Walleye pollock (*Theragra chalcogramma*) spawning in the Okhotsk Sea waters off the north Kuril Islands and south-western Kamchatka

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Abstract

Long-term analysis of ichtyoplankton surveys and growth data indicates that the Okhotsk Sea waters off the north Kuril Islands and south-western Kamchatka is the traditional spawning region of walleye pollock of east Kamchatka origin. In this area the spawning "peak" occurs later than in western Kamchatka waters from the end of April to the beginning of May. So, it is necessary to conduct an additional ichtyoplankton survey at the end of April in order not to underestimate part of the walleye pollock stock.

Introduction

Walleye pollock is one of the most numerous fish species in the North Pacific and is a very important fishery resource. The Okhotsk Sea is a main pollock fishery region. In 1992 the total catch was about 2.7 million metric tons. In the last 5 years it has averaged 0.6 million metric tons.

A great deal of attention is always given to studying walleye pollock biology, stock dynamics, and especially reproduction because:

- Spawning conditions define the efficiency of reproduction leading to generation abundance;
- The walleye pollock fishery in the Okhotsk Sea occurs during the prespawning and spawning periods when the pollock form dense aggregations accessible for fishing;
- Stock estimations and total allowable catch forecasts are based on egg survey data obtained in the period near the spawning peak.

In the eastern part of the Okhotsk Sea ichtyoplankton surveys have been conducted annually by KamchatNIRO since 1972, and from TINRO-Center since 1982. Standard stations grids are used.

The spawning grounds in the Okhotsk Sea have been known for a long time (Fadeev, 1987; Shuntov *et al.*, 1993; Zverkova, 2003) and are located (Fig. 1, counterclockwise from bottom) in the waters of the south Kuril Islands and Hokkaido island; in the waters adjacent to western Kamchatka, including Shelikhov Gulf; in the northwestern part of the Okhotsk Sea; and nearby north-east Sakhalin island.

In the northern part the Okhotsk Sea the center of walleye pollock reproduction is located on the west Kamchatka shelf. In this area, time and location of spawning vary from year to year depending on the temperature conditions (Fadeev and Ovsyannikov, 2001; Varkentin *et al.*, 2001). Reproduction continues from January till July. The average peak of spawning in this region is from the end of March to the beginning of April (Fadeev, 1987).

It is interesting to note that in the beginning of April in the area to the south of 52°N, walleye pollock egg catches are minimal (2–3 eggs/m^2) despite the high concentrations of mature fish there. Is it probable that in this area spawning proceeds later than in the western Kamchatka waters? Some researchers (Fadeev and Ovsyannikov, 2001) have noticed that in the south-western Kamchatka waters usually two spawning peaks, so-called "spawning waves", occur: in the beginning and at the end of April.

Could it be that walleye pollock spawn in the Okhotsk Sea waters off the north Kuril Islands too? Having analyzed archival materials from 1961 to the present, we found that ichtyoplankton surveys have been made here only in the end of March, or in July. These and other questions are the subject of our research.

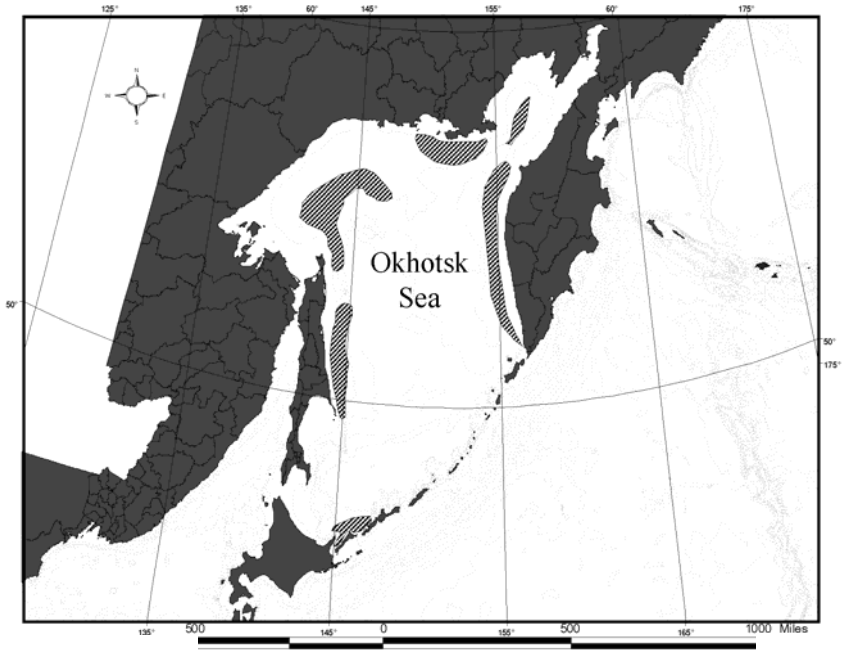

Fig. 1 Walleye pollock spawning grounds (hatched pattern) in the Okhotsk Sea.

