigler et al. 1996; Kaeriyama 1998; Helle et al. 2007) indicate a decisive influence of some common large-scale factors on variability of these parameters. Sharp decline in size of chum salmon, which coincided with a period of increased abundance of salmon in the North Pacific in the 1980-1990s, has led to a widespread opinion that the main reason for the observed changes was the density-dependent factor. Correlation analysis between size of chum salmon from Russian stocks and their catch (table 5), as well as total abundance of Asian populations (table 6), has revealed negative correlation between these parameters.

The largest and statistically significant correlation coefficients were observed between average sizes and total catches of Asian populations (table 6), as well as total catches of chum salmon. These observations indicate that there is a close relation between chum salmon abundance and it's production features.

Various reasons for the observed decrease in salmon size during time of their high abundance in the 1980-1990s have been suggested recently. Widespread opinion, which is based on the evidence of sharp decrease in chum salmon size along with an increase of salmon abundance in the North Pacific in the 1980-1990s, suggests that the reason for those changes was the density factor associated with the lack of food resources and resultant intense intra- and interspecific competition for food. Some authors of this report partly share this point of view (Volobuev & Volobuev 2000; Zavarina 2010; Volobuev & Marchenko, 2011), along with other authors (Ishida et al. 1993; Bigler et al. 1996; Kaeriyama 1998). This hypothesis was developed into a concept, which suggested that oceanic carrying appeared too low to sustain highly abundant salmon stocks, mainly those originating from large-scale artificial reproduction) (Ishida et al. 1993; Gritsenko et al. 2000; Klovatch 2003).

The analysis of multiple actual data on quantitative distribution of pelagic nekton, plankton and small nekton, which constitute the forage base for salmon; studies salmon and nekton feeding, food selectivity and on the influence of food supply on salmon growth; as well as estimates of how much plankton is being consumed by nektonic organisms allowed to cast a doubt on the above-mentioned viewpoint on limitation of salmon abundance by food supply (Shuntov & Temnykh 2008, 2011; Shuntov et al. 2011 a-d; Zavolokin et al. 2011; Naydenko 2010). The first two authors of this report suggest that there are no reliable facts in favor of strong limitation of salmon abundance by food; though certain deficiency in food supply during marine life can negatively impact salmon growth rate.

Suggested negative influence of hatchery chum salmon on population state and production features is also not so evident. For example, during 1935-1949, when there were practically no artificially reproduced chum , the average sizes of chum salmon in the Bolshaya River were significantly less than during subsequent 1960- 2010 (average weight of chum aged 3+ was 2.88 kg., aged 4+ 3.3 kg. (Semko 1954). However, total salmon abundance during that period was notably lower than today. This fact was noted later by Zavarina L.O. (2010). In addition, we have shown above that, in the 1960s, average age and size of chum salmon failed to meet the general rule "low abundance is associated with large fish size and stock "rejuvenation"". Significant negative relationships between salmon abundance in the North

Pacific and chum salmon size were observed only in the 1980-1990s. Afterwards, despite the continued growth of salmon abundance, correlation between these parameters disappeared in most of chum salmon populations. It means that there are other factors determining growth and productivity of chum salmon in the North Pacific. These are variability in water temperature, fish community structure in rivers and internal regulatory mechanisms (Shuntov&Temnykh 2008, 2011; Zavolokin et al. 2012). According to A. Kaev (Kaev, Romasenko 2003; Kaev 2010) long-term changes in size-age structure of chum salmon stocks could emerge from global changes in ecosystems rather than from increase in abundance. These issues are largely unresolved and require further studies.

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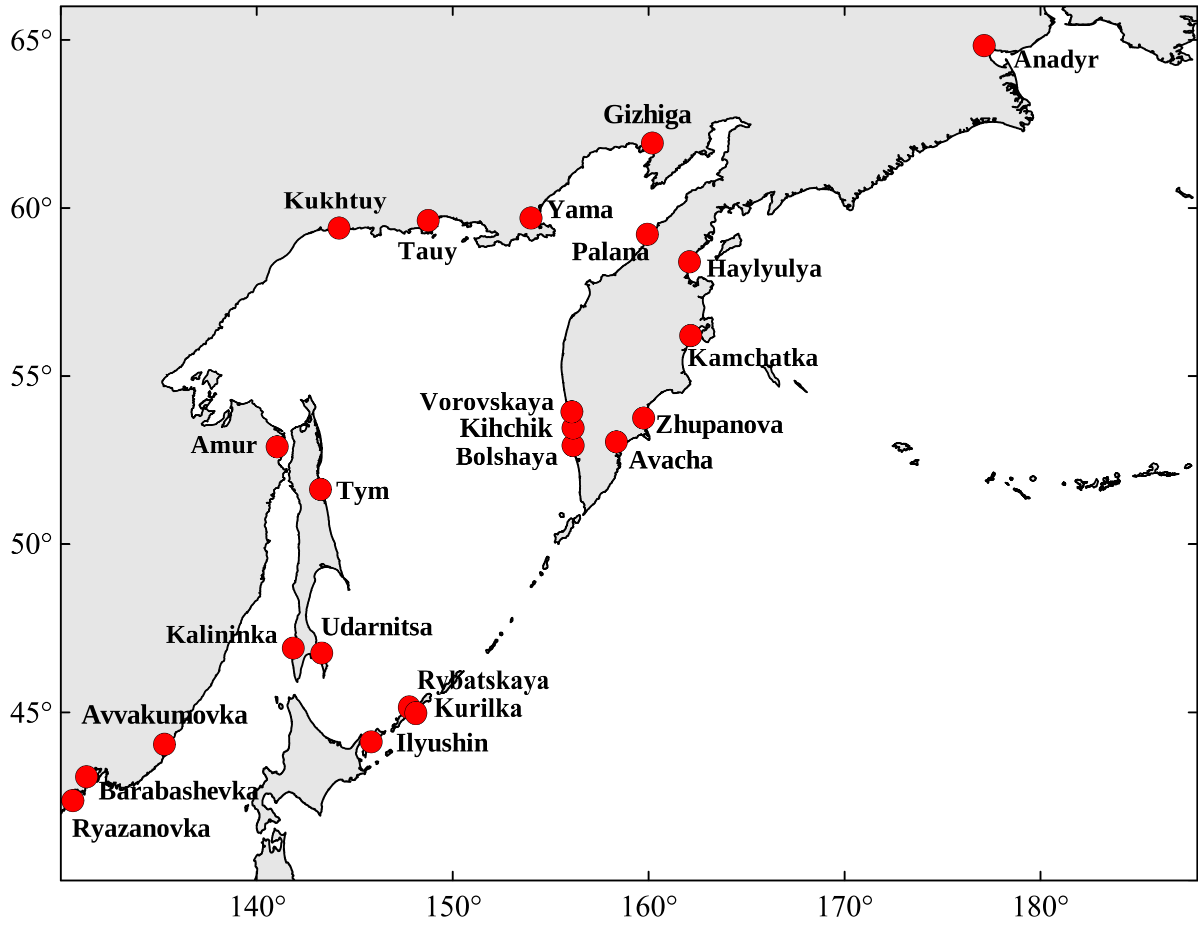



