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CORRELATION BETWEEN PINK SALMON (ONCORHYNCHUS GORBUSCHA (WALBAUM) REPRODUCTION LEVEL WITH TEMPERATURE REGIME AT TIHE PERIOD OF EARLY EMBRYOGENESIS IN THE UTKA RIVER (WEST KAMCHATKA).

By

N. B. Markevich

Kamchatka Research Institute of Fisheries and Oceanography
(KamchatNIRO)
18, Naberezshnaya Str.,
Petropavlovsk-Kamchatskiy,
683602, Russia

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Resume

The data collected for many years on correlation of survival of Pink Salmon smolts in the Utka River (West Kamchatka) with the temperature regime during the first 45 days of spawning have analyzed and summarized in this work.

In 1951-95 Pink Salmon embryogenesis in the Utka River took place at a very variable degree-day summary for the first 45 days of conditional starting of spawning. (The degree-day summary varied in the range of 313 - 401). Comparison of the number of Pink Salmon adults coming for spawning (variating from several thousand fishes up to 6 million fishes) and the number of registered smolts (variating from several hundred thousand fishes up to 90 million fishes) indicates rather close correlation between production of smolts and temperature regime in the course of embryogenesis. Generally production decreases with an increase of degree-day summary for the first 45 days of embryogenesis. Stocks with different abundance show different reaction to variations of temperature regime. Generally with the fall of the abundance in the reproductive stock and at the phase of low reproductive abundance relatively low temperatures at early embryogenesis are more favourable. For the stocks of high abundance the temperature optimum is shifted towards higher meanings.

Introduction

The Utka River (West Kamchatka) is a stream closely adjacent to the main river where reproduction of the Western Kamchatka Pink Salmon stock (the system of the Bolshaya/Bystraya Rivers) take place. The number of Pink Salmon smolts has been registered since 1956. At the same period aerial counts of Pink Salmon adults coming into the river for spawning have been effected. From year to year counts are effected with the use of the unified standard methods and the obtained data is analyzed and compared for a number of years.

The ecology of Pink Salmon spawning is a typical ecology of a mainstream spawning species. Spawning at river patches adjacent to springs with relatively stable temperature is not typical for Pink Salmon. On the other side, earlier research showed that survival of Pink Salmon is rather closely correlated with temperature regime at the initial period of embryogenesis. Too early suffering from low temperature (lower than 4 - 4.5° C) at the stage of eye pigmentation results in practically total mortality of embryos (Combs, Burrows, 1957; Bailey, Evans, 1971; Bailey, Pella, Teylor, 1976).

Experimental incubation of Pink Salmon eggs accomplished at the mainstream spawning grounds of the Bystraya River shows that the majority of embryos die during the period starting from the beginning of spawning and coming to the first days of October when water temperature stabilizes at 4 - 4.5° C. This is also the time when the embryos fertilized at the earlier periods of spawning emerge (Markevich, Vilenskaya, 1991; 1995; 1995a). All this led to an assumption that the temperature regime in the course of embryogenesis can cause the reason for the mortality of Pink Salmon. To check this assumption in the Bolshaya river is not possible due to the lack of data on abundance of smolts in this stream.

The Utka river is very closely located to the Bolshaya river and there is a ground to believe that temperature regime of these rivers is insignificantly different. Rather detailed data available on abundance of spawning Pink Salmon adults in the Utka river as well as data on abundance of smolts make this sort of analysis possible.

Material and methods

Data on the abundance of adults and smolts is represented in the Table 1. Some facts need to be commented.

At very low abundance of parental stock it is very difficult to effect counts of smolts. Dashes for 1965-68 (years of spawning) show that the assessment has been done, however real abundance has not been defined due to very low number of registered smolts. In 1973 and 1976 the assessment of smolts has not been carried out at all.

As an indication of temperature regime the degree-day summary was taken for the period from August 16 to September 30 ($\sum$degree-day). Research of the previous years shows that generally mass spawning period of Pink Salmon at the western coast of Kamchatka starts in mid August. The same research shows that the most intense mortality of embryos at the experimental incubation of eggs at the natural spawning grounds takes place at the same period (Markevich, Vilenskaya, 1991, 1995). For the estimation of the degree-day summary ($\sum$degree-day) the data on average daily water temperature at the station on the Bolshaya-Bystraya river is used. The average parameter for the period 1951-1995 is equal to 357 degree-days. It is obviously seen that the meanings represented in the Table 1 do not correspond with the temperature parameters during spawning or embryogenesis of Pink Salmon in the Utka River. However, in our opinion, the meanings can serve as indicators of the spawning conditions arising every particular spawning year throughout the rivers of Western Kamchatka.