Data and Methods

This work is based on ichtyoplankton surveys conducted in 2007–2008 in the Okhotsk Sea waters off the north Kuril Islands and near western Kamchatka (Table 1, Fig. 2).

An ichtyoplankton Conic Net (ICN-80) was used. Egg collections were obtained from 300 m depth to the surface or from bottom to the surface, if depth was less than 300 m. The net was lifted at a speed 0.5–0.6 m/s.

Stages of development of walleye pollock eggs were defined by the Rass scale (Rass and Kasanova, 1966). Total embryogenesis duration was calculated using the equation of Zolotov *et al.* (1987):

$$T = 38.9e(-0.156\ t).$$

Stage I was 20% of embryogenesis duration (Gorbunova, 1954). Total egg production for the entire spawning season was counted by the Gauss curve (Buslov *et al.*, 2004). In addition, we analyzed data from ichtyoplankton surveys made in western Kamchatka waters later than April 20 between 51° and 58°N latitudes (Table 2).

Table 1 Period and number of stations where ichtyoplankton surveys were conducted in the Okhotsk Sea waters off the north Kuril Islands and near western Kamchatka in 2007–2008.

Region	Period	Number of stations
Western Kamchatka	April 12–18, 2007	72
	April 26–28, 2008	38
Okhotsk Sea waters off north Kuril Islands	April 29–30, 2007	17
	April 26–28, 2008	38

Table 2 Period and number of stations where the ichtyoplankton surveys were conducted in western Kamchatka waters later than April 20.

Year	Period	Number of stations
1978	April 24–30	68
1983	April 24–May 3	89
1984	April 24–May 9	125
1985	May 16–25	111
1986	May 26–June 6	109
1992	May 12–23	99
2001	April 25–30	80
2001	July 2–30	56
2002	April 23–May 9	105

