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A comparison of the growth rate in walleye pollock (Theragra chalcogramma) taken from the open waters of the Bering Sea and those from the open waters of the Okhotsk Sea in 1991.

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A B S T R A C T

The growth of walleye pollock (Theragra chalcogramma) from the international waters of the Bering and Okhotsk Sea was examined in 1991. Mean length at age of pollock was distincly higher in the Bering Sea that in the Okhotsk Sea. A comparison of the von Bertalanffy's growth curves indicated differences in growth between the two regions. These differences are expressed by the L-inf and K parameters, for both males and females. Confidence limits for these two parameters are different and do not overlap. The test of the hypotheses concerning the differences between maens length at age of pollock from the international waters of the Bering and Okhotsk Sea also indicated significant differences between these two regions.

I N T R O D U C T I O N

Pollock (Theragra chalcogramma) is a species distributed over a wide area of the North Pacific. It occurs on the shelf and continental slope from the Sea of Japan through the Okhotsk Sea, Bering Sea and Gulf of Alaska to Vancouver. It has been belived until recently that the species lives near the bottom it turned out, however, that substantial pollock stocks occur also in deep waters,

especially in the Bering Sea, leading a pelagic mode of living. The stocks of this species in the North Pacific are estimated at about 45 M. tons, and the catches in 1989 reached 6 259 thous tons (Yearbook 1990), out of which 3 713 thous tons were extracted from the Bering Sea and about 1 800 thous tons in the Okhotsk Sea. In recent years this species has been the object of the greatest single-species exploitation in the world fishery.

Relatively large genetic differences between pollock from the western and eastern parts of the North Pacific show that these populations are isolated. Genetic differences within these areas are less visible, although regional differences in growth rate, age composition, meristic and morphometric features occur there.

Although the biology and stocks of pollock in the Bering Sea are relatively well known, little is known about pollock from the Okhotsk Sea. The objective of this paper is to present length and age composition of the pollock stock exploited in the international waters of the Bering and Okhotsk Sea and show differences in pollock growth between these two areas.

M A T E R I A L A N D M E T H O D

Materials for the study were collected on Polish fishing vessels operating in the international waters of the Bering and Okhotsk Sea in 1991, by scientists from the Sea Fisheries Institute in Gdynia. In the international waters of the Bering Sea, in January and May-August, measurements were made of 39 389 specimens of pollock and otoliths were removed from 3001 individuals. In the international waters of the Okhotsk Sea, between September and December, 35 646 fish were measured and otoliths were removed from 1801 individuals. Fork length of fish was measured with a split between sexes. The collected otoliths served for age reading. The method and interpretation of growth increments visible on the otolith were accepted according to the reccomendations of the Special Group on Ageing Methodology of Walleye Pollock, held in Gdynia in 1990 [Report

from the Workshop on Ageing Methology of Walleye Pollock (Theragra chalcogramma), 1990].

Areas of fishing operations for pollock conducted by the Polish deep-sea fleet in the open waters of the Bering and Okhotsk Sea in 1991 are presented in Fig.1.

The von Bertalanffy's method was used for calculation of growth rate; according to it, lengths in subsequent years of life are determinated on the basis of eqation:

$$L_t = L_{inf} * (1 - e^{-K * (t - to)}),$$

where:

L_t - length of fish at age t,

parameters calculated on the basis of empirical data:

L_{inf} - mean asymptotic length,

K - growth coefficient (catabolism index), determines the shape of the curve,

t_o - theoretical age, at which the fish would have a length of 0 cm.

The parameters of this equation were calculated by the method described by Allen (1966). In this method, the coefficients are calculated on the basis of mean lengths of fish at a given age, weighted by abundance; in addition, theoretical point 0, 0, is introduced, assuming that the length of fish at age 0 is close to 0 cm.

In order to determine the significance of the differences between pollock populations from these two areas, confidence limits for parameters L_{inf} and K of the von Bertalanffy's equation were examined. An analysis of the significance of the differences between mean lengths of fish in the same age-groups of pollock was also carried out for both areas. The following statistics was used:

$$U = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_1^2}{n_1} - \frac{S_2^2}{n_2}}},$$

where: $\bar{x}_n$ - mean length,

n_n - number in sample,

S_n^2 - variance.

For larger samples ($n_1 > 30$ and $n_2 > 30$), statistical values were reffered to a normal distribution (Z), and for small samples - to t-Student distribution (t).

L E N G T H C O M P O S I T I O N

In the international waters of the Bering Sea pollock had lengths of 34-62 cm, mean being 50.2 cm (Fig.2,3). The main part of the stock (over 75 %) consisted of fish with lengths of 48-53 cm; fish below 41 cm and over 55 cm constituted barely 3.6 %. The difference between mean length of males and females was small (0.5 cm).

In the international waters of the Okhotsk Sea pollock had lengths of 11-62 cm, mean being 40.9 cm. The main part of the stock (60 %) consisted of fish with lengths of 39-43 cm; fish below 33 and over 47 cm constitued only 4.5 %. The difference between mean length of males and females was 1.3 cm.

Mean lengths of pollock by sex in study areas in 1991 are the following:

	Bering Sea	Okhotsk Sea
males	49.9 cm	40.1 cm
females	50.4 cm	41.4 cm
m & f	50.2 cm	40.9 cm

Comparing length distributions of pollock from the two areas one may notice that the curves have a dicisievly single-peak distribution and are similar. Mean lengths of pollock from the Bering Sea were greater by over 9 cm than in fish from the Okhotsk Sea.

A G E C O M P O S I T I O N

The age composition of the exploited stocks differed considerably in the two areas.

In the international waters of the Bering Sea 4- to 23-year-olds were present in the stock, with the oldest and the youngest age groups represented by only single specimens. Most numerous were 13-year old pollock (year class of 1978); they constitued 22 % of the population occuring in this area (Fig.4,5) and fish aged 12 and 14 - 12 and 11 % of the population, respectively.