There is evident correlation, specific for both even and odd broods, between the abundance of spawning Pink Salmon adults and of smolts. Mathematic equation for each brood is separately represented in Figure 1. For the estimations the abundance expressed in a base of natural logarithms is used: Ln n/1000 - the abundance of adults and Ln N/1000 - the abundance of smolts. Mathematic equation to each brood - even and odd, can help to calculate the expected abundance of smolts (Nt) with given number of spawners observed in every particular year of spawning (Table 1).

For the estimation of the level of the smolts production (SP) the value = N*100%/Nt is used. This value is called the smolts production parameter (SP). Evidently, with SP equal to 100% - the level of reproduction corresponds with theoretic expectations. If SP<100% or SP>100% - the level is correspondingly

lower or higher than the expected level. One of determinants causing SP deviation from theoretic expectation, on our view, could be the temperature regime on the spawning ground in the course of spawning and embryogenesis.

A number of assumptions were allowed during the analysis of data. Thus it was assumed that at all reproduction cycles the starting periods of mass Pink Salmon spawning took place in mid August. In reality variations can make minimum ± 7 day in relation to the fixed date.

Another allowed assumption was that temperature parameters received from the observation station on the Bolshaya/Bystraya river indicated the temperature regime of the Utka river at the spawning period.

Results and Discussion

Figure 2 shows a correlation between SP and $\sum$ degree-day for 46 days (from August 16 to September 30). Horizontal line shows 100% SP level.

In $\sum$ degree-day range of 335-420 quite reliable inverse correlation between the analyzed values is observed. SP gets decreased with an increase of the $\sum$ degree-day. The destroyed correlation. is observed within the range of $\sum$ degree-day lower 335 (in even years). Generally the dispersion is rather significant (Figure 2).

It is known, that the abundance of Pink Salmon stock both of even and of odd broods fluctuate extensively. Three phases of these fluctuations can be determined: 1 - high stock abundance, 2 - decreasing stock abundance and 3 - depressive stock abundance and initial growth of abundance. At the considered period of time, stocks of both broods have passed all the phases (Figure 3).

The phases we have defined are quite conventional. But it can be noticed that in both broods the initial growth of parental stocks abundance followed the spawning cycles where temperature regime ($\sum$ degree-day) did not significantly vary from cycle to cycle. In odd broods these years are 1969, 1971, 1973 and 1975; in the even broods - 1972, 1974, 1976 and 1978. For both broods $\sum$ degree-day in the accounted period was lower than average for many years (Figure 3).

All said above allows the assumption that the reply of Pink Salmon stock to the dynamics of the temperature regime in the course of spawning likely relates to the phase of stock abundance at a particular stage. In both broods the years given in Table 2 can be added to the three defined phases.

Table 2

Phases of stock abundance in spawning years

Phase of parental stock abundance	Years of reproduction
Decreasing of parental stock abundance	1957; 1959; 1961; 1985; 1987; 1989; 1958; 1960; 1962; 1964; 1990; 1992
Low stock abundance and initial growth	1963; 1969; 1971; 1991; 1995; 1970; 1972; 1974; 1978
High stock abundance	1975; 1977; 1979; 1981; 1983; 1956; 1980; 1982;1984;1986;1988; 1984

In the groups given in table 2 the correlation between SP and $\sum$ degree-day for the period of spawning and embryogenesis is observed more clearly (figures 4, 5 and 6).

The correlation is mostly evident in the stocks at the phase of stock abundance decreasing (figure 4). Only one extrapolation (1964) greatly deviates from general tendency (SP=117, $\sum$ degree-day =322). It should be mentioned that in this case taken $\sum$ degree-days corresponds to conditional period of mass spawning. Actually the beginning of mass spawning can be shifted to later periods. According to our knowledge In 1994-1998 placing of the pioneer lot of Pink Salmon eggs for experimental incubation in the spawning grounds of the Karymayskaya stream took place during the period of August 10-25 which is connected to the period of spawners maturity (Markevich, Vilenskaya, 1991; 1995). With late maturation of the first spawners it is natural to expect shift of the mass spawning period to the latest date. In this case the eggs and embryos could be effected by excessively cold temperature resulting in stagnation of eggs development and in embryonal mortality. These effects have been mentioned in some earlier publications (Combs, 1965; Bailey, Evans, 1971). Thus deviations shown in the diagram do not contradict our knowledge of peculiarities of Pink Salmon embryogenesis.