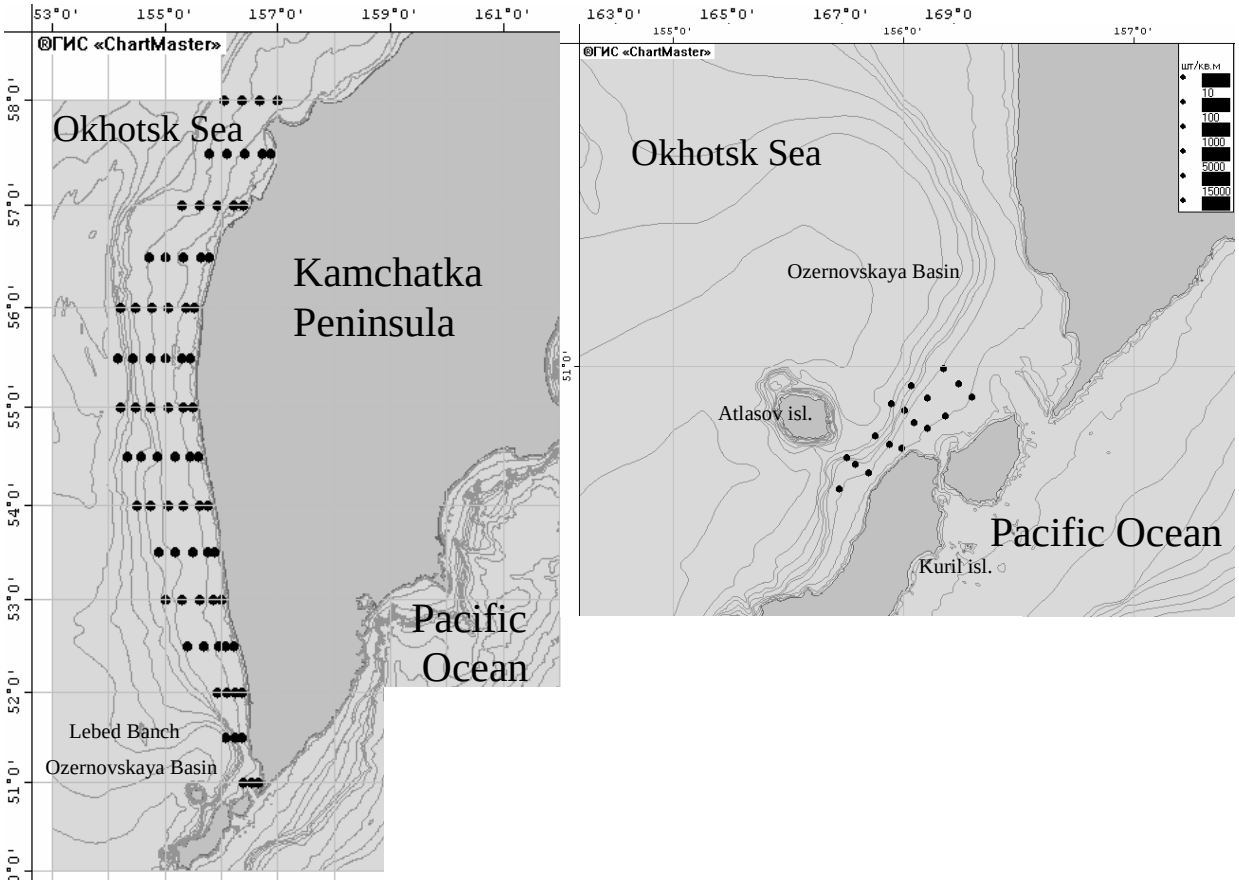

Fig. 2 Standard ichtyoplankton station grid (left) in western Kamchatka waters (from 1972) and additional stations (right) in Okhotsk Sea waters off the north Kuril Islands (from 2007).

Results and Discussion

Relative centers of spawning were determined by the concentrations of stage I eggs. In the western Kamchatka waters, the duration of stage I eggs varies from 7 to 10 days, depending on temperature (Zolotov *et al.*, 1987). Most of the walleye pollock eggs and larvae develop within a quasi-stationary current circulation system created by the West Kamchatka and Compensate Currents (Karmanov, 1982; Vasilkov and Glebova, 1984; Zolotov, 1991; Varkentin *et al.*, 2001).

In the middle of April 2007, egg distribution in the western Kamchatka waters appeared typical. The main concentrations of stage I eggs were found between 53° and 56°N latitudes. The relative center of spawning was at 53°N latitude at a depth of 90 m (Fig. 3). We consider that had the survey been made after the spawning peak, more than 30% of all eggs would be at stage II (Table 3). It is worth noting that south of the research area, egg collections were minimal: about 10 eggs/m^2 despite the high concentrations of mature fish.

An additional survey conducted in the north Kuril Islands area at the end of April shows that there was intensive spawning in this region (Fig. 4; Table 3). Concentrations of stage I eggs reached 12,000 eggs/m^2 at a depth of 80 m. It is the first time that such high egg concentrations have been found in this area.

In 2008 walleye pollock spawning in the Okhotsk Sea waters off the north Kuril Islands and south-western Kamchatka waters also occurred at the end of April, but the area of highest egg concentrations was situated further to the north compared to 2007 (Fig. 5, Table 3).

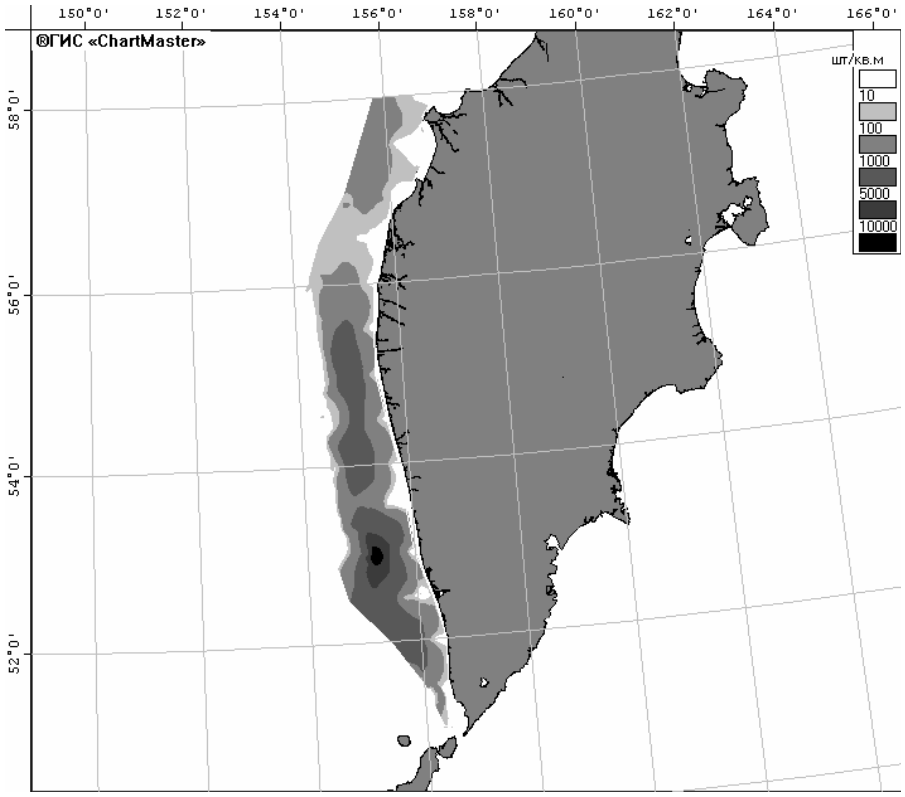

Fig. 3 Walleye pollock eggs on I stage distribution (eggs/m^2) in the west Kamchatka waters during the period April 12–18, 2007.