In the international waters of the Okhotsk Sea 1- to 18-year-olds were present. Young fish aged 5 and 6 years (year classes of 1986 and 1985) predominated; they constitued 26 and 42 % of the population, respectively (Fig.4,5).

Mean age of pollock in the two areas was the following:

	Bering Sea	Okhotsk Sea
males	12.3	6.3
females	10.7	6.1
m & f	11.6	6.2

The considerable difference in mean age between males and females from the Bering Sea is a result of the large abundance of females from the 1983 and 1984 year classes.

G R O W T H R A T E

The results of analyses of mean lengths of fish in individual age-groups exhibit considerable differences between the stocks of pollock inhabiting the two areas (Table 1). Mean lengths of pollock from the international waters of the Bering Sea were larger in all age-groups between 5 and 15 years than those in fish from the Okhotsk Sea.

Growth rate curves calculated on mean lengths in subsequent years of life point to considerable differences between the two areas (Fig.6,7). The calculated values of the von Bertalanffy's equation parameters have the following form:

	Bering Sea			Okhotsk Sea		
	males	females	m & f	males	females	m & f
L_{inf}	51.2	54.3	52.6	44.5	48.4	45.6
K	0.3293	0.2814	0.3031	0.4712	0.3659	0.4357
t_o	0.0096	0.0062	0.0083	-0.1237	-0.2051	-0.1393

The growth of pollock from the Bering Sea is slower than that in fish from the Okhotsk Sea. Approximately at age of 9 years, at a length of about 50 cm, growth is arrested and in later years length increments are insignificant. In the Okhotsk Sea the growth of pollock in the first years of life is faster, but at the age of about 7 years it reaches an almost asymptotic length and its further growth is arrested.

Confidence limits for the L_{inf} and K parameters of the von Bertalanffy's equation are different for fish from these two areas (Fig.8,9). Only for females, the confidence limits of parameter K overlap for the range of 0.28 to 0.30.

The tested difference between mean lengths of fish in the same age-group turned out to be significant for the populations studied at probability $p < 0.001$, with the exception of age-group 15, for which probability $p < 0.01$. Testing mean lengths separately for males and females showed that the differences are insignificant for males age-group 5 and for females age-group 12. This may be explained by the large difference in abundance of tested fish between the Bering and Okhotsk Sea.

D I S C U S S I O N

A comparison of length and age structure of pollock stocks in the international waters of the Bering and Okhotsk Sea reveals distinct differences between these two stocks. Genetic, morphometric and meristic studies (Iwata., 1975 Bakkala et al, 1983) suggested that the stocks of the Bering and Okhotsk Sea do not mingle. However, within these stocks there is a number of isolated spawning

populations.

In the Bering Sea, despite expending in recent years a large research potential, the structure of the pollock stock was not clearly defined (AFSC proc. Rep. 91-06, 1991). The greatest controversy surrounds the origin of the pollock stock from the international waters, where current investigation are centred. Length and age composition, growth rate of pollock from the international waters differ considerably from those of pollock inhabiting the shelves of the Bering Sea (Dawson 1988,1990).

As regards the Okhotsk Sea ,there is no agreements either as to the number of pollock stocks inhabiting this sea. Iwata (1975) distinguishes six stocks, while Fadiejew (1987) distinguishes five spawning stocks only in the northern part of the sea. In this case, just as with respect to the Bering Sea, there is no certainty from which stock fish taken for examination came. Bakkala (1983) presents great susceptibility of spawning stocks to environmental changes and the size of the spawning stock. Such situation had probably taken place in the international waters of the Bering Sea, where due to very intensive exploitation of the pollock stock distinct changes in its growth rate occured (Janusz 1991), mostly as a result of a decrease in feeding competition.

The differences in the structure and growth of pollock from the international waters of the Bering and Okhotsk Sea, presented in this paper, cannot be treated as the only determinants of independent stocks.

It may be said, however, that there are significant differences in the growth of pollock between these two areas expressed by parameters L_{inf} and K of the von Bertalanffy's equation, both for males and females. This is confirmed also by significance tests between mean lengths of fish in the same age-group.

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Table 1. Mean length at age and test for hypotheses concerning the differences between mean lengths of walleye pollock from the international waters of the Bering and Okhotsk Sea in 1991

MALES

	Bering Sea			Okhotsk Sea				
age	mean length	N.o.	variance	mean length	N.o.	variance	t	Z
5	40.13	23	2.29	38.84	188	2.48	-	
6	43.47	83	4.10	41.18	183	2.77		p<0.001
7	45.83	120	3.84	43.10	67	2.45		p<0.001
8	47.94	129	3.31	44.35	46	2.05		p<0.001
9	49.10	115	4.51	45.00	22	5.09	p<0.001	
10	49.69	100	3.03	45.45	20	4.05	p<0.01	
11	49.52	144	4.39	46.21	19	4.27	p<0.05	
12	49.41	162	3.97	45.67	18	2.89	p<0.05	
13	49.48	352	2.93	45.08	24	3.08	p<0.001	
14	49.83	166	3.21	46.35	26	5.69	p<0.001	
15	49.45	20	2.75	45.45	11	2.98	p<0.001	

FEMALES

	Bering Sea			Okhotsk Sea				
age	mean length	N.o.	variance	mean length	N.o.	variance	t	Z
5	40.19	37	2.64	39.35	173	2.97		p<0.01
6	43.29	97	5.13	42.33	315	3.24		p<0.001
7	46.28	179	5.25	44.35	132	3.76		p<0.001
8	49.36	149	6.42	45.70	50	5.13		p<0.001
9	51.20	120	6.49	46.86	35	7.15		p<0.001
10	52.27	106	7.82	48.48	31	5.54		p<0.001
11	52.29	96	7.79	49.14	21	7.17	p<0.001	
12	51.99	124	4.78	50.53	15	13.45	-	
13	52.41	244	4.93	49.76	17	7.24	p<0.001	
14	52.56	119	3.88	50.15	27	6.57	p<0.001	
15	54.38	8	2.73	50.60	15	15.84	p<0.01	