Actually similar correlation has been found in stocks at the phase of low stock abundance (figure 5).The general tendency of SP decreasing with $\sum$ degree-day increasing is broken by the parameter marked in the diagram with the arrow (1972, SP=76, $\sum$ degree-day=330). The reason for this can also be explained by later actual periods of spawning (compared with conditionally accepted: mid August).

Thus, the correlation between SP and $\sum$ degree-day in stocks at the phase of decreasing stock abundance and at the phase of low abundance is of the same type. With increase of $\sum$ degree-day for the period of 45 days from the conditional beginning of the spawning period (mid August) SP decreases. The data analyzed in the two diagrams (figures 4 and 5) covers 21 years of observation. And only 2 years (10%) do not correspond to the general tendency.

In stocks with high abundance of spawners correlation between SP and $\sum$ degree-day is of a slightly different character. This correlation can be represented by a dome-shaped curve given in figure 6.

There are extrapolations not corresponding to the general tendency (marked with arrows in figure 6). In years 1956, 1984 and 1983 a great number of spawning Pink Salmon adults came into the Utka River (1350 - 6800 thousand individuals). SP decrease in these years could be explained by high mortality of eggs due to overcrowding of spawners at the spawning grounds. After 1956 and 1983 Pink Salmon stock abundance in both even and odd cycles of reproduction has greatly decreased. Pink Salmon stock of even cycle of reproduction needed 11 reproduction cycles to overcome depression. And the Pink Salmon stock of odd reproduction cycle has been in depression since reproduction collapse in 1983. And it has not overcome this depression so far.

The question arises why the character of correlation between SP and $\sum$ degree-day in highly abundant stocks is different from situation in stocks of decreasing or minimum abundance. On our view, the difference can be explained by the influence of two factors: number of spawners and temperature regime in the course of spawning.

Embryonal mortality evidently grows with high abundance of spawning due to the fact of digging the nests over again (Smirnov, 1975). The elimination of eggs of earlier spawning stages is most likely to happen. In this case the eggs spawned at the second part of the spawning period in relatively cold years can suffer from unfavourable temperature conditions and get eliminated as well. It will result in decrease of total level of smolts survival.

If at the phases of decreasing of spawners stocks abundance or at the phases of their lower abundance maximum value of SP corresponds to $\sum$ degree-day range of 335-340 (figures 4 and 5) at the phases of high abundance of spawners stock with the same $\sum$ degree-day range SP significantly decreases (Figure 6).

In warm years with the high abundant stock of spawners the eggs from the earlier periods of spawning can also get eliminated due to digging the nests over again. Another reason for elimination of these eggs could be suffering from unfavourable temperature conditions (high temperature). The eggs from the latest half of the spawning period having survived the digging over could safely develop at favourably colder temperatures. Maximum and high SP meanings correspond with $\sum$ degree-day range of higher meanings - 350-360 (figure 6). But further temperature rise at the spawning period again effects the parameter of total survival. With $\sum$ degree-day range over 360 degree-days SP decreases again (figure 6).

In this publication we did not intend to express correlation between SP and $\sum$ degree-day through mathematic equation. In this case we would have to

exclude from consideration a group of significantly deviating extrapolations. And we do not have sufficient grounds to do this.

Dividing the parental stocks in the phases of stock abundance seems to be quite grounded, although clear differentiation of boundary reproduction cycles is hardly possible. Sometimes, as it was observed in the even brood in 1984-1994, rapid decrease of stock abundance was immediately followed by sharp increase without passing the phase of stable depression.

With the allowed assumptions the correlation between SP in Utka River and Σ degree-day at spawning and embryogenesis at all phases of spawning stock abundance is quite obviously observed. This fact is rather important as the Utka River and adjacent rivers is the center of Pink Salmon reproduction of West Kamchatka stock. It might be supposed that local Pink Salmon is «well adjusted» to the existing temperature regime at the spawning period, and this regime should not significantly influence fluctuation of reproduction levels. However the represented data shows that even in the "center" of Pink Salmon reproduction temperature regime during the period of spawning and embryogenesis greatly influences the level of smolts survival and correspondingly effect the dynamics of the stock abundance.