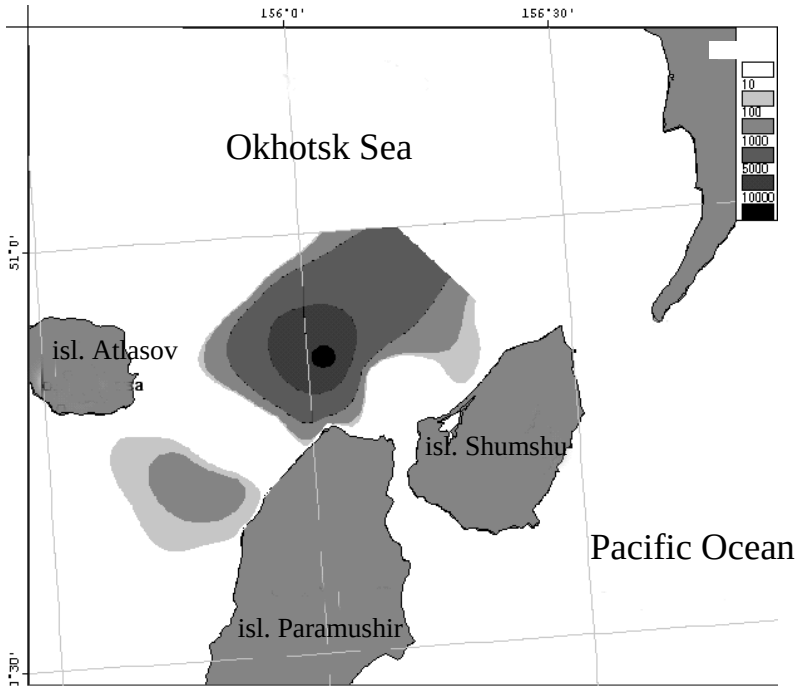

Fig. 4 Stage I walleye pollock egg distribution (eggs/m^2) in the Okhotsk Sea waters off the north Kuril Islands during the period April 29–30, 2007.

Table 3 Walleye pollock eggs composition (%) in 2007–2008.

Region	Average survey date	Stage I	Stage II	Stage III	Stage IV
	2007				
Western Kamchatka	April 15	56.6	31.2	11.4	0.8
Okhotsk Sea waters off the north Kuril Islands	April 30	87.7	12.2	0.1	+
	2008				
Okhotsk Sea waters off the north Kuril Islands and south-western Kamchatka waters	April 27–28	18.8	72.3	8.3	0.7

Note: + indicates less than 0.01%

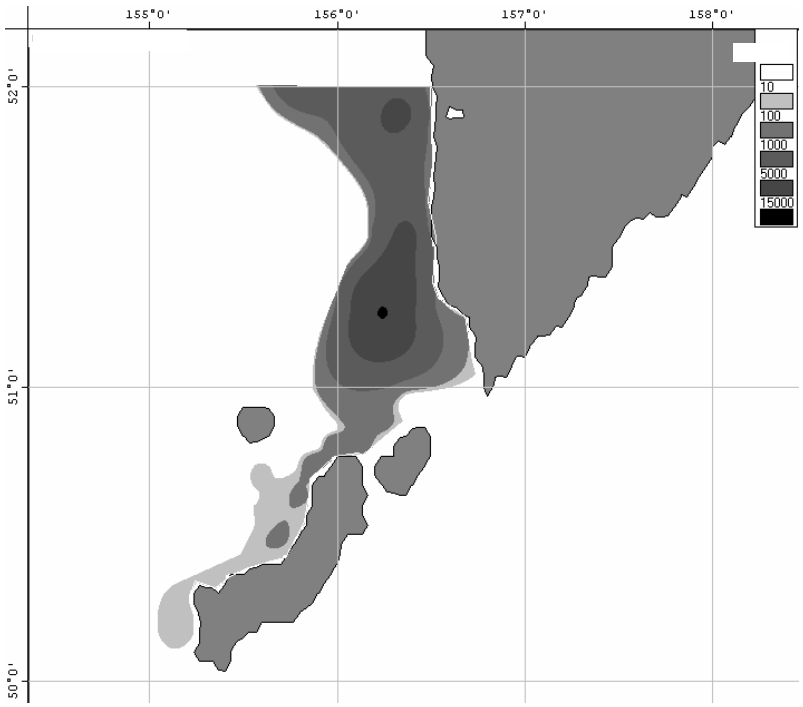

Fig. 5 Stage I walleye pollock egg distribution (eggs/m^2) in the Okhotsk Sea waters off the north Kuril Islands and in the south-western Kamchatka waters during the period April 26–28, 2008.