**Fig. 1.** Map of the study area

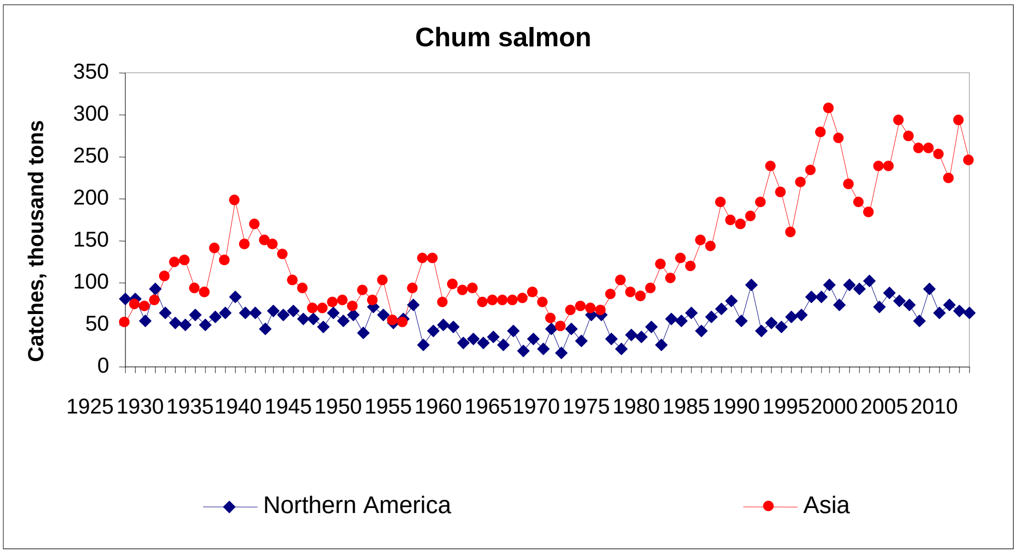



**Fig. 2.** Chum salmon catch on the American and Asian coasts during 1925-2010

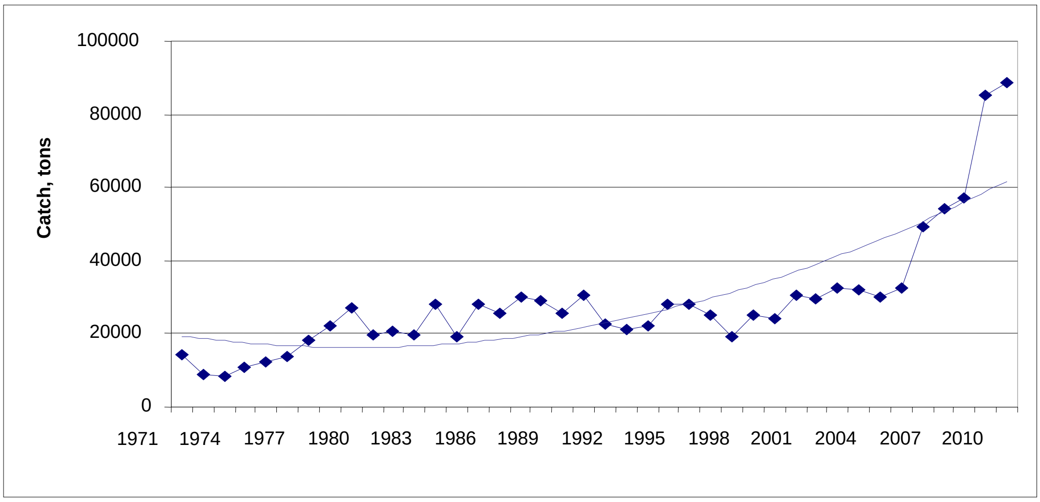



Fig. 3. Chum salmon total catch in the Far East during 1971-2010

