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Feeding of Herring Larvae in the Lower Volga before and after the Construction of the Volgograd Dam

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(Caspian Scientific Research Institute of Marine Fishing and Oceanography; Astrakhan')

Introduction

Hydroelectric power station construction on the Volga has caused a severe deterioration of the spawning conditions of many Caspian fish, particularly migratory fish--herring and sturgeons. Dams have cut off the access of these fish to their usual spawning grounds. A particularly marked reduction in the spawning areas and displacement of them to the lower reaches of the river was brought about by the commencement of operations of the Volgogradskaya Electric Power Station in autumn 1958. Below the Volgograd Dam, during the spawning period, a tremendous number of fish began to accumulate which had been deprived of the opportunity of going further upriver. In connection with this, at the present time as never before, the problem of providing food for the larvae, which previously foraged over a much greater area of the river, has become a pointed one.

The literature on the feeding of Caspian herring larvae is very much limited. L. A. Chayanova (1951) and R. P. Matveyeva (1957a) took up the study of the feeding of young herring in the North Caspian. The only work on the feeding of Caspian herring larvae during the river period of their existence has been the article by A. P. Sushkina (1940). This author determined the daily rations of the larvae of different age groups and the quantity of food necessary for cultivation of young herring from the beginning of active feeding to the age of two months.

Material and Method

The material was collected in 1958-1959 (Table 1) in the section of the river between Volgograd and Astrakhan' at 13 transverse sections (at the villages of Streletskoye, Zam'yany, Seroglazovka, Yenotayevsk, Rybnyy Khutor, Kopanovka, Burunskoye, Vetlyanka, Nikol'skoye, Solenoye Zaymishche, Chernyy Yar, Kamennyy Yar and Svetlyy Yar) in the three summer months, with three stations at each section--two shore stations and one in the middle of the river.

The larvae were caught for 10 minutes with a roe-net 80 cm in diameter and made of No 140 miller's gauze.

In studying the feeding the weight method was used (Zenkevich and Brotskaya, 1931; Bogorov, 1934; Shorygin, 1952).

Table 1

Material on the Feeding of Herring Larvae, Collected in 1958-1959

Время сбора (1)	(2) Число станций		(3) Число вскрытых личинок		(4) Пустые кишечники			
					1958 г.		1959 г.	
	1958 г.	1959 г.	1958 г.	1959 г.	n	%	n	%
(5) Июнь	9	11	206	156	112	54,4	93	59,5
(6) Июль	18	18	887	568	227	25,5	293	51,5
(7) Август	11	18	300	358	95	31,6	193	34,0
(8) Итого	38	47	1393	1082	434		579	

1. time of collection; 2. No of stations; 3. No of larvae dissected; 4. empty intestines; 5. June; 6. July; 7. August; 8. Total.

From each sample 10 specimens of larvae were selected of different size groups. In the division of larvae under 10 mm into groups the interval used between classes was 1 mm; for the larger larvae, 5 mm. The total weights of various size groups were determined. Analysis of the intestinal contents was made individually. In the calculation of the average figures (weight, food, intestinal content indices) attention was given to the larvae with empty intestines, with the exception of the prolarvae.

Simultaneously with the collection of the material on feeding observations were made of the condition of the food supply of the larvae. Samples of plankton were collected with a large Apshteyn net made of No 49 miller's gauze. In all, 415 general zooplankton catches were made.

Food Supply of the Volga Herring Larvae

Herring larvae feed on zooplanktor.

Many investigators have studied the zooplankton of the Volga River. The works of N. L. Chugunova (1918), A. P. Sushkina (1940), V. S. Ivlev (1940), A. T. Dyuzhikov (1955), I. K. Vonokov (1957) and R. P. Matveyeva (1957b) were on the study of the quantity and species composition of the river zooplankton for purposes of determining their importance as food for young fish. However, none of these data is very comparable with the rest or with my 1958-1959 material, either with respect to time or areas of studies made.

As is seen from the data of Table 2, the species composition of the plankton in 1959 remained the same as in 1958, that is, before the construction of the Volgograd Dam (V. S. Tanasiychuk and P. N. Khoroshko collected the material on the feeding of herring and the food supply in 1958; I processed it). In both years the most common species were the same: Of the Rotatoria, Asplancha priodonta, Brachionus calyciflorus, Keratella quadrata, Euchlanis dilatata; of the Cladocera, Daphnia longispina, Bosmina longirostis, Chydorus Sphericus, Ceriodaphnia pulchaella; of the Copepoda--Cyclos, Eurytemora and their larvae. The typical forms of stagnant water bodies were also encountered, for example, Eurycercus, Grabtoleberis, Acroperus, Scapholeberis, Macrothrix and others. At the same time, species, the majority of which are typical of the North Caspian, were caught in large numbers: Eurytemora, Calanipeda, Heterocope, Brachionus capsuliflorus.

A characteristic feature of 1959 was the mass development of algae among the plankton: in June, diatoms (Melosira, Asterionella, Synedra); in July and August, blue-green algae (Microcystis, Anabaena, Aphanizomenon). Their numbers were so great (for example, the census of Microcystis ranged from 40,000-120,000 colonies per cubic meter (Astakhova, Kun, Teplyy, 1960)) that they made work with the plankton net difficult.

The abundance of algae in the section of the river below Volgograd was brought about by the chain of reservoirs on the Volga: in these reservoirs, because of the very slow water flow, shallowness and better heating, favorable conditions were created for the luxuriant development of the phytoplankton, which was carried off to the river en masse.

The development of the phytoplankton was so great that it had an influence on the chemical composition of the river water. According to the data of L. A. B[illegible]sukova, the quantity of phosphates was reduced by more than two times by comparison with past years. The quantity of silicon was also reduced.

In 1958, there was much less phytoplankton.

In 1959, the quantity of zooplankton increased considerably by comparison with the previous year.