How much spawning occurs regularly in nearby south-western Kamchatka? We analyzed data of ichtyoplankton surveys made in the western Kamchatka waters later than April 20 for the period 1978 to 2002. Figure 6 clearly shows that in all years there was intensive walleye pollock spawning here. Considering their high migratory activity, it is quite probable that pollock from elsewhere spawn in this region.

The nearest walleye pollock spawning grounds are situated in the south-eastern Kamchatka and north Kuril Islands waters (Fig. 7) which are inhabited by the East-Kamchatka population (Buslov and Tepnin, 2007). Intensive spawning occurs at the end of April to the beginning of May, which is approximately at the same time as at south-western Kamchatka. There appear to be no geographical barriers to walleye pollock migrations from this region to the Okhotsk Sea. They can migrate into the Okhotsk Sea through the north Kuril Islands straits with the East Kamchatka Current (Fig. 8).

For proof of this hypothesis, we made a size-at-age analysis because it is known that the rate of pollock growth in the eastern part of the Okhotsk Sea is lower than in the east Kamchatka area (Buslov, 2003). A selection was made of 6-, 7-, 8-year-old

mature fishes caught in three different regions in the period from February until April:

1) To the north from 53°N in the western Kamchatka waters;
2) To the south from 53°N in Okhotsk Sea waters off the north Kuril Islands and in the south-western Kamchatka waters;
3) To the south from 52°N in Pacific Ocean waters off the north Kuril Islands and in the south-eastern Kamchatka waters.

As noted in Figure 9, the size structure of pollock is different by regions, and is connected with distinct rates of growth. The southeast region (3) has the largest average length-at-age pollock, the western Kamchatka region (1) has the smallest average size, and south-western Kamchatka (2) is intermediate (Table 4). Differences were statistically significant among all regions within age class, except between regions 2 and 3 for 8-year olds (Table 5).