MALES & FEMALES

	Bering Sea			Okhotsk Sea			
age	mean length	N.o.	variance	mean length	N.o.	variance	Z
5	40.12	60	2.41	39.08	361	2.78	p>0.001
6	43.37	180	4.67	41.91	498	3.38	p>0.001
7	46.10	299	4.74	43.93	199	3.66	p>0.001
8	48.70	278	5.48	45.05	96	4.11	p>0.001
9	50.17	235	6.62	46.14	57	7.17	p>0.001
10	51.04	206	7.12	47.29	51	7.15	p>0.001
11	50.63	240	7.59	47.75	40	7.94	p>0.001
12	50.53	286	5.96	47.88	33	13.56	p>0.001
13	50.68	596	5.83	47.02	41	10.12	p>0.001
14	50.97	285	5.30	48.28	53	9.75	p>0.001
15	50.86	28	7.69	48.42	26	16.86	p>0.01

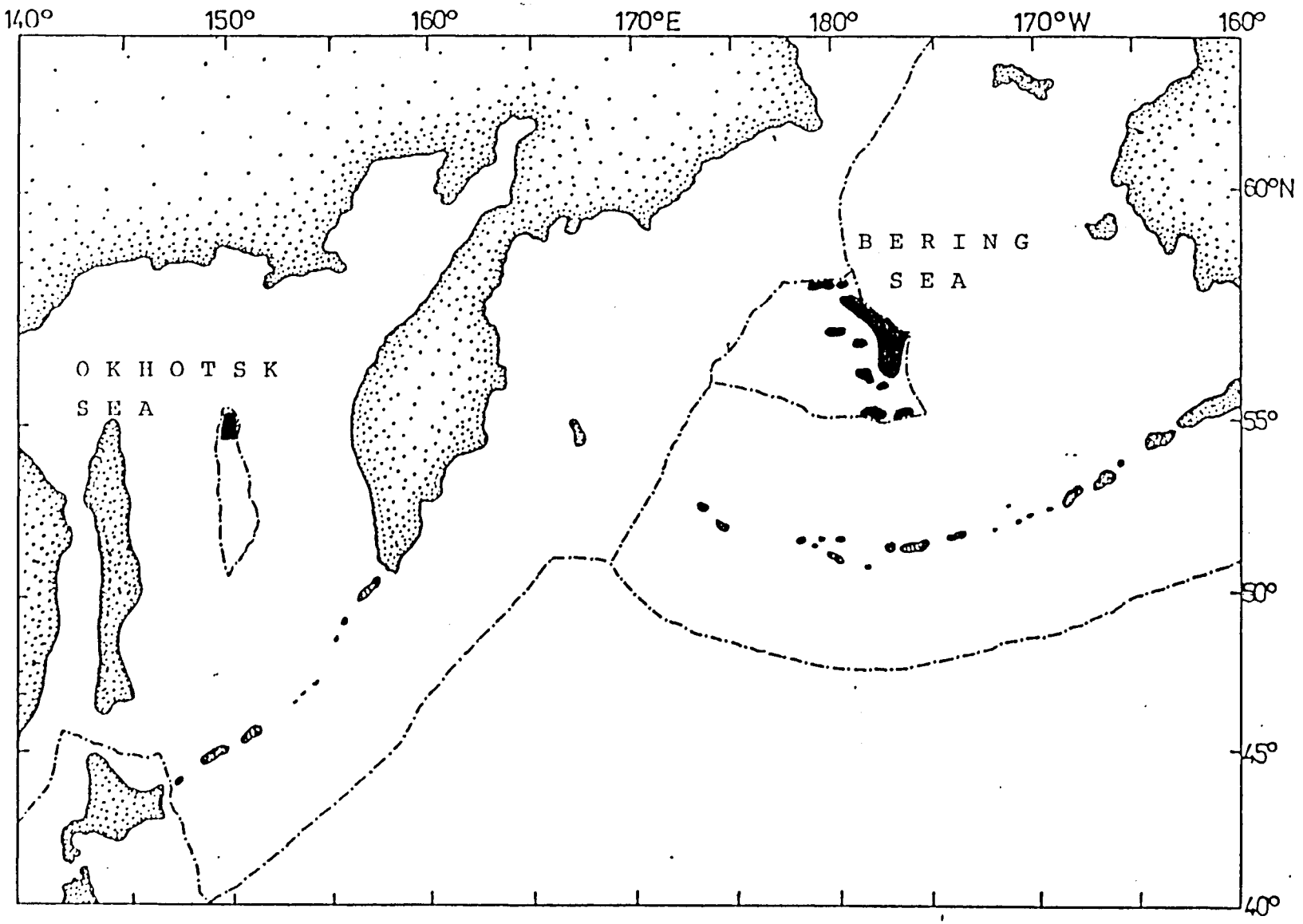


Fig. 1. Sampling areas of walleye pollock in the international waters of the Bering and Okhotsk Sea in 1991.