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Supplement

Table 1

Parameters of stock abundance, smolts production (SP) and temperature regime (Σ degree-day)

Spawning years	number of spawners		number of smolts				SP= N*100%/Nr	Σdegree-day
	n, thousand	Ln n/1000	fact		theoretic Nt, thous	Ln Nt/1000		
1955	590	6,4	-	-	13913	9,5	-	377
1957	485	6,2	2000	7,6	12637	9,4	16	376
1959	252	5,5	6101	8,7	8611	9,1	71	355
1961	29	3,4	800	6,7	1228	7,1	65	359
1963	61	4,1	5380	8,6	2700	7,9	199	376
1965	170	5,1	-	-	6530	8,8	-	352
1967	60	4,1	-	-	2657	7,9	-	325
1969	90	4,5	4700	8,5	3881	8,3	121	345
1971	55	4,0	5500	8,6	2438	7,8	226	337
1973	100	4,6			4257	8,4		348
1975	690	6,5	47700	10,8	14931	9,6	319	347
1977	2400	7,8	47623	10,8	21552	10,0	221	373
1979	2500	7,8	36885	10,5	21685	10,0	170	336
1981	650	6,5	46352	10,7	14544	9,6	319	353
1983	6800	8,8	6198	8,7	22437	10,0	28	391
1985	55	4,0	2892	8,0	2438	7,8	119	347
1987	10	2,3	126	4,8	321	5,8	39	360
1989	33	3,5	167	5,1	1421	7,3	12	389
1991	39	3,7	2500	7,8	1706	7,4	147	362
1993	3	1,1	-	-	52	3,9	-	368
1995	3	1,1	151	5,0	52	3,9	292	336
1956	1800	7,5	11000	9,3	30044	10,3	37	334
1958	63	4,1	1200	7,1	7429	8,9	16	388
1960	7	1,9	280	5,6	658	6,5	43	367
1962	27	3,3	3300	8,1	3360	8,1	98	363
1964	3,2	1,2	243	5,5	208	5,3	117	322
1966	1,5	0,4	-	-	59	4,1	-	349
1968	2,5	0,9	-	-	140	4,9	-	366
1970	1,5	0,4	70	4,2	59	4,1	119	401
1972	9	2,2	700	6,6	922	6,8	76	330
1974	30	3,4	9200	9,1	3745	8,2	246	354
1976	70	4,2			8098	9,0	-	337
1978	90	4,5	38802	10,6	9838	9,2	394	333
1980	455	6,1	6430	8,8	23708	10,1	27	313
1982	650	6,5	38554	10,6	26369	10,2	146	346
1984	1350	7,2	16723	9,7	29720	10,3	56	354
1986	495	6,2	33136	10,4	24381	10,1	136	412
1988	560	6,3	41136	10,6	25319	10,1	162	387
1990	135	4,9	17489	9,8	13030	9,5	134	342
1992	32	3,5	8000	9,0	3996	8,3	200	336
1994	3000	8,0	87000	11,4	29121	10,3	299	391