As is evident from Fig. 1, the change in the quantity of zooplankton from May through September was generally the same in both years: the lowest biomass was observed in May; the highest, in June-July. However, in 1959 the latter was observed somewhat earlier than in 1958. This phenomenon is related to the difference in the flood (water level) characteristics in these years, which is readily seen from Fig. 1. By comparison with 1958, the 1959 flood lasted a shorter time and was characterized by a low level and later onset. Its highest level was noted on 6 June, reaching 234 cm. The greatest quantity of zooplankton was observed during the period of decline of the spring high water.

Table 2

The Species Composition of the Zooplankton of the Volga River below the Volgograd Dam

(1) Зоопланктонты	1958 г.	1959 г.	(1) Зоопланктонты	1958 г.	1959 г.	(1) Зоопланктонты	1958 г.	1959 г.	(1) Зоопланктонты	1958 г.	1959 г.
Rotatoria			Schizocerca diversicornis	+	+	Scapholeberis mucronata	+	—	**Varia**		
Asplanchna priodonta	+	+	Brachionus angularis	+	+	Moina rectirostris	+	+	Arcella vulgaris	+	+
Brachionus calyciflorus	+	+	Conochilus volvox	+	+	Sida crystallina	+	—	Bryozoa	+	+
Keratella quadrata	+	+	Distyla sp.	+	+	Eurycercus lamellatus	+	+	Lamellabranchiata	+	+
Notholca longispina	+	+	Monostyla bulla	+	+	Acroperus harpae	+	+	Ostracoda	—	+
N. striata	+	+	Diurella tigris	+	+	Alona rectangula	+	+	Chironomidae (lar.)	+	+
Testudinella patina	+	+	Platyias militaris	+	—	Peracantha truncata	+	+	" (2) куколка	+	—
Keratella cochlearis	+	+	Lepadella oblonga	+	—	Alonella nana	+	—	Oligochaeta	+	+
Brachionus capsuliflorus	+	+	Pedalion oxyure	—	+	Macrothrix hirsuticornis	+	+	Gammaridae	+	+
Synchaeta pectinata	+	+	Rotifer sp.	—	+	Bythotrephes longimanus	—	+	Apus nauplii	+	—
Polyarthra trigla	+	+	**Cladocera**			**Copepoda**			Hirudinea	+	—
Trichocerca longiseta	+	+	Daphnia longispina	+	+	Cyclops strenuus	+	+	Odonata	+	+
Filina longiseta	+	+	D. pulex	+	+	Nauplii Copepoda	+	+	Culicidae	+	—
Mytilina ventralis	+	—	Bosmina longirostris	+	+	Diaptomus sp.	+	+	Trichoptera	+	+
Ploesoma hudsoni	+	+	Ceriodaphnia pulchaella	+	+	Eurytemora lacustris	+	+	Coleoptera	+	—
Trichotria tetractis	+	+	Chydorus sphaericus	+	+	Eur. affinis	+	+	Chaoborus	+	—
Lecane luna	+	+	Diaphanosoma brachiurum	+	+	Heterocope caspia	+	+	Hydracarina	+	+
Brachionus urceus	+	+	Leptodora kindtii	+	+	Calanipeda aquae dulcis	+	+	Hydra	+	+
Euchlanis dilatata	+	[illegible]	Graptoleberis testudinaria	+	—	Harpacticidae	+	+	Nematodes	+	+
									Колонии (3) Verticella	+	+

1. zooplankton; 2. pupa; 3. colonies.

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The same regularities were noted by A. T. Dyuzhikov (1955) for the Volga plankton in the region of Saratov.

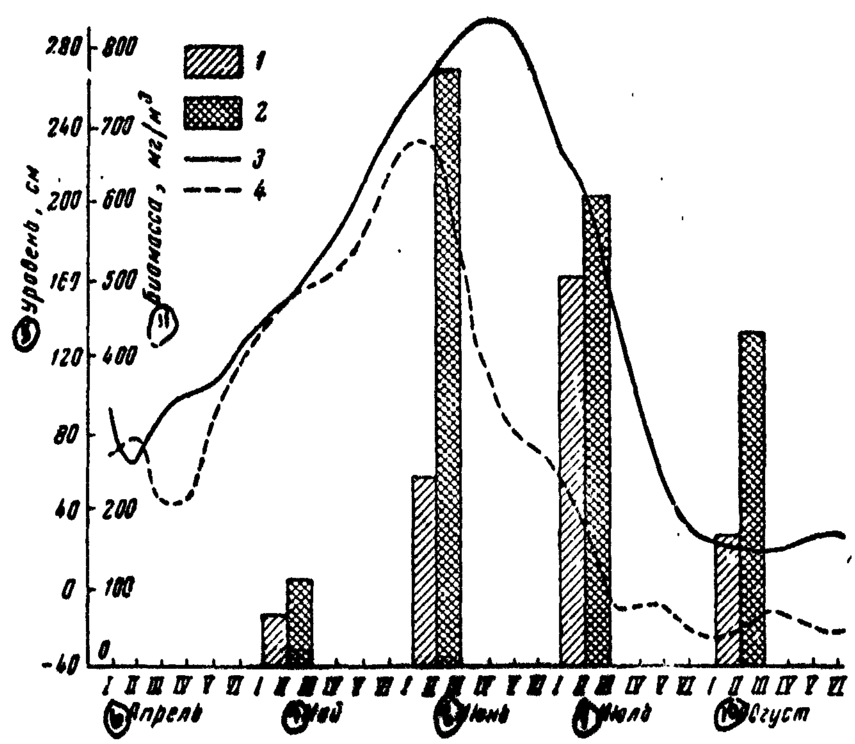

Fig. 1. Variations in the Water Level and in the Zooplankton Biomass in the Volga River. 1 and 2--biomass (mg/cu.m.) in 1958 and 1959; 3 and 4--level (cm) in 1958 and 1959; 5. level, cm; 6. April; 7. May; 8. June; 9. July; 10. August; 11. biomass, mg/cu. m.

Feeding of the Herring Larvae

Herring larvae begin to capture food when they reach a size of 6-7 mm, that is, approximately on the fourth day after hatching from the roe corn

(Kryzhanovskiy, 1956). Occasional specimens of the feeding larvae have a yolk sac. The mass change to external feeding occurs with the complete absorption of the yolk sac.