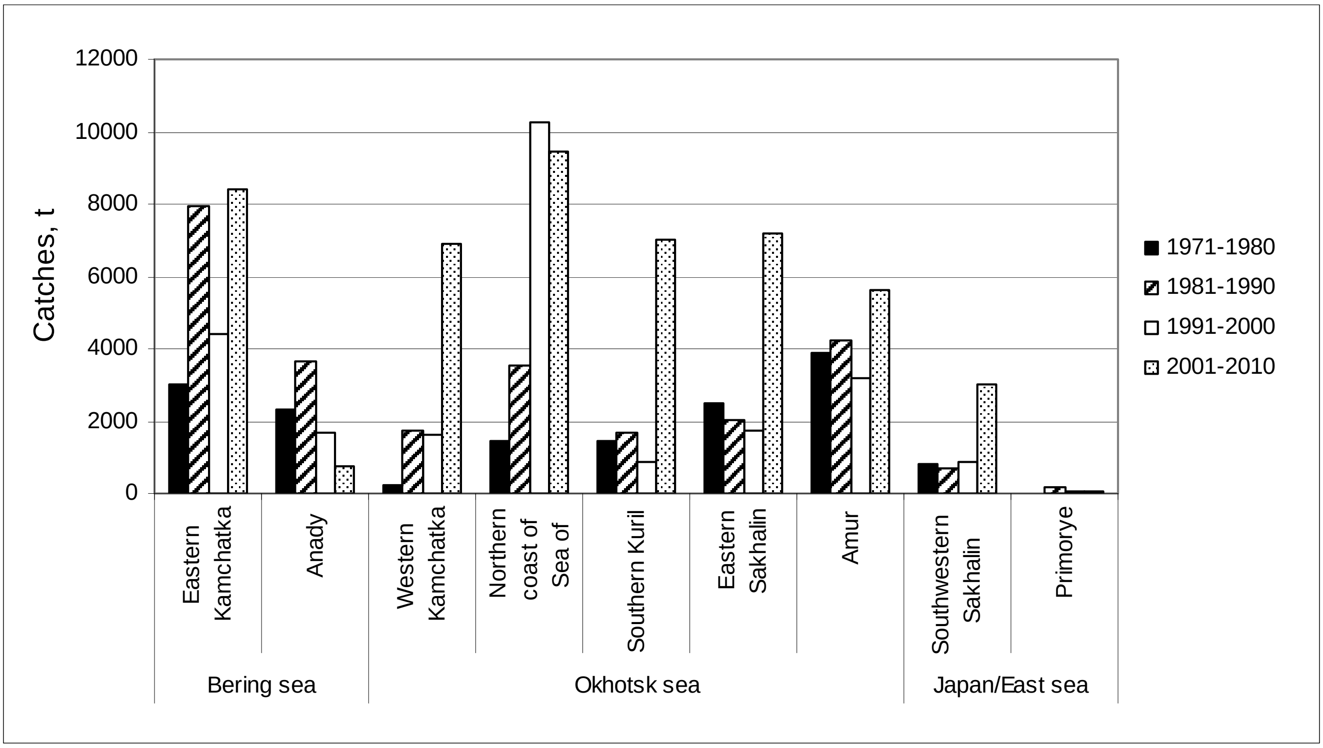



Fig. 4. Average decade catches of chum salmon in different reproduction regions during 1970-2010

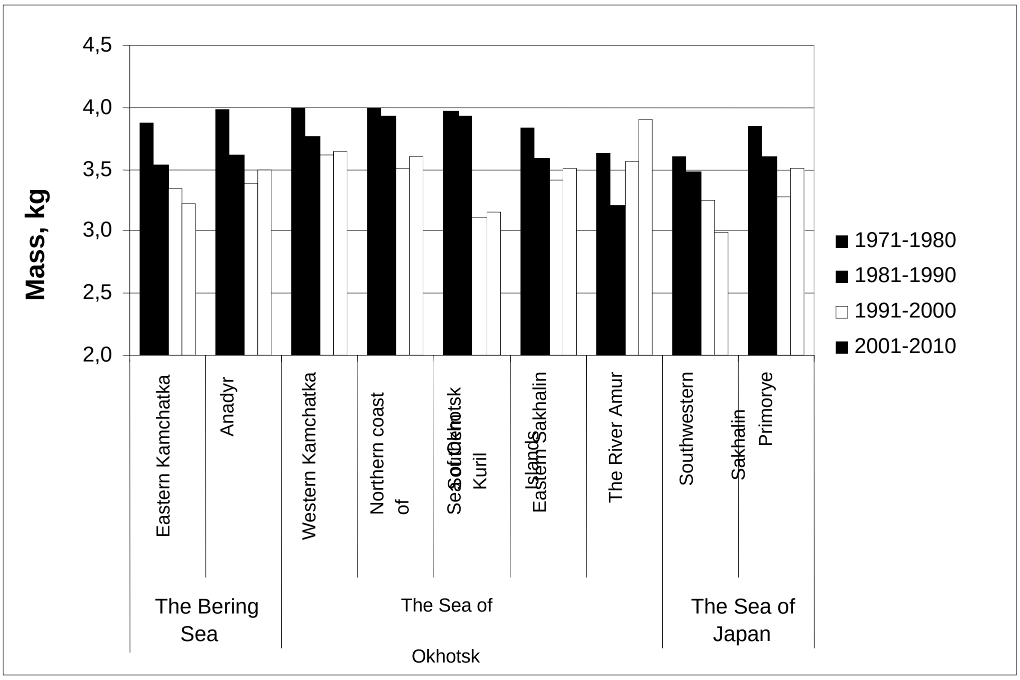
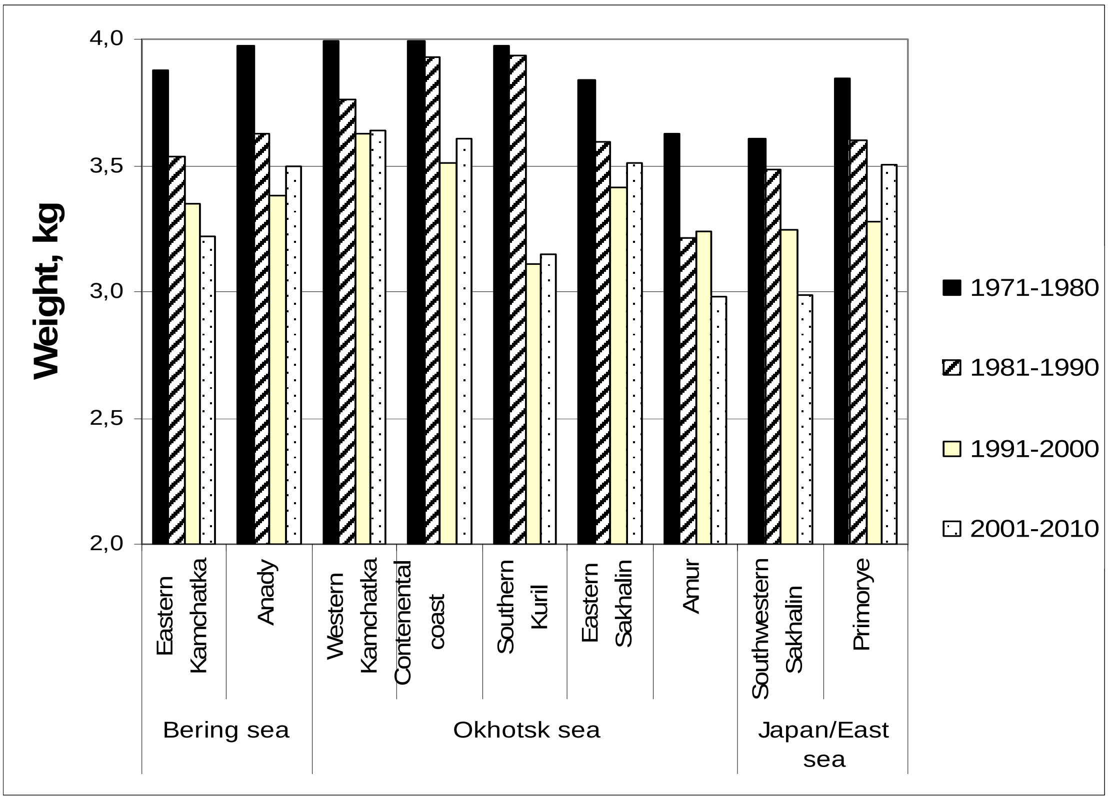