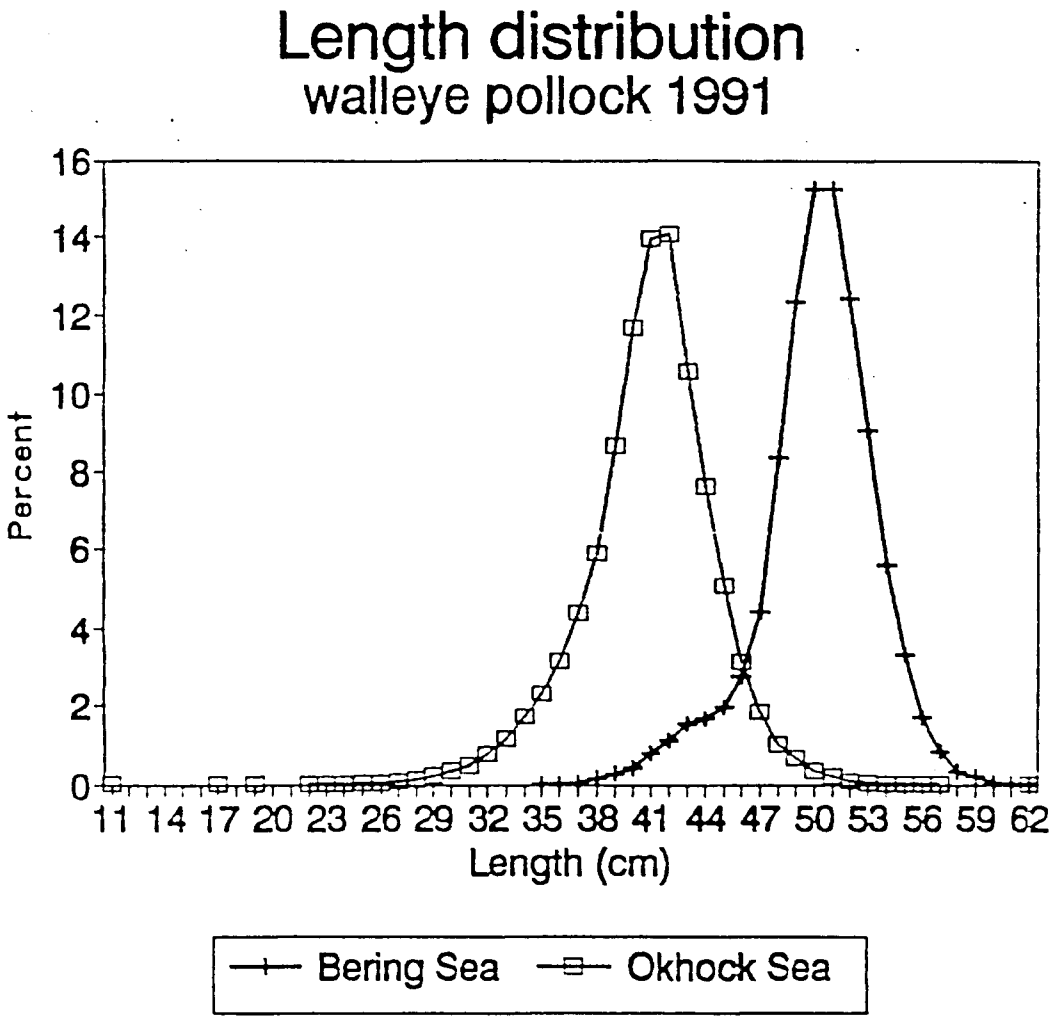
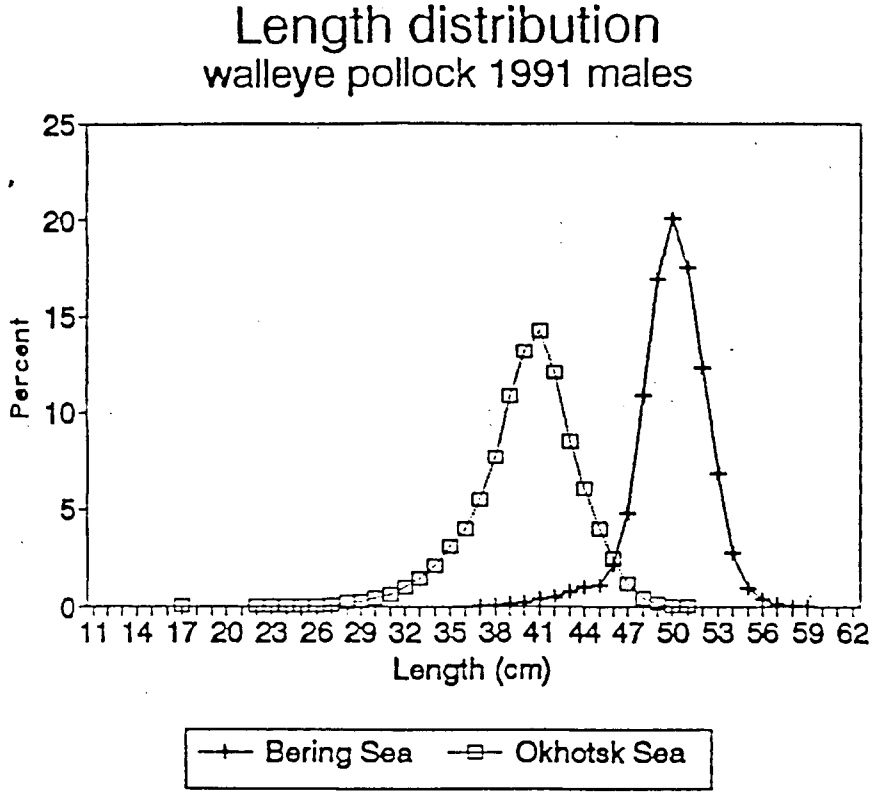


Fig. 2. Length distribution of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991 (males and females).

a)



b)