The composition of the chunks of food eaten by the larvae in both years was the same and was quite varied: it included seven forms of Copepoda, 12 of Cladocera, eight of Rotatoria, and six of the other components (Table 3).

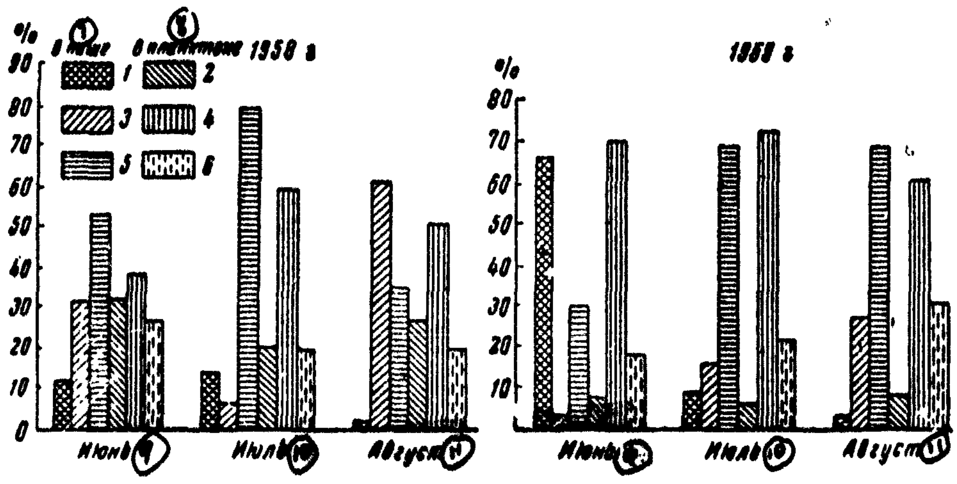

Fig. 2. Interrelationship of Food Organisms in the Food of Herring Larvae and in the Plankton (in Percentages of the Weight). 1,2-Rotatoria; 3,4--Cladocera; 5,6--Copepoda; 7. in the food; 8. in the plankton; 9. June; 10. July; 11. August.

A comparison of Tables 2 and 3 as well as Fig. 2 permits us to note that the herring larvae made fullest utilization of the copepods; Cladocera and rotifers were used less. If we take the number of species of each plankton group as 100 percent, the consumption of them by the herring larvae is expressed by the following figures: Copepoda, 100; Cladocera, 66; Rotatoria, 25.

Of the copepods, Cyclops and Eurytemora were of the greatest importance as food. These forms were encountered in the intestines throughout the observation period. Of the Cladocera, Daphnia longispina and Bosmina longirostris predominated in the food; of the rotifers, Brachionus calyciflorus. Gammaridae and Chironomidae were of no importance in the feeding. They were encountered in the intestines only as single specimens and only in larvae measuring more than 20 mm. Along with the animal organisms the larvae ingested

Table 3

Species Composition of the Food of the Herring Larvae

Организм (1)	1958 г.	1959 г.
Copepoda		
Nauplii Copepoda	+	+
Cyclops strenuus	+	+
Halicyclops sp.	—	+
Diaptomus sp.	+	+
Eurytemora lacustris	+	+
Heterocope caspia	+	+
Harpacticidae	—	+
Cladocera		
Daphnia longispina	+	+
D. pulex	+	+
Bosmina longirostris	+	+
Ceriodaphnia pulchaela	+	+
Diaphanosoma brachiurum	+	+
Chydorus sphaericus	+	+
Moina rectirostris	+	+
Polyphaemus pediculus	—	+
Macrothrix hirsuticornis	+	+
Leptodora kindtii	—	+
Pleuroxus uncinatus	+	—
Simocephalus vetulus	+	—
(2) Зародыши Cladocera	—	+
Rotatoria		
Brachionus calyciflorus	+	+
B. angularis	+	+
Diurella tigris	+	+
Euchlanis dilatata	+	+
Keratella cochlearis, K. quadrata	+	+
Mytina ventralis	—	+
Monostyla bulla	+	—
Brachiomus sp. (ovae)	+	+
Varia		
Lamellabranchiata (ovae)	+	+
Chironomidae	+	+
Gammaridae	+	—
(3) Детрит	+	+
(4) Песчинки	+	+
Microcystis aeurginosa	+	+

1. organism; 2. embryos; 3. detritus; 4. particles of sand.

the alga Microcystsis, which in 1958 and particularly in 1959 was present en masse in the river phytoplankton. Colonies of this alga in t' intestine always maintained their bright blue-green color. Evi...ly, the digestive enzymes exerted no effect on them.

The larvae also ingested objects that were not food--pieces of sand measuring 0.1-0.2 mm, but in the majority of cases the sand constituted hundredths of a percent of the total weight of the food aggregate.

With increase in the size of the larvae the indices of fullness* and, therefore, also the feeding rate increase (Table 4). This is also evidenced by reduction in the number of empty intestines with age (Table 5). The greatest number of them was noted in the earliest stages of development, during the period of transition of the larvae to external feeding. However, thereby Sushkina's data (1940) should be kept in mind, according to which the larvae at the early stages of development readily regurgitate recently swallowed food (in an aquarium) (Under natural conditions, I have noted larvae in the early stages of development, in which only amorphous particles remain, indicating that there had been food). She calls the time of transition of the larvae to external feeding "critical." At this time, mass death is observed among the larvae.

As is evident from Table 4, the intestinal filling indices of the herring larvae in June and July 1959 were markedly reduced compared with the previous year. This was particularly characteristic of the first few size groups, in which the reduction amounted to almost 90 percent as compared with 1958. In August 1959, the indices in the larvae of all size groups increased considerably (Table 6).

The degree of fattening up of the fish depends not only on the concentration of food organisms but also on the fish census at the feeding migration sites. According to the data of V. S. Tanasiychuk, in 1959 there were considerably fewer larvae than in 1958. With a greater biomass of zooplankton and a small number of herring larvae in 1959 an increase in the indices should have been expected; the reverse came about. What was the reason for this?