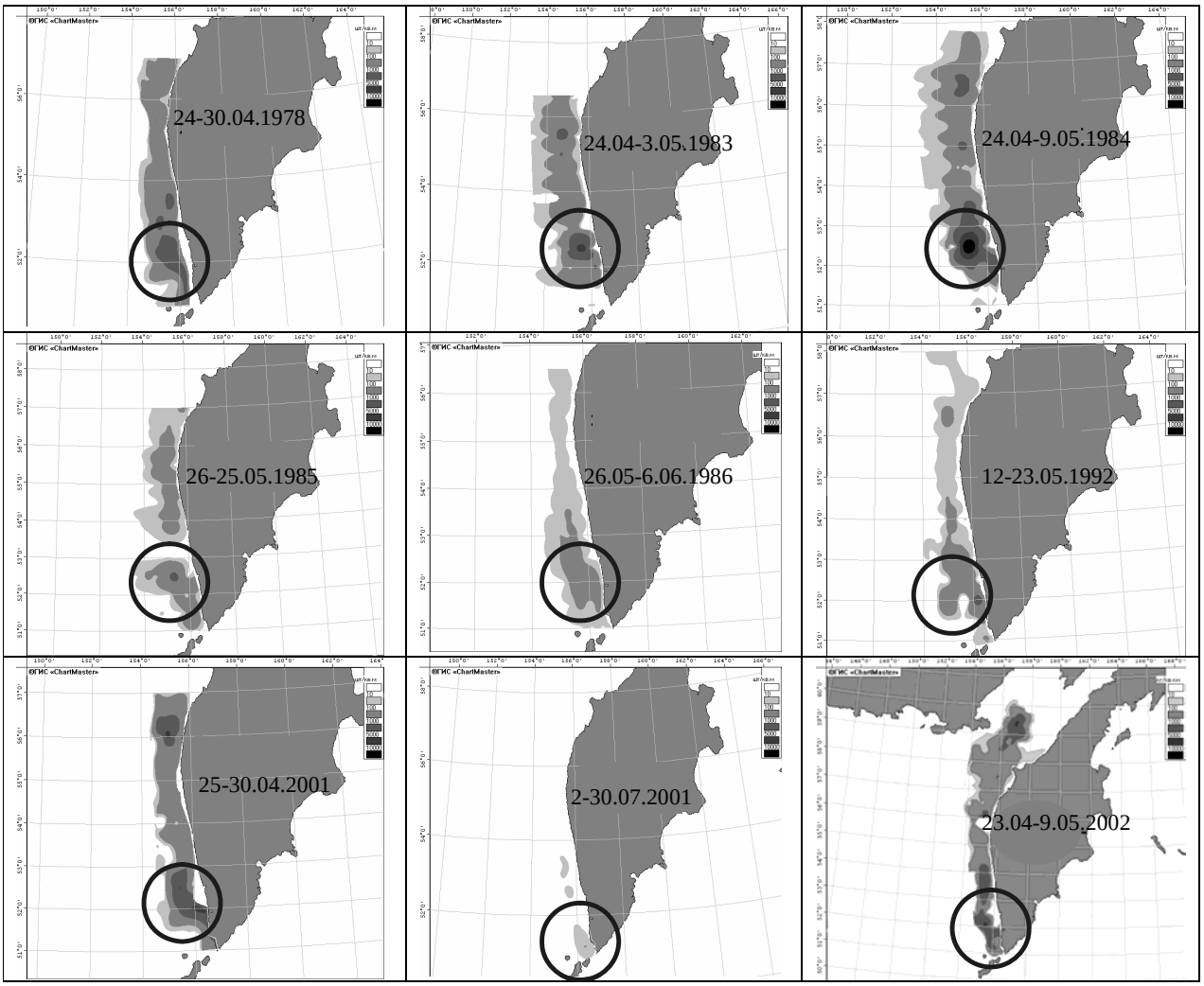

Fig. 6 Interannual stage I walleye pollock egg distribution (eggs/m^2), indicated by the circles, in the south-western Kamchatka waters later April 20 for the period from 1978– 2002.

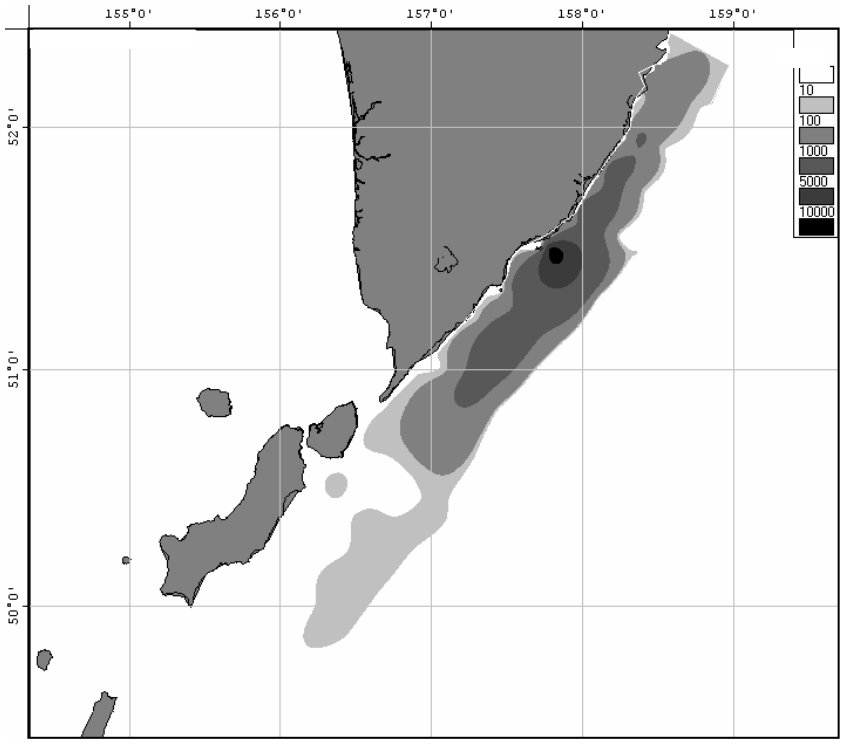

Fig. 7 Stage I walleye pollock egg distribution (eggs/m^2) in the waters adjacent to south-eastern Kamchatka and north Kuril Islands April 25–27, 2007.