Fig. 5. Average decade weight of chum salmon in different reproduction regions during 1970-2010



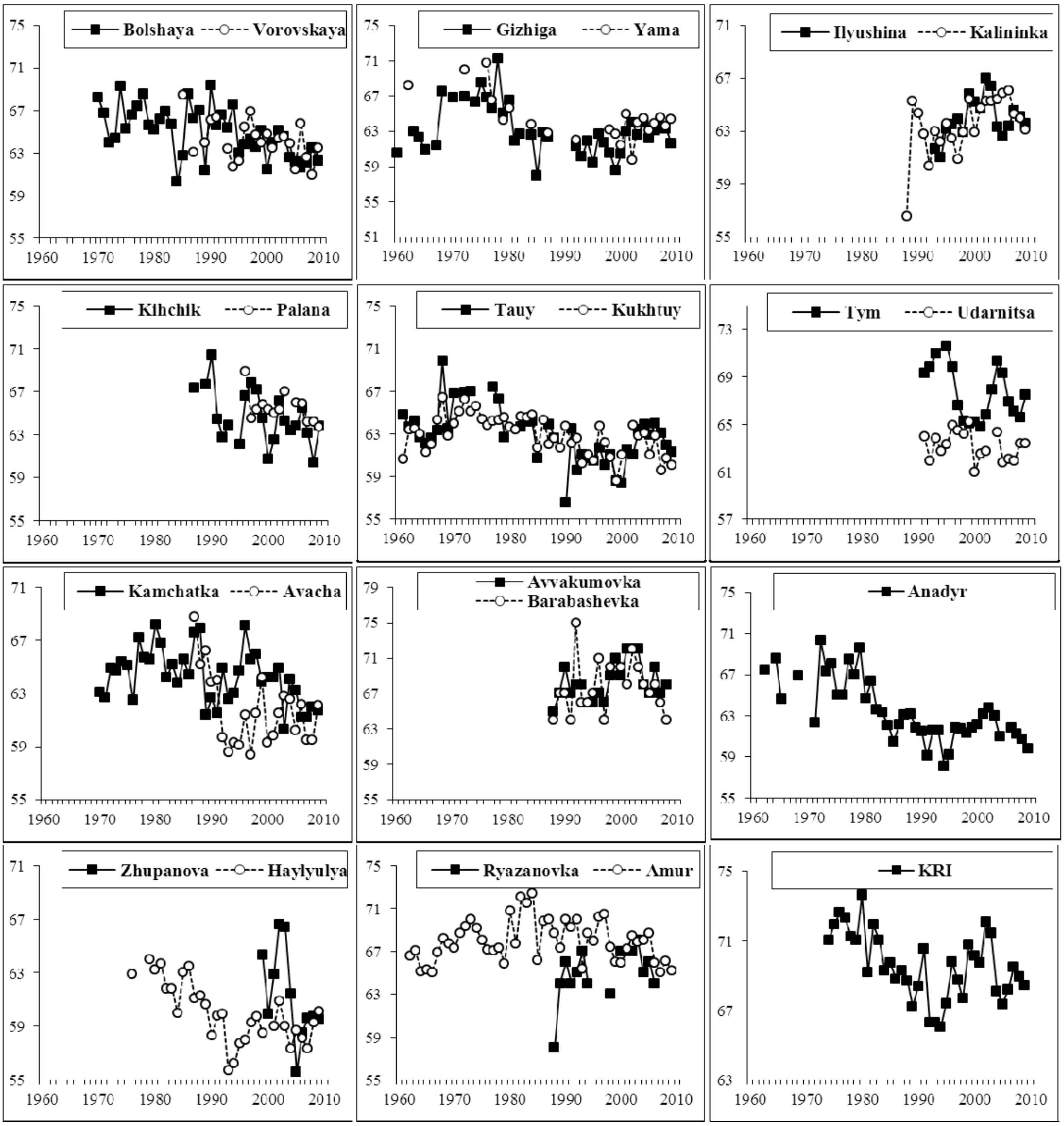



Fig. 6. Annual dynamics of average length of chum salmon aged 3+ in different reproduction regions