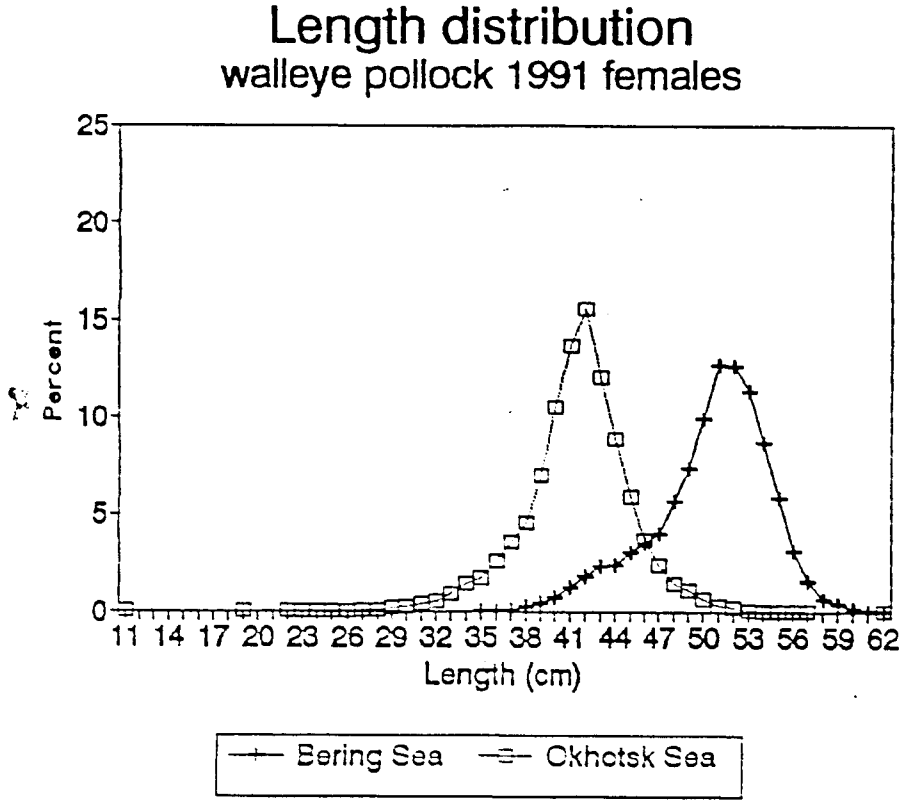


Fig. 3. Length distribution of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991

a) males

b) females

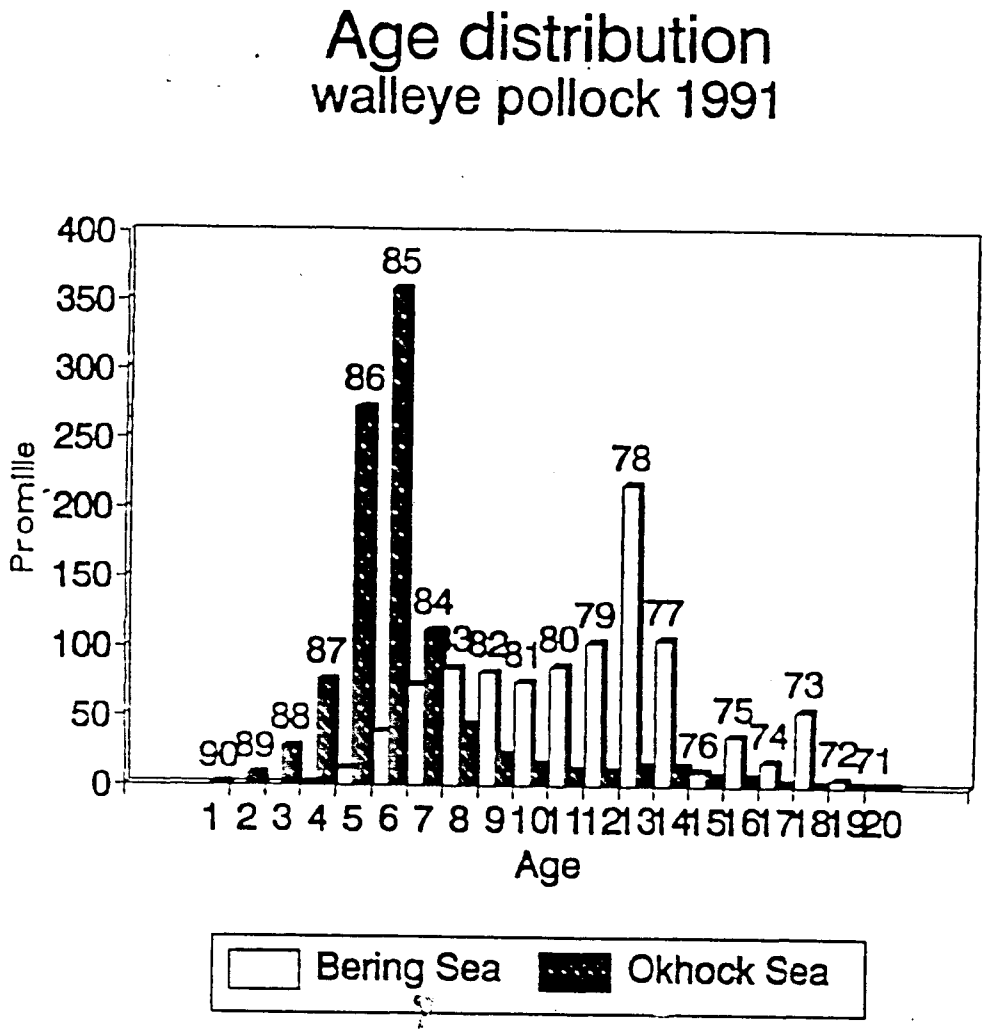
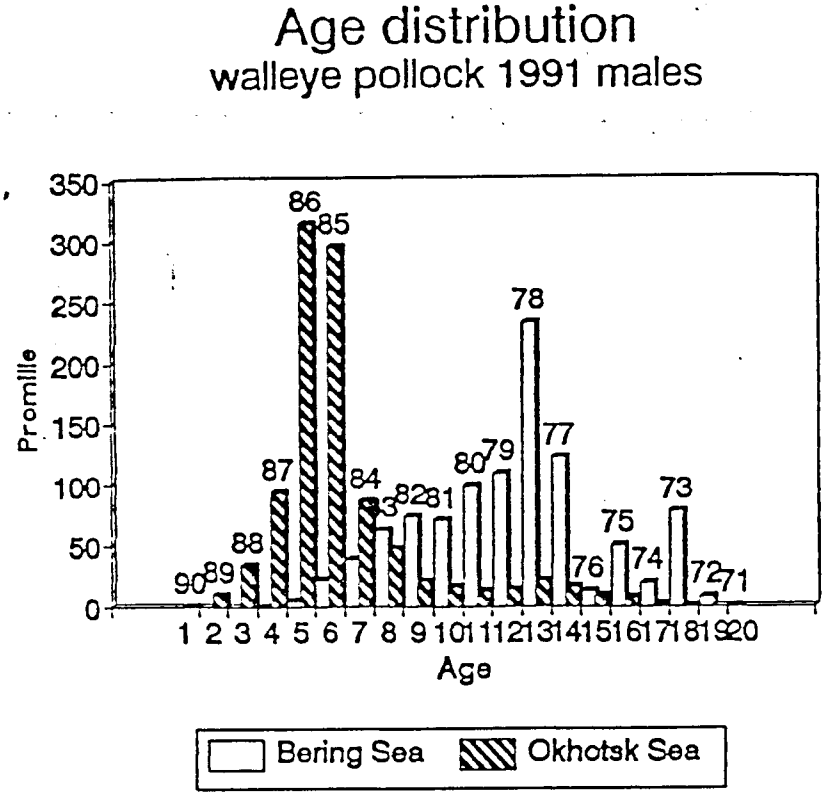