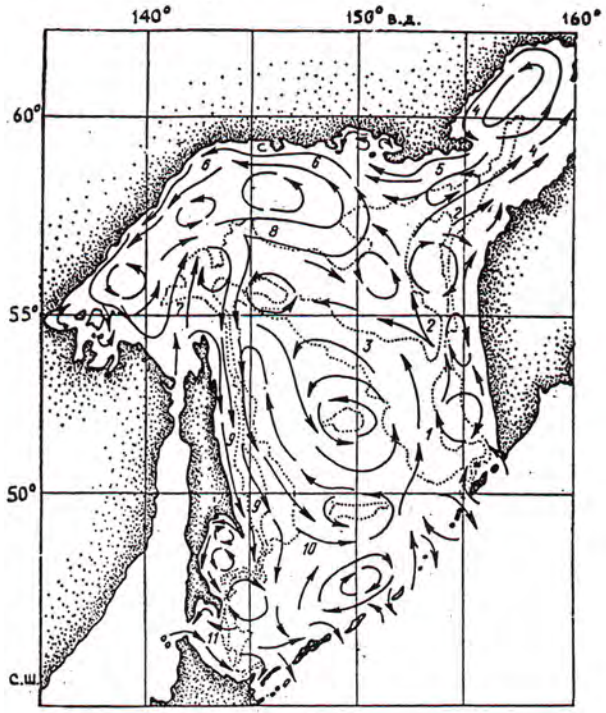

Fig. 8 General currents scheme in the Okhotsk Sea and Kuril Islands area (Chernyavsky *et al.*, 1993). 1 – West Kamchatkan Current, 2 – Northern Branch, 3 – Median Current, 4 – Penzhin Current, 5 – Yamskoye Current, 6 – Northern Okhotsk Current, 7 – Amursky Current, 8 – Northern Okhotsk Counterflow, 9 – East Sakhalin Current, 10 – Northeastern Current, 11 – Soya Current, 12 – East Sakhalin Counterflow.

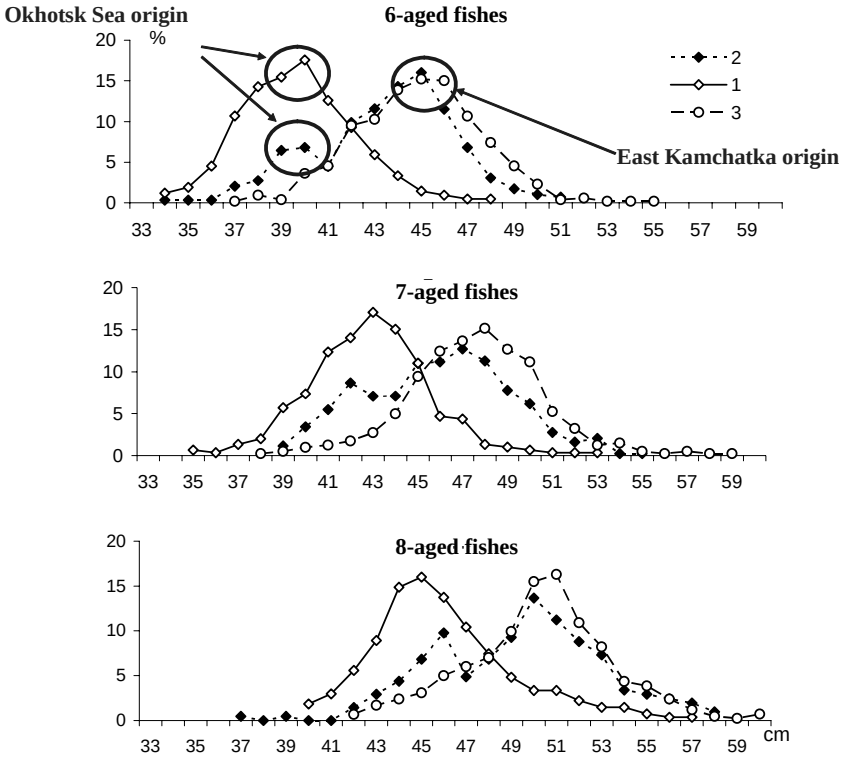

Fig. 9 Walleye pollock size composition at ages 6 to 8 years by statistical region from 2005–2007.

Table 4 Average walleye pollock length (cm) at ages 6 to 8 in February–April for the period 2005–2007, by statistical regions.

	Region								
	1			**2**			**3**		
	Age (year)			**Age (year)**			**Age (year)**		
	6	7	8	6	7	8	6	7	8
N	421	299	269	294	438	205	526	614	414
M	39.21	42.36	45.49	42.75	45.29	48.84	44.40	46.56	49.20
δ	2.51	2.75	3.20	3.03	3.25	3.77	2.73	3.09	3.65

Notes: 1 – western Kamchatka, 2 – south-western Kamchatka, 3 – south-eastern Kamchatka
N – sample size, *M* – average length (cm) , δ – standard deviation

Table 5 Values of Student *t*-criterion in comparison analysis.

	6-year olds			**7-year olds**			**8-year olds**		
	Region			**Region**			**Region**		
Region	1	2	3	1	2	3	1	2	3
1	–	17.02	30.53	–	12.79	20.00	–	10.47	13.59
2	–	–	7.86	–	–	6.41	–	–	1.15

Notes: 1 – western Kamchatka, 2 – south-western Kamchatka, 3 – south-eastern Kamchatka
Correlation is significant at $p < 0.05$ for underlined values.