An analysis of the material gives us the explanation for this phenomenon. It turns out that for herring larvae less than 10 mm in size (the greatest census of the larvae in the river is observed in June) the food consisted mainly of rotifers (Brachionus calyciflorus) (Tables 7 and 8).

By comparison of the quantity of B. calyciflorus in the plankton in 1958 and 1959 it was learned that its average census in July 1958 amounted to 13,600 specimens per cubic meter; in 1959, only 900 specimens per cubic meter. Therefore, in 1959 the census of this form decreased by 15 times compared with 1958, which was the reason for the reduction in the indices of fullness in 1959.

The reasons for the reduction of the B. calyciflorus census in 1959 remain unclarified to date. Possibly, the exceptional abundance of blue-green algae in 1959 had an influence on this. As has been

*[the index of fullness is the weight of food in the stomach or intestine as a percentage of the body weight]

pointed out by some authors (Vinberg, 1954; Hughes, Gorham and Lender, 1958; Kun, 1960), the blue-green algae, chiefly Microcystis, Anabaena and Aphanizomenon, produce toxic substances when they die the effect of which kills animals. However, for the purpose of solving the problem of the effect of the blue-green algae on the development of B. calyciflorus experimental work is needed.

Table 4

Indices of Fullness of Herring Larvae by Size Groups (in Ten-Thousandths of the Weight of the Larvae)

Год (1)	Месяц (2)	(3) Размерная группа, мм							
		6,1—7,0		7,1—8,0		8,1—9,0		9,1—10,0	
		n	и. н. (4)	n	и. н. (4)	n	и. н. (4)	n	и. н. (4)
1958	(5) Июнь . . .	53	28,00	80	48,86	34	86,00	10	177,66
	(6) Июль . . .	154	116,45	152	156,58	158	191,29	148	180,62
	(7) Август . . .	52	6,85	44	25,35	45	51,53	31	144,65
1959	(5) Июнь . . .	64	16,46	40	25,58	20	55,62	6	191,20
	(6) Июль . . .	143	16,30	147	21,50	74	57,62	70	151,08
	(7) Август . . .	103	20,65	57	50,96	34	287,64	31	218,16

1. year; 2. month; 3. size group, mm; 4. index of fullness; 5. June; 6. July; 7. August.

In 1958, the indices of selectiveness with respect to rotifers were less than unity for the entire period of foraging, which was associated with their considerable development among the plankton. In 1959, these indices increased considerably. All this indicates that the herring larvae possess the capacity to select their food (Table 9).

On the basis of an analysis of the material for 1958-1959, the conclusion may be drawn that the conditions of foraging of herring larvae in 1959 in the Volga were less favorable than in 1958.

Undoubtedly, the new conditions of the hydrological and hydrochemical profiles after construction of the Volgograd Dam had an influence here.

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Table 5

The Number of Empty Intestines of Herring Larvae by Size Groups (% of the Total Number of Intestines)

(1) Год	(2) Месяц	(3) Размерная группа, мм							
		6,1—7,0	7,1—8,0	8,1—9,0	9,0—10,0	10,0—15,0	15,0—20,0	20,0—25,0	25,0—30,0
1958	Июнь (4)	79	65	55	40	11	—	—	—
1959		82	77	50	0	—	—	—	—
1958	Июль (5)	53	30	24	24	11	4	0	—
1959		53	72	47	32	19	0	0	—
1958	Август (6)	75	56	44	19	9	0	0	0
1959		70	47	40	16	11	0	0	—

1. year; 2. month; 3. size group, mm; 4. June, 5. July; 6. August.

Table 6

Changes in Indices of Fullness in 1959, Expressed in Percentages of the 1958 Indices (Compare Table 4)

(1) Год	(2) Месяц	(3) Размерная группа, мм			
		6,1—7,0	7,1—8,0	8,1—9,0	9,1—10,0
1959	(4) Июнь	— 42	— 48	— 36	+ 7
	(5) Июль	— 87	— 87	— 71	—16
	(6) Август . . .	+204	+101	+458	+50

1-6. [Same as Table 5]

Table 7

The Number of Food Organisms in the Intestines of Herring Larvae in July 1958 (A) and 1959 (B)

(1) Размерная группа личинок, мм	(2) Число экземпляров на один кишечник							
	Copepoda		Cladocera		Rotatoria		Varia	
	А	Б	А	Б	А	Б	А	Б
6,1— 7,0	0,03	0,01	—	—	1,10	0,10	0,05	0,10
7,1— 8,0	0,10	0,05	0,02	—	1,70	0,20	0,04	0,10
8,1— 9,0	0,50	0,30	—	0,04	1,00	0,50	—	0,04
9,1—10,0	0,70	1,20	0,02	0,05	2,10	0,60	—	0,03
10,1—15,0	2,50	2,80	0,07	0,30	1,20	0,30	0,02	—
15,1—20,0	5,40	5,60	0,20	0,70	—	—	0,04	0,10
20,1—25,0	12,40	3,00	5,80	5,60	—	—	—	—

1. Size group of larvae, mm; 2. number of specimens per intestine.

Table 8

Frequency with Which Brachionus Calicyflorus was Encountered in the Food of Herring Larvae in July

Год (1)	(2) Размерная группа личинок, мм						
	6,1—7,0	7,1—8,0	8,1—9,0	9,1—10,0	10,1—15,0	15,1—20,0	20,1—25,0
1958	40,9	58,5	50,6	57,3	26,1	—	—
1959	5,0	9,5	21,6	21,4	24,5	—	—

1. year; 2. size group of larvae, mm.

Table 9

Indices of Selective Capacity (after Shorygin) of Herring Larvae with Relation to Plankton

(1) Год	(2) Месяц	(3) Группа кормовых организмов		
		Rotatoria	Cladocera	Copepoda
1958	(4) Июнь	0,3	0,8	2,0
	(5) Июль	0,7	0,1	4,2
	(6) Август	0,04	1,2	1,7
1959	(4) Июнь	8,5	0	1,7
	(5) Июль	2,1	0,2	3,4
	(6) Август	0,03	0,4	2,4

1. year; 2. month; 3. group of food organisms; 4. June; 5. July; 6. August.