Fig. 4. Age distribution of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991 (males and females)

a)



b)

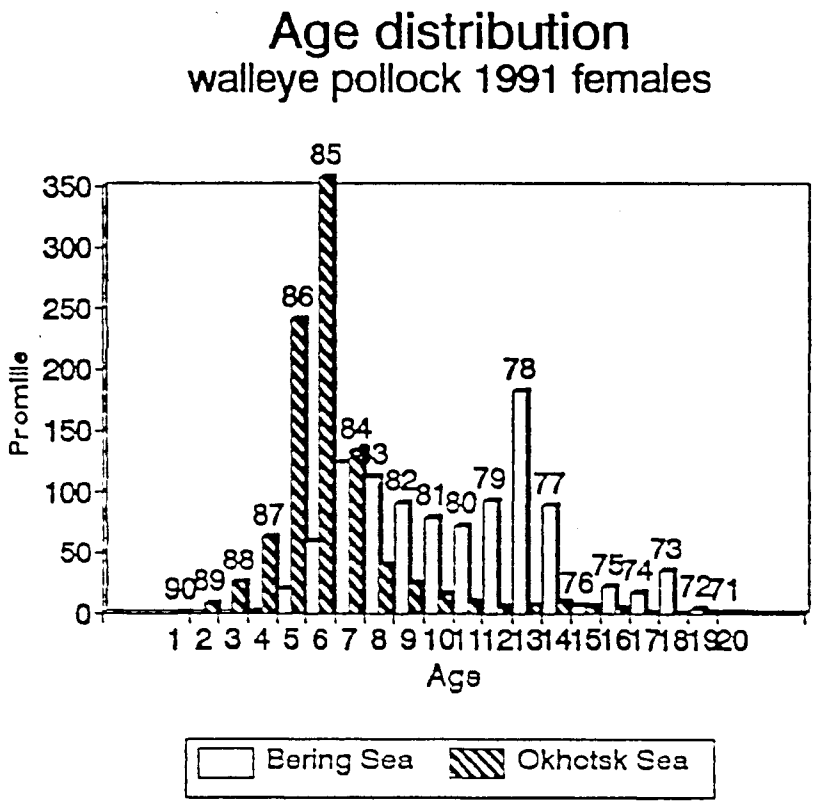


Fig. 5. Age distribution of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991