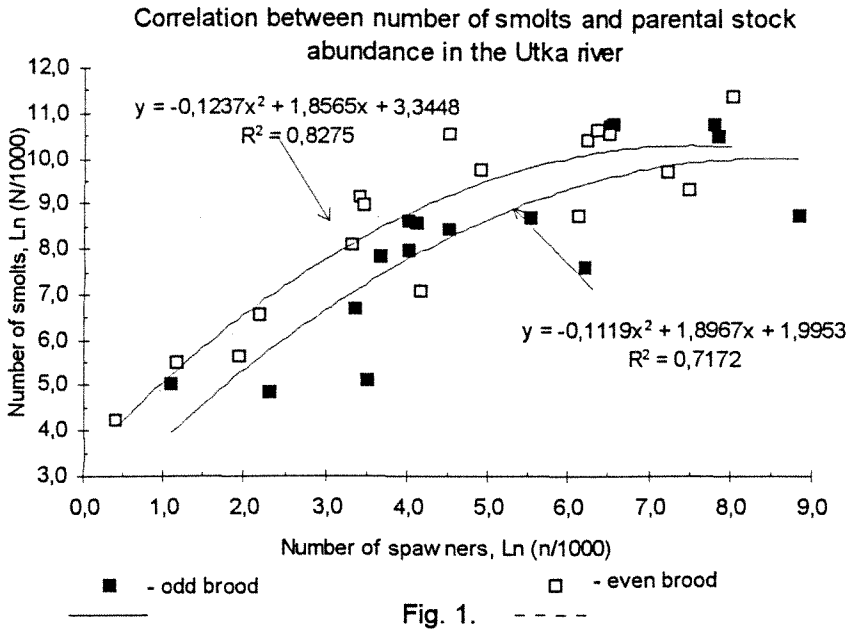
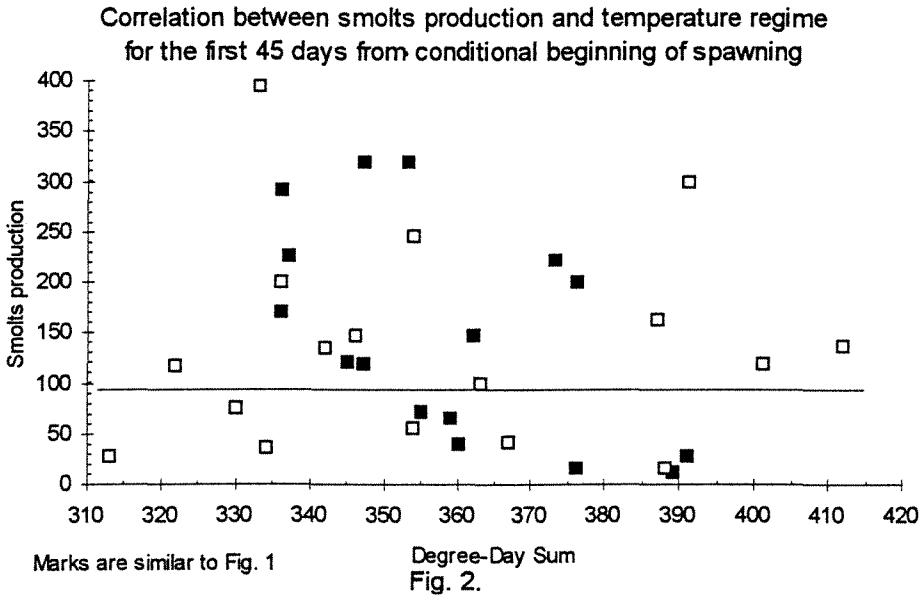


Fig. 1.



Marks are similar to Fig. 1

Fig. 2.

Dynamics of parental stocks of Pink Salmon in the Utka river and dynamics of temperature regime in 1953-1996.

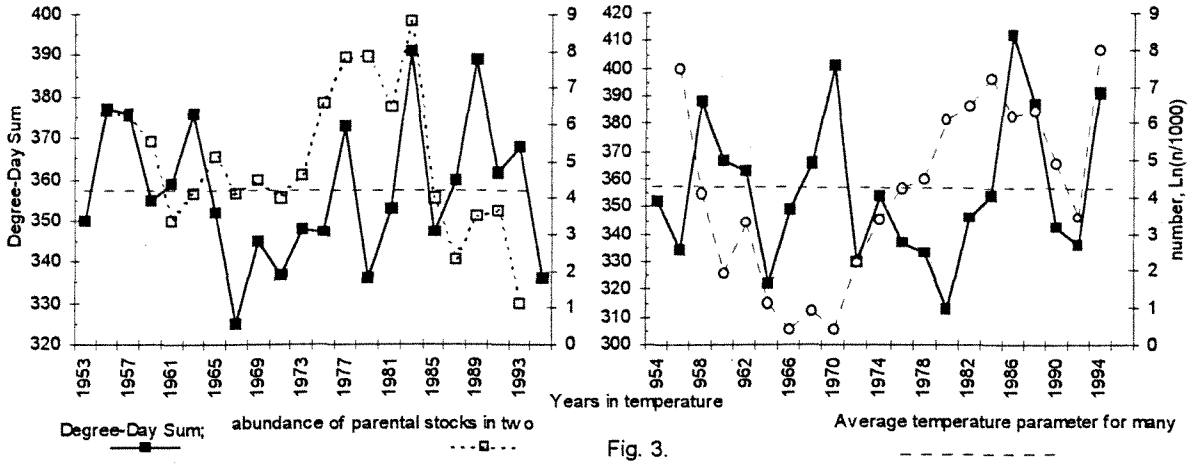


Fig. 3.