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Conclusions

1. The species composition of zooplankton in 1958-1959 did not change. In both years the same species were predominant in the plankton.

2. The biomasses of the various groups of zooplankton in 1959 were much greater than in 1958. The rotifers, the biomass of which decreased considerably, constituted an exception. In both years the main form of rotifer was Brachionus calyciflorus.

3. In 1959, there was a very considerable development of the blue-green algae in the Volga plankton. It may be supposed that they exert a harmful influence on some species of plankton, particularly on B. calyciflorus.

4. When they change to external feeding, herring larvae 6-7 mm in length eat chiefly B. calyciflorus. With growth of the larvae the number of rotifers in the food decreases, and Copepoda and Cladocera begin to predominate.

5. In 1959, the intestinal filling indices were less for all size groups than in 1958. The greatest number of empty intestines was observed in 1959. Reduction of the indices of fullness in 1959 was caused chiefly by the small number of one of the main food organisms, B. calyciflorus, in the plankton.

6. Comparison of the percentage relationships of the food organisms in the food of the herring larvae and in the plankton shows that the larvae possess the capacity of selecting their food. They choose Rotatoria and Copepoda to the greatest degree.

7. In 1959, with the river flow regulated after construction of the Volgograd Dam, the foraging conditions of the herring larvae became less favorable than in 1958.

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The Problem of Acclimatization of Commerical Crabs to the Barents Sea

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Introduction

The problem of acclimatization of the Kamchatka crab [king crab] (Paralithodes camtschatica) to the Barents Sea first arose at the end of the 1920's at the State Oceanographic Institute (now the All-Union Scientific Research Institute of Marine Fishing and Oceanography) and at the Pacific Institute of Fishing (now the Pacific Scientific Research Institute of Marine Fishing and Oceanography), and at the beginning of the 1930's a method for practical realization of this acclimatization began to be worked out. L. G. Amelina performed experiments on collection and transportation of the crab eggs in 1931; Ye. M. Kreps and Ye. K. Plechkova in 1932-1933 and I. G. Zaks in 1932 tried to transport living female egg-bearing crabs by railroad, and D. N. Logvinovich in 1935 brought three young, 6-7-month crabs to Murmansk.

Experiments on the transportation of the Kamchatka crab were continued on a commercial scale in 1951-1953 by the Primor'ye Acclimatization Station of the Primor'ye Scientific Research Institute for Fish Breeding and Protection of Fishing (N. N. Tareycheva) with the participation of a worker of the Central Commerical Acclimatization Station of the Main Administration for Fish Breeding and Protection of Fishing, Yu. Ya. Misharev. In the experiments the females survived only 48 hours, which could not constitute the basis for transportation of the crabs from Primor'ye [maritime coast of the Far East] to the Murmansk coast. Therefore, work on acclimatization was stopped.

In 1959, at the Murmansk Council of the National Economy the question of acclimatization of the Kamchatka crab to the Barents Sea was raised again. Work was begun early in 1959 under the direction of A. F. Karpevich.

In this article a brief biological substantiation is given of the advisability of stocking the Barents Sea with commercial crab and which was presented to the Consultations Council for Acclimatization of Fish and Invertebrates to Water Bodies of the Soviet Union, a project which was approved by the Council on 3 March 1961; brief data are also presented on the practical realization of crab acclimatization to this sea.

The possibility of acclimatization of the Kamchatka crab to the Barents Sea was expressed by I. G. Zaks (1936), L. A. Zenkevich (1940), and B. S. Il'in (1954). However, Yu. I. Galkin (1960) believes that acclimatization of the crab to the Barents Sea is an unsuccessful venture in a commercial respect. This author bases himself chiefly on the idea that extent of distribution of the Kamchatka crab will be limited to the boundary between the boreal and arctic fauna, which passes near the shore of the Kola Peninsula and reaches only the middle of it. Galkin's opinion, however, does not have sufficient basis, because the problem of where to categórize the Sea of Okhotsk and the Bering Sea (the main habitats of the crabs)--in the arctic or in the boreal zone--is disputable to date, which is reflected even in study aids (Bobrinskiy, Gladkov, 1961). Therefore, in working out the biological substantiation consideration was given both to the relationship of the crabs to the environment and the specific abiotic conditions and food resources of the Barents Sea.

The Main Features in the Biology of Crabs

The Kamchatka crab is widespread in the Pacific Ocean; in the South it is encountered as far as Tsusimskiy Proliv [strait], and in the North it reaches Norton Sound.

The Kamchatka crab is now caught in the Pacific Ocean and in the Sea of Japan, Bering Sea and, chiefly, in the Sea of Okhotsk (along the western shore of Kamchatka). Here, in 1957, Soviet and Japanese fishing fleets caught 29,500,000 crabs and made 384,000 boxes of preserves(Galkin, 1959), which amounts to three-fourths of the world production of canned crab meat.

Crabs are caught mainly by fixed gill nets, which are set up on the approach routes of the crabs to the shores.

The size of the males (the size of the females is not given, because commercially only the males are caught and processed) along the shores of Kamchatka amounts to about 16 cm (judging by the width of the carapace) with a weight of 1840 grams; In Primor'ye, these figures are, respectively 18 cm and 3200 grams; sometimes, the males can reach 25 cm and weight up to 7 kg.

The greatest depth at which the crab lives and hibernates is 270 meters; along the western shore of Kamchatka crabs are found at a depth of 4 meters in the spring.

Almost all commercial crab stocks along the shores of Kamchatka are located at depths of 5-30 meters in the spring; in Zaliv [gulf] Petra Velikogo (in the spring and autumn), from 15 to 50 meters.

Commercial stocks of the Kamchatka crab in the Sea of Okhotsk are encountered on the sandy and sandy-oozy bottom.