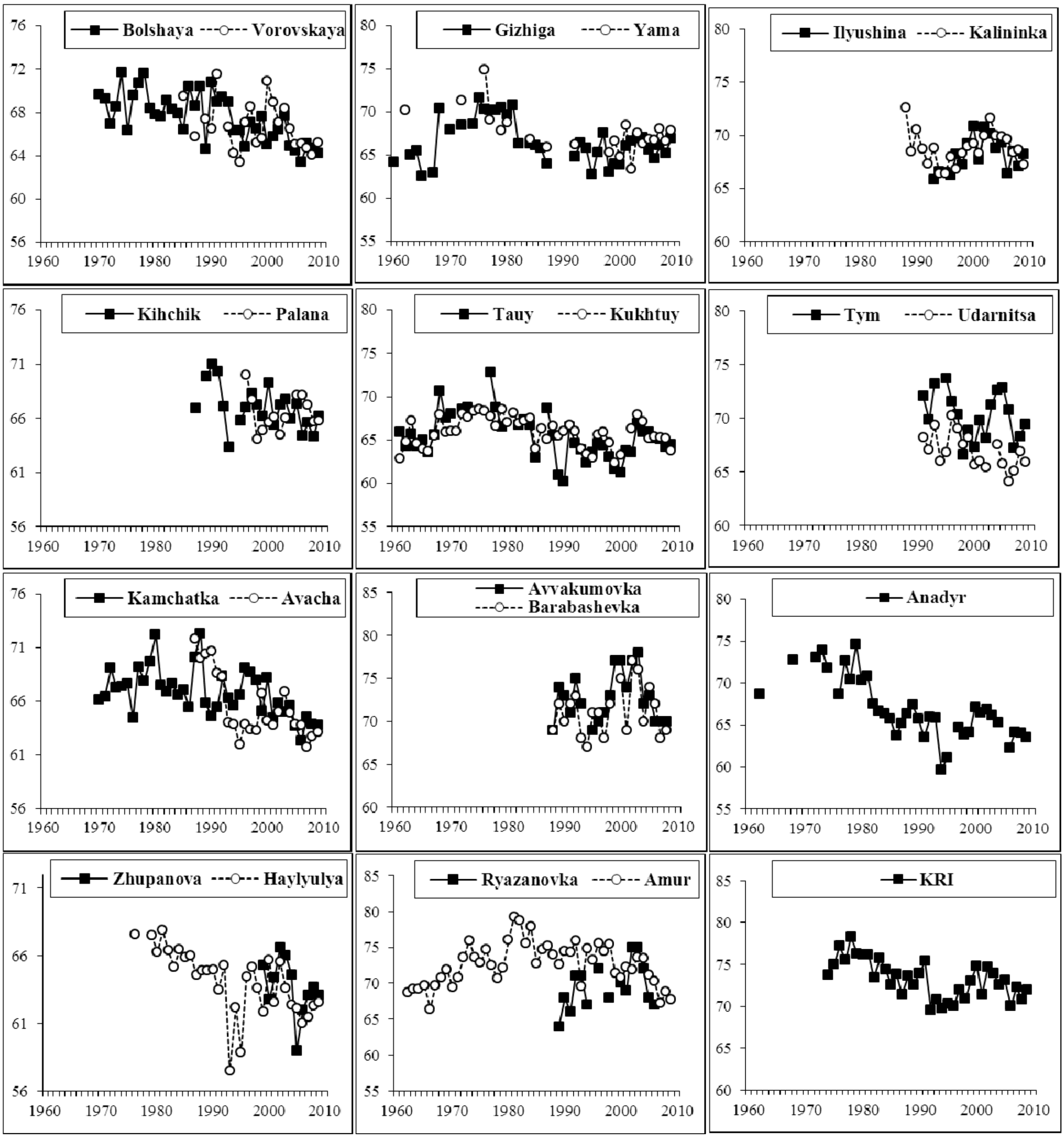



Fig. 7. Annual dynamics of average length of chum salmon aged 4+ in different reproduction regions