a) males

b) females

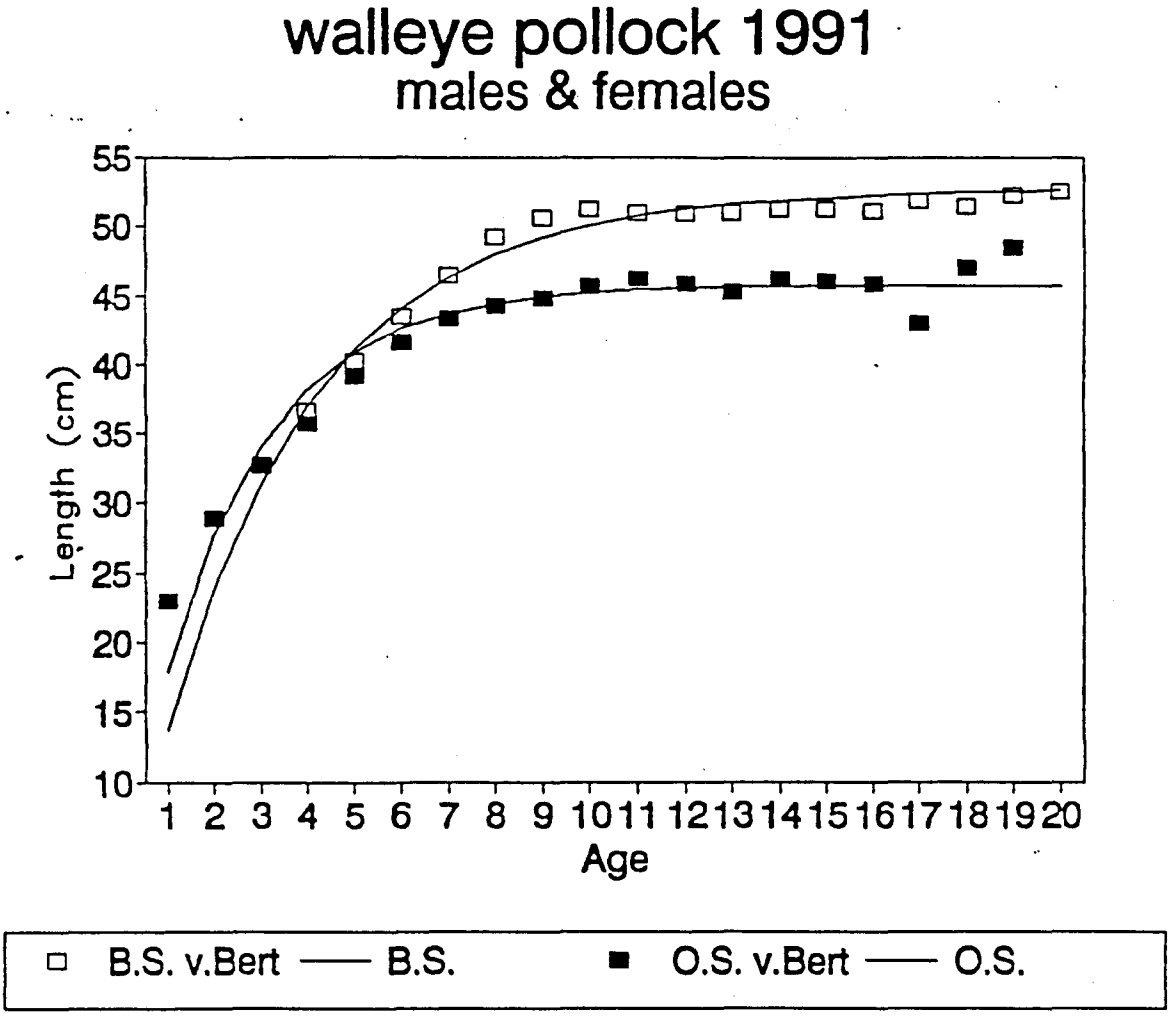
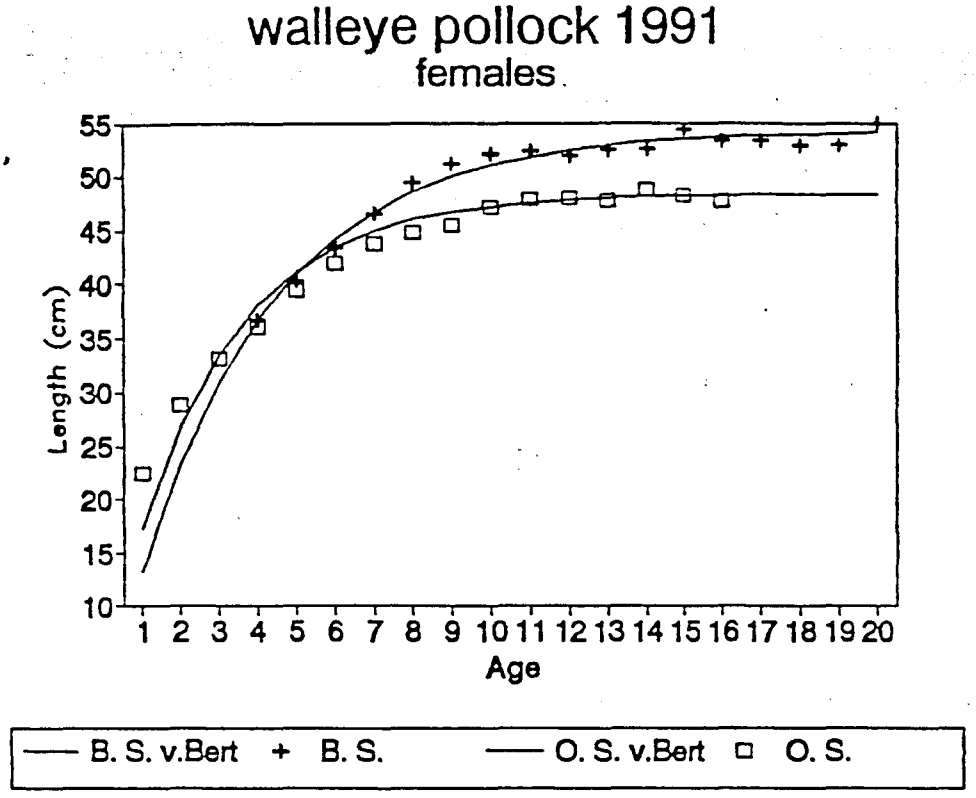


Fig. 6. Growth curves of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991 (males and females)

a)



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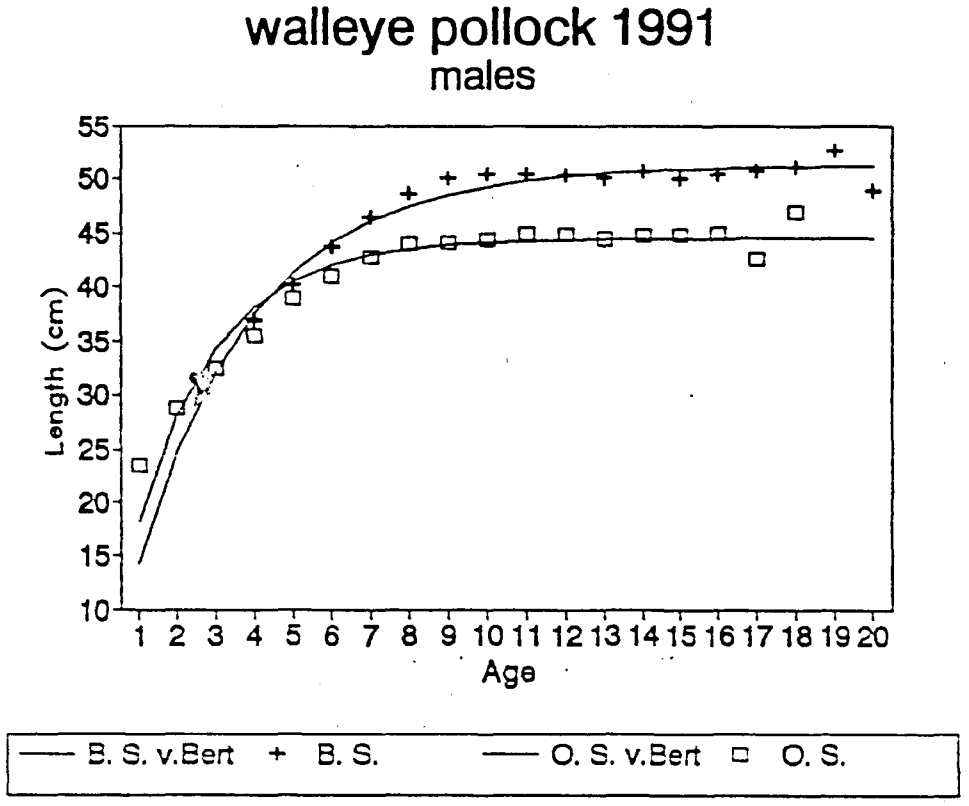