The crab can live in temperatures from -1.6 to +18°. However, the optimum temperatures are within limits of +2 and +7°. The salinity

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of the water in places where the Kamchatka crabs live is equal to 32-35 grams per thousand.

The fecundity of the females comes to 20,000-300,000 berries, usually about 200,000. The length of embryonic development is 11.5 months. Along the shore of Kamchatka the females are in berry from the middle of June to the end of May of the next year, while in Zaliv Petra Velikogo, this time extends from the end of April until the end of March-beginning of April of the next year.

The prozoea hatches out of the egg, and is converted into the zoea in several minutes.

For about two months the zoea leads a planktonic mode of life and thereby molts four times, after which it is converted into a megalops, which settles on algae (ahnfeltia) and hydroids. After 20 days, the megalops molts and becomes a young immature crab, like the adult crab. After reaching the age of three years the young go to sandy places, and at the age of 6-7 years they collect in schools and begin to migrate.

It is believed that crabs become sexually mature at the age of eight or nine years (the males reach a size of 10-12 cm; the females, 9 cm).

According to V. F. Fenyuk's data (1945), the food of the Kamchatka crabs consists mainly of mollusks, crustaceans, worms, ascidians and echinoderms. Sponges, bryozoans, rhizopodans, algae and fish are rarely found the crab stomachs. In some areas ascidians and echinoderms predominate as the crab food.

N. P. Navozov-Lavrov asserts that crabs move at a speed of up to 1.8 km an hour; however, the schools migrate much more slowly, at about 4 km a day. On the western shore of Kamchatka the food migrations of the crab reach about 200 km. In Zaliv Petra Velikogo the places where the crabs hibernate are 80 km away from the places on the shoal where the crabs go in the spring.

N. P. Navozov-Lavrov (1927) reports that the enemies of the Kamchatka crabs are the octopuses. When the crabs molt they can become the prey of the cod. Crab larvae are eaten by fish and its young.

It is known that acorn barnacles, hydroids and worms settle on the carapaces of the crabs; on the ventral side of the abdomen gammaruses and leeches and their cocoons are found. All the organisms mentioned, with the exception of leeches, are not typical parasites and therefore do not cause great harm to the crabs. The presence of leeches is readily detected, and they can be removed without any special effort. Parasitological study of crabs made in March-April 1961 by N. L. Nechayeva showed that the crabs are not infected with any pathogenic parasites, are not intermediate hosts of parasitic worms of fish or other vertebrates. No clinical signs of infectious disease were found. In connection with what has been stated above, the acclimatization of the Kamchatka crabs to other bodies of water carries no epizootological hazard.

Characterization of the Possible Area of Distribution of Commercial Crabs in the Barents Sea

The area of the Barents Sea is 1360,000 square kilometers. It is a relatively shallow body of water,the average depth of which is 199 meters. By comparing the area occupied by depths from 0 to 250 meters, at which the crabs live along the western shore of Kamchatka with the area occupied by the same depths in the Barents Sea, it may be seen that in the Barents Sea this area is 4.5 times greater than along the western shore of Kamchatka (Table 1).

Table 1

Areas Occupied by Different Depths in the Barents (within Limits of the Assumed Area of Distribution of the Crabs) Sea and the Sea of Okhotsk

Водоем [1]	[2] Площади (тыс. $км^2$), занимаемые разными глубинами (м)				
	0—50 *	0—100	0—150	0—200	0—250
[3] Охотское море (западное побережье Камчатки) .	23	51	69	75	81
[4] Баренцево море.	49	171	247	300	377

*Along the shore of Novaya Zemlya Island depths of 0-50 meters occupy an area of 10,800 square kilometers. However, the crab will not live here because of the constant low bottom temperatures; therefore, this area was not considered in the calculations.

1. water body; 2. areas (thousands of sq. km) occupied by different depths (meters); 3. Sea of Okhotsk (western shore of Kamchatka); 4. Barents Sea.

Positive bottom temperatures in the Barents Sea extend far to the East. The maximum distribution of positive bottom temperatures, according to the data of the Morskoy. . . .Obzor [Marine. . . . Review] (1959-1961), comes in November; the minimum, in April (Fig. 1).

In the Barents Sea the adult crabs must make longer migrations than in the seas of the Far East. The longest forced route of migration in the Barents Sea is shown by the line A-B in Fig. 1. The distance between the points A-B is about 400-500 km. At a rate of 4 km a day this distance would be covered in three or four months by the crab schools, and they can therefore follow the movement of the zero isotherm.

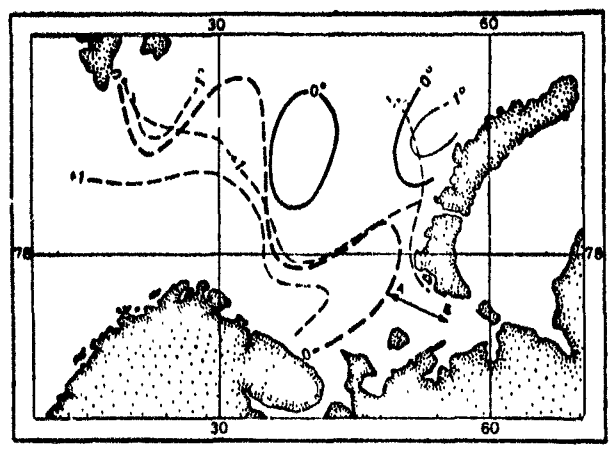

Fig. 1. Average Annual Water Temperature at the Bottom in April (Broken Lines) and in November (Solid Lines) (The Second +1 Isotherm from the Bottom (Broken Line) also applies to November).

During the molting period of the crabs the currents, along with the temperature, probably play a role of more than a little importance.

Water comes into the Barents Sea from the North, between Spitsbergen and Franz-Josef Land and between Franz-Josef Land and Novaya Zemlya. The strongest current comes into the Barents Sea from the West. This current, called the North Cape current, is a branch of the Gulf Stream. In the Barents Sea the North Cape Current divides into two branches. The southern branch, washing the shore of the Kola Peninsula, penetrates far to the East. This branch of the North Cape Current has an influence, by and large, on the scattering of the larvae.