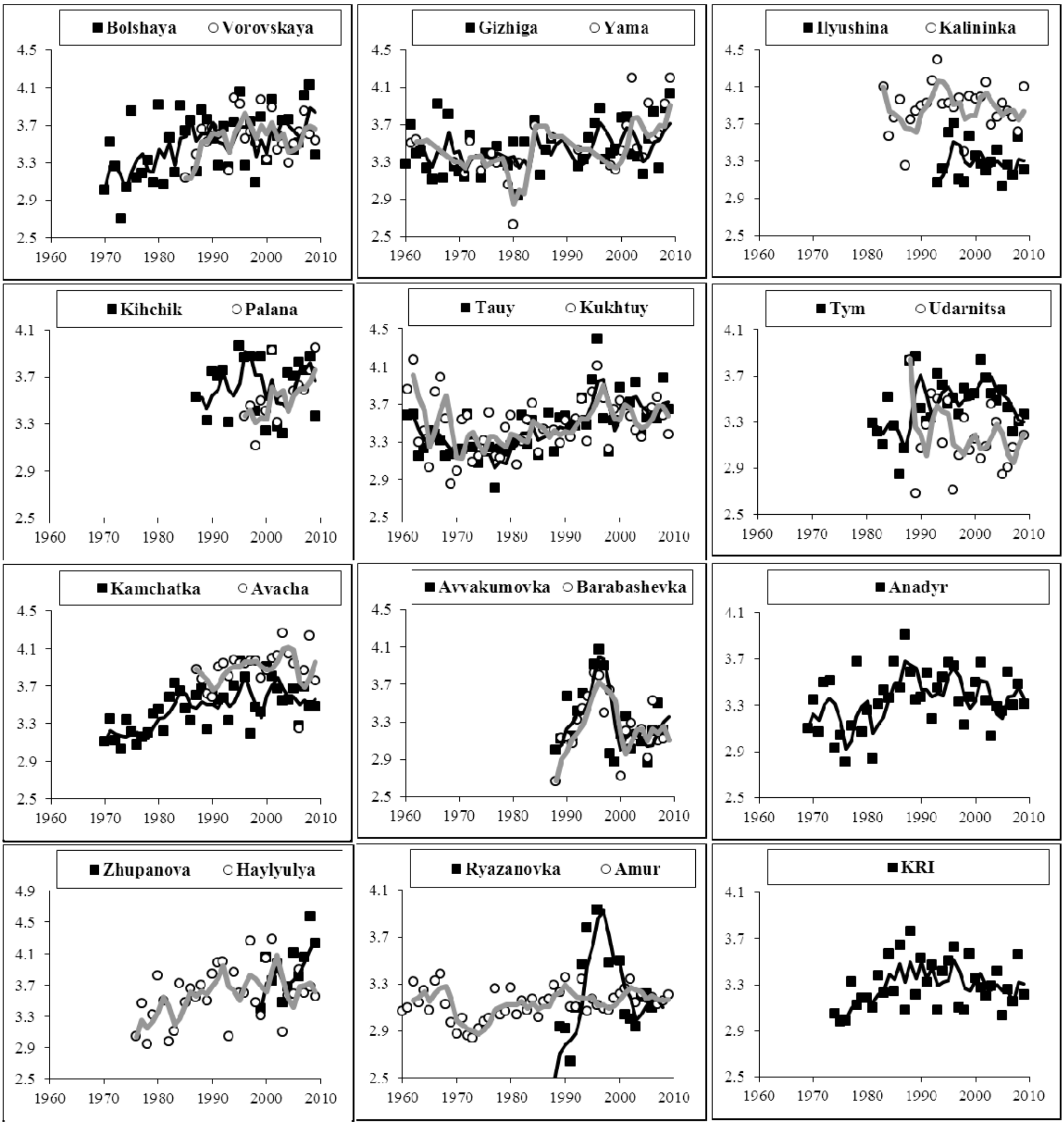



Fig. 8. Annual dynamics of average age of chum salmon in different reproduction regions

Table 1

Average age and weight of chum salmon aged 3+ and 4+ in different reproduction areas in 1960-s – 2000-s