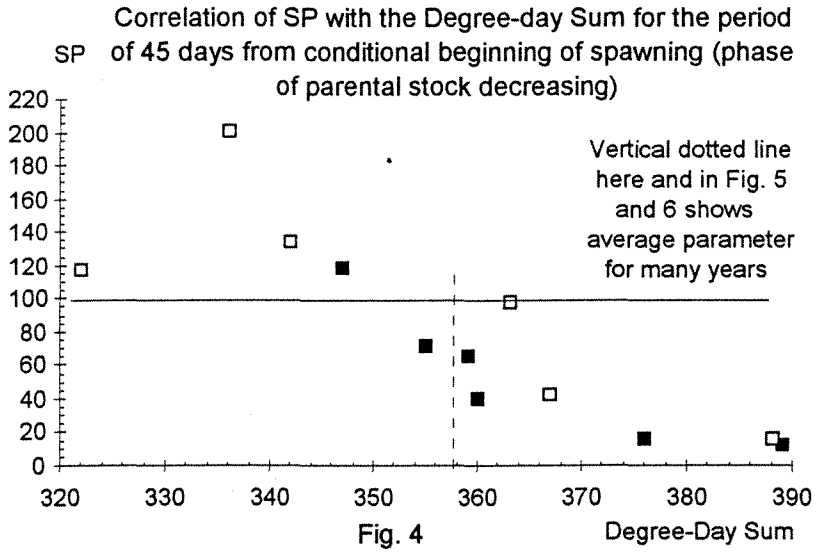


Fig. 4

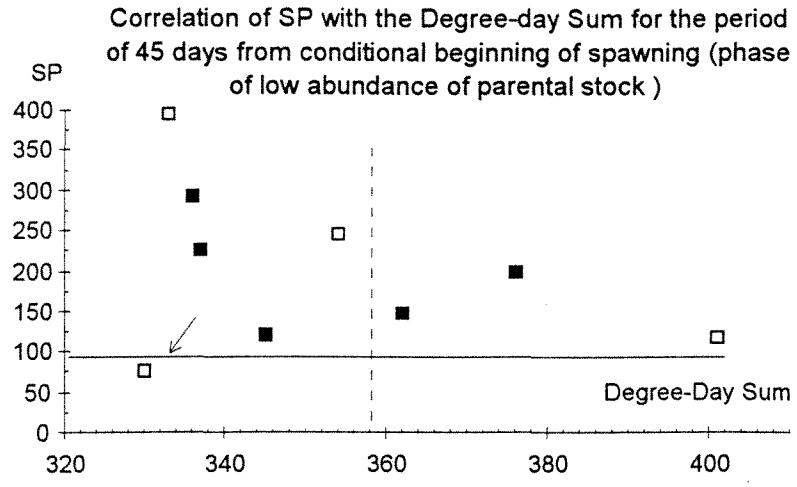

Correlation of SP with the Degree-day Sum for the period of 45 days from conditional beginning of spawning (phase of low abundance of parental stock)
SP
400
350
300
250
200
150
100
50
0
320
340
360
380
400
Degree-Day Sum

Fig. 5

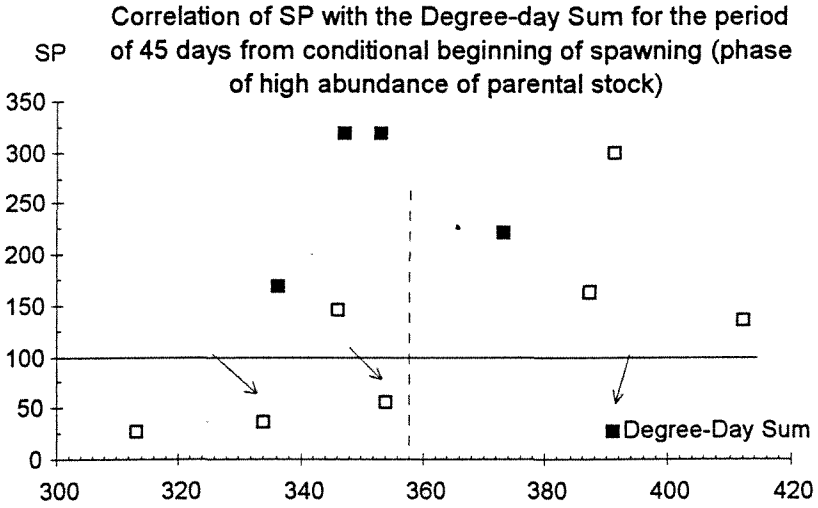

Correlation of SP with the Degree-day Sum for the period of 45 days from conditional beginning of spawning (phase of high abundance of parental stock)
SP
350
300
250
200
150
100
50
0
300
320
340
360
380
400
420
Degree-Day Sum

Fig. 6