L. A. Zenkevich (1947) points out that the speed of this branch of the North Cape Current amounts to 4.5 cm/sec. If its speed and direction as well as the duration of the larval (plankton) stages of development of the Kamchatka crab are analyzed, it may be supposed that the larvae, hatching out in the area between Poluostrov [peninsula] Rybachiy and Ostrov Kolguyev, will not be carried out into the Kara Sea and northern regions of the Barents Sea and will die there, without molting further.

According to Sato (1958), the development of the larval stages (zoea I to zoea IV) takes 64 days at a temperature of 6-7°; that of megalops, 20 days. At a speed of 4.5 km/sec the southern branch of the North Cape Current can take the larvae no more than 250 km from the hatching site in 64 days. In the region of Ostrov [island] Kolguyev the larvae, in all probability, will be retarded, because the speed of the current in this area is sharply reduced, and its direction becomes less definite.

According to O. F. Kondratsova's data (1957, 1958), in the shoal water of the region of Mys [cape] Svyatoy Nos the highest temperature is 6-7°; the lowest, -1°; in the deep water layers near the bottom these figures are, respectively, +4-5° and no less than +1°. The warm-up period in the shoal water lasts 180 days; in the deep areas, 250 days (Table 2).

Table 2

Average Monthly Water Temperature of the Top 50-Meter Layer of the Barents (As an Average for Three Sections) (According to Kondratsova's Data (1957, 1958)

(1) Месяц	(2) Год	(3) Разрез		
		(4) Кильдинский	(5) Дальнезеленецкий	(6) Святоносский
(7) Апрель	1953	2,3°	2,6	0,6
	1954	1,2	1,1	—0,6
(8) Август	1953	8,2	8,4	7,0
	1954	7,6	7,8	7,2

1. month; 2. year; 3. section; 4. Kil'din; 5. Dal'nezelenetsk; 6. Svyatoy Nos; 7. April; 8. August.

It is believed that the larvae live on the bottom (at a depth of 20-30 meters), and come to the top layers of the water for only a short time during the day.

Kondratsova's data as well as the analysis of maps with temperature readings (Karakash, 1956) of the upper layer of water permit us to believe that the crab larvae can go through all the stages of their development (four zoea stages and the megalops stage) in a single summer season.

The salinity of the water of the Barents Sea within limits of the assumed area of distribution of the crabs is close to that in the ocean. Therefore, the salt content factor is not lethal to the crabs. This is indicated by experiments performed by A.P. Kazayev. The female crab normally lived in water with a salt content of 24 grams per thousand for 45 days. Thereby, premature hatching of the larvae occurred, which has also been observed in other females, which were in water of normal oceanic salinity. According to Kurata's data (1960), the larvae of the Kamchatka crab survive in a salt content of 21 to 39 grams per thousand.

It is believed that the megalops can die if it drops to an oozy bottom rather than on an appropriate substratum. Algae and hydroids are widespread in the southern and south-eastern parts of the Barents Sea. However, determination of the areas occupied by algae and hydroids and which can be shelters for the young crab requires making special studies.

In determining the boundaries of the assumed area of distribution of the Kamchatka crab in the Barents Sea consideration was given to the depths (isobath of 250 meters), whether positive temperatures exist constantly on the bottom layer of water or whether they are temporary, and the standing crop of the benthos (no less than 25 grams per square meter).

Then the boundary of the area of distribution will go almost directly north from Varanger Fjord along the 250-meter isobath. Then it turns to the East, and skirting the trough with depths reaching 380 meters, where the bottom layers of water usually show minus temperatures, it goes up to 74° north latitude at the island of Novaya Zemlya. Along the coast of the Kola Peninsula the boundary passes to the East, to Gorodetskiy Mayak, and then joins the line between Gorodetskiy Mayak and Kanin Nos. A line passing from Mys Russkiy Zavorot and Mys Sakhalina connects the continent with Novaya Zemlya Island (Fig. 2).

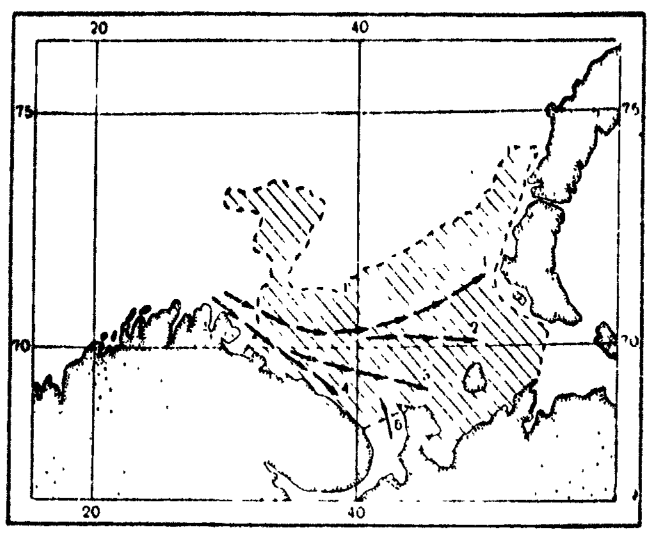

Fig. 2. Proposed Region of Distribution of the Crab in the Barents Sea and Diagram of the Main Currents: 1) Novaya Zemlya; 2) Kolguyevo-Pechora; 3. Kanin; 4. Murmansk coastal; 5. White Sea.

Spread of the crab to the west of the proposed area of distribution in large numbers is not very likely, because in these areas great depths predominate. In addition, the larvae which hatch out along the shore of the Kola Peninsula, will be carried by currents from West to East. However, there is still a certain possibility of migration of the adult crabs to the west along the narrow coastal strip of Norway. Spread of the Kamchatka crab to the north and east of the area of distribution outlined will be checked by the low bottom temperatures.