| Western Bering Sea and Eastern Kamchatka Regions | | | | | |
|---|---|---|---|---|---|
| Indicator | Period | The Anadyr | Khaylyulya | Kamchatka | Avacha |
| Average Age | The 1960 - s | 3,2 | | 3,1 | |
| | The 1970 - s | 3,2 | 3,3 | 3,2 | |
| | The 1980 - s | 3,4 | 3,5 | 3,5 | 3,7 |
| | The 1990 - s | 3,4 | 3,7 | 3,6 | 3,9 |
| | The 2000 - s | 3,4 | 3,7 | 3,6 | 3,9 |
| Average 3+ | The 1960 - s | 3,7 | | 3,7 | |
| | The 1970 - s | 3,7 | 3,5 | 3,8 | |
| Weight | The 1980 - s | 3,5 | 3,1 | 3,3 | 3,3 |
| | The 1990 - s | 2,9 | 2,7 | 3,1 | 2,8 |
| | The 2000 - s | 3,2 | 2,7 | 3,2 | 2,9 |
| Average 4+ | The 1960 - s | 4,3 | | 4,3 | |
| | The 1970 - s | 4,6 | 4,1 | 4,3 | |
| Weight | The 1980 - s | 4,2 | 3,9 | 3,8 | 4,1 |
| | The 1990 - s | 3,4 | 3,4 | 3,6 | 3,4 |
| | The 2000 - s | 3,7 | 3,3 | 3,6 | 3,4 |
| Western Kamchatka Region | | | | | |
| Indicator | Period | The Bolshaya | Palana | Vorovskaya | Kihchik |
| Average Age | The 1960 - s | 3,0 | | | |
| | The 1970 - s | 3,3 | | | |
| | The 1980 - s | 3,6 | | 3,5 | 3,5 |
| | The 1990 - s | 3,5 | 3,4 | 3,6 | 3,7 |
| | The 2000 - s | 3,7 | 3,7 | 3,6 | 3,6 |
| Average 3+ | The 1960 - s | 3,7 | | | |
| | The 1970 - s | 3,9 | | | |
| Weight | The 1980 - s | 3,4 | | 3,8 | 3,6 |
| | The 1990 - s | 3,1 | 3,5 | 3,5 | 3,7 |
| | The 2000 - s | 3,3 | 3,4 | 3,5 | 3,4 |
| Average 4+ | The 1960 - s | 3,8 | | | |
| | The 1970 - s | 4,4 | | | |
| Weight | The 1980 - s | 3,9 | | 4,1 | 3,7 |
| | The 1990 - s | 3,5 | 3,5 | 3,9 | 4,0 |
| | The 2000 - s | 3,7 | 3,7 | 4,0 | 3,7 |
| Northern Sea of Okhotsk Region | | | | | |
| Indicator | Period | The Gizhiga | Kukhtuy | Tauy | Yama |
| Average Age | The 1960 - s | 3,4 | 3,5 | 3,3 | 3,4 |
| | The 1970 - s | 3,3 | 3,4 | 3,2 | 3,2 |
| | The 1980 - s | 3,4 | 3,4 | 3,4 | 3,5 |
| | The 1990 - s | 3,5 | 3,6 | 3,7 | 3,3 |
| | The 2000 - s | 3,6 | 3,5 | 3,7 | 3,8 |
| Average 3+ | The 1960 - s | 3,5 | 3,6 | 3,7 | 3,9 |
| | The1970 - s | 3,7 | 3,9 | 3,9 | 3,9 |
| Weight | The 1980 -s | 3,2 | 3,7 | 3,5 | 3,7 |
| | The 1990 -s | 3,1 | 3,3 | 3,2 | 3,2 |
| | The 2000 - s | 3,1 | 3,3 | 3,2 | 3,3 |
| Average 4+ | The 1960 - s | 3,9 | 4,0 | 4,0 | 4,3 |
| | The 1970 - s | 4,2 | 4,5 | 4,5 | 4,4 |
| Weight | The 1980 - s | 3,9 | 4,2 | 4,1 | 4,2 |
| | The 1990 - s | 3,8 | 3,9 | 3,7 | 3,8 |
| | The 2000 - s | 3,6 | 4,0 | 3,5 | 3,8 |
| The Sakhalin Island and the South Kuril Islands | | | | | |
| Indicator | Period | The Tym | Udarnitsa | Kalininka | KRI |
| Average Age | The 1970 - s | | | | 3,1 |
| | The 1980 - s | 3,3 | 3,2 | 3,8 | 3,4 |
| | The 1990 - s | 3,5 | 3,2 | 4,0 | 3,4 |
| | The 2000 - s | 3,5 | 3,1 | 3,9 | 3,3 |
| Average 3+ | The 1970 - s | | | | 4,1 |
| | The 1980 - s | | | 2,5 | 3,7 |
| Weight | The 1990 - s | 3,4 | 2,9 | 2,7 | 3,4 |
| | The 2000 - s | 3,4 | 2,9 | 3,0 | 3,5 |
| Average 4+ | The 1970 - s | | | | 4,8 |
| | The 1980 - s | | | 3,9 | 4,4 |
| Weight | The 1990 - s | 3,8 | 3,6 | 3,6 | 3,9 |
| | The 2000 - s | 3,9 | 3,4 | 3,7 | 3,9 |
| The Sea of Japan Region | | | | | |
| Indicator | Period | The Amur | Ryazanovka | Avvakumovka | Barabashevka |
| Average Age | The 1960 - s | 3,2 | | | |
| | The 1970 - s | 3,0 | | | |
| | The 1980 - s | 3,2 | 2,8 | 3,2 | 3,0 |
| | The 1990 - s | 3,1 | 3,4 | 3,5 | 3,4 |
| | The 2000 - s | 3,2 | 3,1 | 3,2 | 3,2 |
| Average 3+ | The 1960 - s | 4,4 | | | |
| | The 1970 - s | 4,7 | | | |
| Weight | The 1980 - s | 4,3 | 2,6 | 3,7 | 3,0 |
| | The 1990 - s | 4,0 | 3,0 | 3,6 | 3,4 |
| | The 2000 - s | 3,8 | 3,2 | 3,8 | 3,4 |
| Average 4+ | The 1960 - s | 5,2 | | | |
| | The 1970 - s | 5,9 | | | |
| Weight | The 1980 - s | 5,5 | 3,0 | 4,7 | 3,6 |
| | The 1990 - s | 5,0 | 3,6 | 4,5 | 3,7 |
| | The 2000 - s | 4,5 | 4,1 | 4,5 | 4,1 |

Table 2

Pearson's correlation coefficients between body length of chum salmon in different Far Eastern rivers (data time-series for more than 30 years)

| | River | Amur | Anadyr | Bolshaya | Gizhiga | Kamchatka | KRI | Kukhtuy | Tauy |
|---|---|---|---|---|---|---|---|---|---|
| Age 3+ | Amur | 1 | | | | | | | |
| | Anadyr | -0,04 | 1 | | | | | | |
| | Bolshaya | 0,25 | **0,33** | 1 | | | | | |
| | Gizhiga | 0,17 | **0,63** | **0,44** | 1 | | | | |
| | Kamchatka | **0,36** | **0,42** | 0,26 | 0,14 | 1 | | | |
| | KRI | 0,15 | **0,59** | 0,25 | **0,55** | 0,29 | 1 | | |
| | Kukhtuy | **0,49** | **0,65** | **0,41** | **0,68** | 0,31 | **0,50** | 1 | |
| | Tauy | 0,12 | **0,54** | 0,21 | **0,80** | 0,23 | **0,42** | **0,55** | 1 |
| | Khaylyulya | 0,22 | **0,67** | 0,27 | 0,33 | **0,42** | **0,58** | **0,56** | 0,07 |
| Age 4+ | Amur | 1 | | | | | | | |
| | Anadyr | 0,13 | 1 | | | | | | |
| | Bolshaya | 0,31 | **0,43** | 1 | | | | | |
| | Gizhiga | 0,18 | **0,80** | **0,42** | 1 | | | | |
| | Kamchatka | **0,42** | **0,49** | **0,37** | 0,29 | 1 | | | |
| | KRI | 0,14 | **0,72** | **0,49** | **0,76** | 0,25 | 1 | | |
| | Kukhtuy | **0,43** | **0,70** | **0,42** | **0,75** | 0,26 | **0,62** | 1 | |
| | Tauy | 0,12 | **0,60** | **0,42** | **0,65** | 0,34 | **0,38** | **0,64** | 1 |
| | Khaylyulya | **0,60** | **0,66** | **0,39** | **0,55** | **0,42** | **0,66** | **0,63** | 0,13 |