Despite the long period of walleye pollock study in the Okhotsk Sea, we are just now learning something new about its biology. It is necessary to improve the ichtyoplankton survey method in view of this new knowledge by conducting a second survey in the Okhotsk Sea waters off the north Kuril Islands and in south-western Kamchatka (to the south of 53°N) at the end of April. Otherwise, part of the walleye pollock stock spawning in this area later than in the west Kamchatka waters will be underestimated.

By our assessment, the spawning stock biomass in 2007 in the Okhotsk Sea waters off the north Kuril Islands was about 45,000 metric tons. This allows us to recommend about an additional 9,000 metric tons for a coastal fishery by Danish seine vessels. It is very important for coastal fishery development in this region.

Conclusions

Okhotsk Sea waters off the north Kuril Islands and south-western Kamchatka area is the traditional spawning region of walleye pollock of east Kamchatka origin. In this area a pollock spawning "peak" occurs later than in the western Kamchatka waters at the end of April–beginning of May.

It is necessary to conduct a second ichtyoplankton survey in Okhotsk Sea waters off the north Kuril Islands and in the south-western Kamchatka waters at the end of April. New data will give us the means to develop the walleye pollock fishery in the south-western Kamchatka waters.

References

Buslov, A.V. 2003. Walleye pollock growth and size-age composition of its populations. Dissertation abstract, Candidate of Biol. Science, TINRO, Vladivostok, 24 p.

Buslov, A.V. and Tepnin, O.B. 2007. Walleye pollock spawning in the north Kuril Islands area and south-eastern Kamchatka waters. Investigations of the marine resources nearby Kamchatka peninsula and in the North Pacific area. KamchatNIRO Publishers. Petropavlovsk-Kamchatsky I. 8.

Buslov, A.V., Tepnin, O.B. and Dubinina, A.Y. 2004. Some peculiarities of walleye pollock spawning and embryogenesis in the east Kamchatka waters. *TINRO News* **138**: 282–298.

Chernyavsky, V.I., Zhigalov, I.A. and Matveev, V.I. 1993. Oceanographic bases for the high productivity zones in the Sea of Okhotsk. Seas hydrometeorology and hydrochemistry. "Seas" project. V. IX. Sea of Okhotsk. I. 2. Hydrochemical Conditions and Oceanographic Basis of Biology Productivity. Hydrometeo Press, St. Peterburg, pp. 157–160.

Fadeev, N.S. 1987. Walleye pollock spawning time and location in the northern part Sea of Okhotsk. Walleye Pollock Population Structure, Stock Dynamics and Ecology. TINRO, Vladivostok:, pp. 5–22.

Fadeev, N.S. and Ovsyannikov, E.E. 2001. Walleye pollock distribution and spawning dynamics in the northern part Sea of Okhotsk in winter-spring period. *TINRO News* **128**: 103–124.

Gorbunova, N.N. 1954. Walleye pollock spawning and development. Institute of Oceanography Issues, Vol. 11, pp. 132–195.

Karmanov, G.E. 1982. Some peculiarities of current dynamics during walleye pollock spawning in the west Kamchatka waters. Ecology and spawning conditions of fishes and invertebrates in the Far-Eastern Seas. TINRO, Vladivostok, pp. 3–10.

Lisovenko, L.A. 2000. Reproduction of fishes with interrupt embrioginesys and portion spawning for Walleye pollock nearby west Kamchatka. VNIRO, Moscow, 112 pp.

Rass, T.S. and Kasanova, I.I. 1966. Methodical Guide on Eggs, Larvae and Fry Gathering. Food Industry, Moscow, 42 pp.

Shuntov, V.P., Volkov, A.F., Temnykh, O.S. and Dulepova, E.P. 1993. Walleye pollock in the ecosystems of Far-Eastern Seas. TINRO, Vladivostok, 426 pp.

Varkentin, A.I., Buslov, A.V. and Tepnin, O.B. 2001. Some peculiarities of Walleye pollock spawning and eggs distribution in the west Kamchatka waters. *TINRO News* **128**: 177–187.

Vasilkov, V.P. and Glebova, S.Y. 1984. Factors defined Walleye pollock generations abundance in the west Kamchatka waters. *Ichthyol. Issues* **24**: 561–570.

Zolotov, O.G. 1991. Walleye pollock eggs distribution and drift in the west Kamchatka waters. Investigations and Stock Dynamics of Marine Commercial Fishes in the West Kamchatka Shelf. I. 1. Part 1, Petropavlovsk-Kamchatski, pp. 167–182.

Zolotov, O.G., Kachina, T.F. and Sergeeva, N.P. 1987. Walleye pollock stock estimation in the eastern part Sea of Okhotsk. Walleye Pollock Population Structure, Stock Dynamics and Ecology. TINRO, Vladivostok, pp. 65–73.

Zverkova, 2003. Walleye pollock. Biology, Stock Abundance. TINRO, Vladivostok, 248 pp.