Fig. 7. Growth curves of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991

a) females

b) males

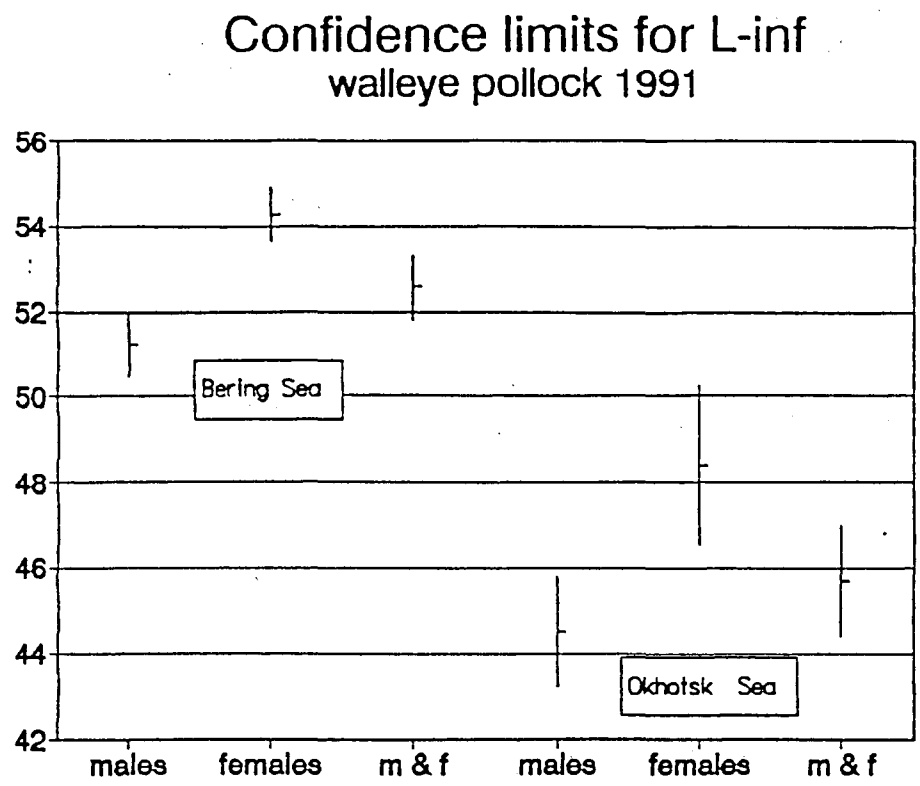

Fig. 8. Confidence limits for L-inf of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991

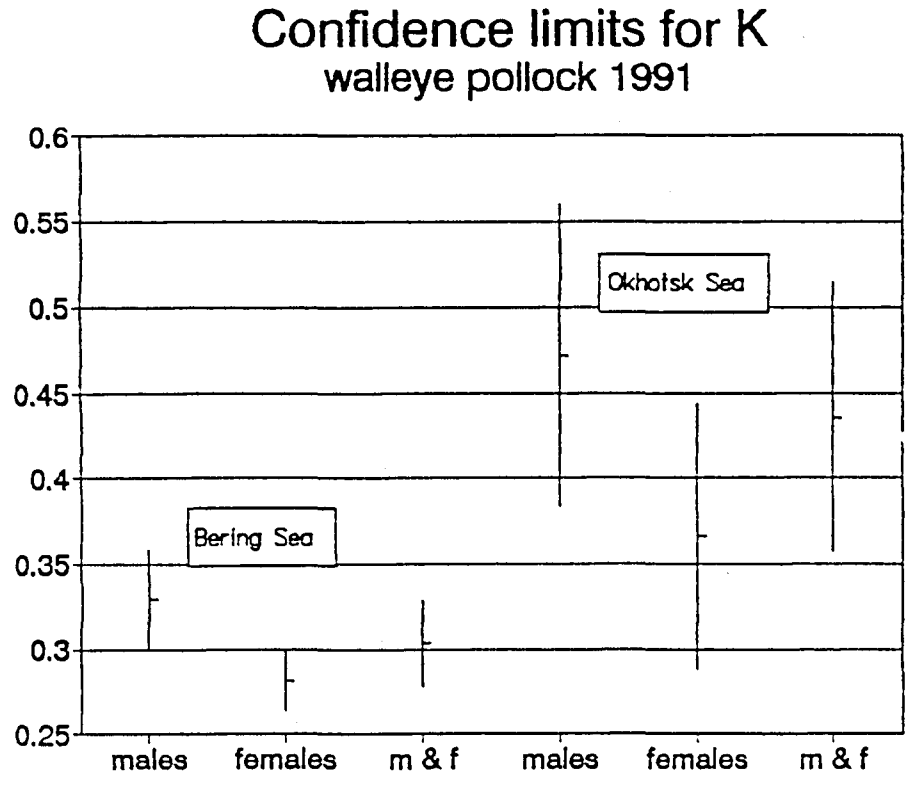

Fig. 9. Confidence limits for K of walleye pollock caught in the international waters of the Bering and Okhotsk Sea in 1991