*Endnote*. Significant correlation coefficients are highlighted in bold type ($p<0.05$)

Table 3

Pearson's correlation coefficients between body weight of chum salmon in several certain Far Eastern rivers (data time series for more than 30 years)

| | River | Amur | Anadyr | Bolshaya | Gizhiga | Kamchatka | KRI | Kukhtuy | Tauy |
|---|---|---|---|---|---|---|---|---|---|
| Age 3+ | Amur | 1 | | | | | | | |
| | Anadyr | **0,52** | 1 | | | | | | |
| | Bolshaya | 0,27 | **0,55** | 1 | | | | | |
| | Gizhiga | **0,74** | **0,51** | **0,54** | 1 | | | | |
| | Kamchatk | **0,59** | **0,70** | **0,63** | **0,67** | 1 | | | |
| | KRI | **0,45** | **0,67** | **0,43** | **0,54** | **0,69** | 1 | | |
| | Kukhtuy | **0,77** | **0,60** | **0,41** | **0,82** | **0,62** | **0,54** | 1 | |
| | Tauy | **0,51** | **0,49** | 0,26 | **0,67** | **0,42** | **0,44** | **0,58** | 1 |
| | Khaylyuly | **0,38** | **0,78** | **0,45** | **0,42** | **0,67** | **0,67** | **0,48** | 0,33 |
| Age 4+ | Amur | 1 | | | | | | | |
| | Anadyr | **0,46** | 1 | | | | | | |
| | Bolshaya | **0,39** | **0,63** | 1 | | | | | |
| | Gizhiga | **0,68** | **0,49** | **0,42** | 1 | | | | |
| | Kamchatk | **0,48** | **0,60** | **0,53** | **0,62** | 1 | | | |
| | KRI | **0,51** | **0,74** | **0,64** | **0,48** | **0,68** | 1 | | |
| | Kukhtuy | **0,71** | **0,56** | **0,51** | **0,70** | **0,55** | **0,56** | 1 | |
| | Tauy | **0,53** | **0,55** | **0,53** | **0,55** | **0,51** | **0,56** | **0,60** | 1 |
| | Khaylyuly | **0,54** | **0,74** | **0,35** | **0,41** | **0,41** | **0,69** | **0,61** | **0,50** |

*Endnote*. Significant correlation coefficients are highlighted in bold type ($p<0.05$)

Table 4

Pearson's correlation coefficients between average age of chum salmon in several Far Eastern rivers (data time series for more than 30 years)

| River | Amur | Anadyr | Bolshaya | Gizhiga | Kamchatka | KRI | Kukhtuy | Tauy |
|---|---|---|---|---|---|---|---|---|
| Amur | 1 | | | | | | | |
| Anadyr | 0,23 | 1 | | | | | | |
| Bolshaya | **0,46** | 0,19 | 1 | | | | | |
| Gizhiga | **0,30** | **0,52** | 0,28 | 1 | | | | |
| Kamchatka | **0,51** | **0,38** | **0,44** | **0,44** | 1 | | | |
| KRI | **0,36** | **0,39** | **0,45** | **0,42** | **0,45** | 1 | | |
| Kukhtuy | **0,51** | 0,26 | **0,41** | **0,44** | **0,50** | 0,29 | 1 | |
| Tauy | 0,26 | **0,39** | **0,37** | **0,51** | **0,53** | 0,33 | **0,57** | 1 |
| Khaylyulya | 0,27 | 0,26 | **0,37** | 0,31 | 0,32 | 0,23 | 0,27 | 0,19 |

Table 5

Pearson's correlation coefficients between chum salmon sizes (length and weight) and region catches in 1971-2009

| River | Length | | Weight | |
|---|---|---|---|---|
| | 3+ | 4+ | 3+ | 4+ |
| Amur | -0,31 | **-0,32** | **-0,41** | **-0,37** |
| Anadyr | 0,20 | 0,19 | **0,37** | 0,30 |
| Bolshaya | **-0,49** | **-0,61** | **-0,35** | **-0,38** |
| Gizhiga | **-0,53** | **-0,65** | **-0,56** | **-0,49** |
| Kamchatka | -0,12 | -0,25 | -0,27 | **-0,38** |
| KRI | 0,04 | -0,06 | -0,07 | -0,16 |
| Kukhtuy | **-0,70** | **-0,72** | **-0,60** | **-0,66** |
| Tauy | -0,34 | **-0,50** | **-0,53** | **-0,55** |
| Khaylyulya | **0,46** | **0,35** | **0,45** | 0,28 |

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Table 6

Pearsons' correlation coefficients between chum salmon dimensions (length and weight) and total Asian catch in 1971-2009

| River | Length | | Weight | |
|---|---|---|---|---|
| | 3+ | 4+ | 3+ | 4+ |
| Amur | -0,22 | -0,27 | **-0,57** | **-0,65** |
| Anadyr | **-0,73** | **-0,80** | **-0,64** | **-0,65** |
| Bolshaya | **-0,42** | **-0,58** | **-0,60** | **-0,70** |
| Gizhiga | **-0,60** | **-0,63** | **-0,59** | **-0,45** |
| Kamchatka | **-0,32** | **-0,41** | **-0,75** | **-0,72** |
| KRI | **-0,53** | **-0,66** | **-0,56** | **-0,64** |
| Kukhtuy | **-0,65** | **-0,56** | **-0,63** | **-0,56** |
| Tauy | **-0,45** | **-0,57** | **-0,51** | **-0,55** |
| Khaylyulya | **-0,73** | **-0,64** | **-0,71** | **-0,56** |

*Endnote*. Significant correlation coefficients are highlighted in bold type ($p<0.05$)