Yu. I. Galkin (1960) points out that the crabs are encountered in areas with a total biomass of above 150-200 grams per square meter and, therefore, the crab cannot live in the Barents Sea in areas with a biomass of less than 100 grams persquare meter; for this reason, it will be impossible to create commercial concentrations of the crab. However, Yu. I. Galkin does not analyze the regions with benthos biomasses and commercial concentrations of crabs in the Bering Sea.

Nevertheless, as is seen from a comparison of the maps of the benthos biomass of the Bering Sea (Neyman, 1960) and the areas of distribution of the crabs (Canned Crab Industry of Japan, 1948), the Kamchatka crabs in this sea live in areas with a benthos biomass of 25 to 200 grams per square meter, where a considerable area is occupied by biomass quantities of 25 to 100 grams per square meter, and despite this low biomass the Kamchatka crab is found in large commercial concentrations here.

On the bulk of the area of the proposed area of distribution of the Kamchatka crab in the Barents Sea the benthos biomass ranges from 50 to 200 grams per cubic meter (Fig. 3) /in Russian, " $/m^2$" means "per square meter"; " $/m^3$" means"per cubic meter". Therefore, it is easy to err in this respect; with the exception of the " /m3" in the last sentence all the others were written " $/m^2$", erroneously/. Therefore, in the Barents Sea food will not be a factor interfering with the formation of mass commercial stocks of crab.

The benthos in the Barents Sea is varied and consists of mollusks, echinoderms, coelenterates, crustacenas, sponges, rhizopodans and other speices (more than 1500).

Some species of benthos in the Barents Sea (for example, echinoderms), poorly utilised by the local fauna, will be the food for the crabs.

Therefore, additional food resources will be opened up in the Barents Sea.

As the result of a brief analysis of the living conditions of crabs in the Barents Sea it may be said that the benthos stocks within the proposed area of distribution of the crabs can probably provide for the existence of the same number of commercial crabs as live along the western shore of Kamchatka, because the somewhat lower benthos biomass of the Barents Sea, compared with the western shore of Kamchatka, is balanced by the greater area of the proposed area of distribution of the crabs to be introduced.

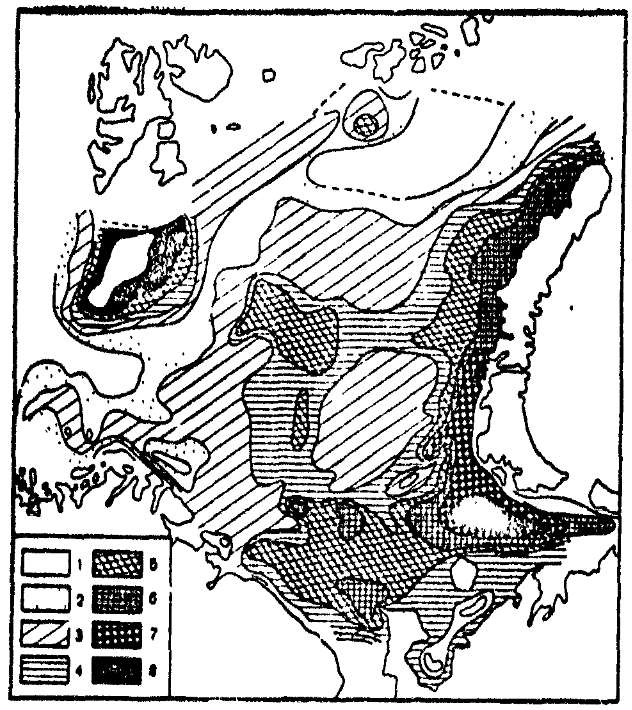

Fig. 3. Benthos Biomass Distribution (grams per sq. meter [cubic meter intended] in the Barents Sea (after Brotskaya and L. A. Zenkevich, with additions by Filatova; taken from L. A. Zenkevich (1947)). 1. less than 10; 2. 10-25; 3. 25-50; 4. 50-100; 5. 100-200; 6. 200-300; 7. 300-500; 8. more than 500.

The crab census, however, will depend not only on the quantity of food but also on the effects of enemies, parasites, presence of shelters, the possibility of traveling great distances in the spawning migrations, and others. The effects of these factors can only very tentatively be taken into account at present. Therefore, in order to determine the maximum possible crab census in the Barents Sea, an experiment must be performed: a large number of crabs should be introduced into the Barents Sea. This procedure should be accompanied by considerable scientific research work.

Another far eastern commercial crab--the blue crab (Paralithodes platypus)--is of great interest as a valuable object for acclimatization, because it can become more widespread in the Barents Sea than the Kamchatka crab. According to L. G. Vinogradov's data (1941), the schools of this crab stay in deeper places and at places with lower temperatures--usually from -1 to +2°, than those of the Kamchatka crab.

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Draft of Plan of Practical Measures for Acclimatization of Crabs to the Barents Sea

In all probability, successful results in acclimatization of the crabs can be attained in the next 10-15 years in the Barents Sea only by means of the mass introduction of growing young into places abounding in macrophytes or hydroids, bryozoans and sponges.

The following acclimatisation plan is being proposed. The eggs are removed from the female yolk sac pedicle and put into isothermic boxes on the shoreof Kola Peninsula. The eggs can be collected either in the autumn or in the spring--shortly before the larvae hatch out; in March-April (in Primor'ye); or in May, on the coast of Kamchatka. The crab eggs should be collected and transported for 5-10 years, in numbers of 100,000,000-200,000,000 berries a year.

For the post-incubation* of the eggs and cultivation of the crab young it is necessary to construct a special crab-rearing station. The post-incubation of the eggs is carried out in apparatuses of the Chez [?] type. In order to be able to control the rate of embryonic development the water temperature must be regulated. If it is possible, by means of specially performed experiments, to bring about hatching of the normal larvae in the autumn, the incubator and the crab-rearing station will be able to manage two production cycles a year.

The young crab is cultivated for 1.5-2 months, during which it undergoes four molts and changes into a megalops. For cultivation of the young crab Artemia larvae can be used as food (Sato, 1958 and Kurata, 1959, 1960).

A. P. Kazayev, who performed experiments of cultivatation of the zoea of the Kamchatka crab in floating live boxes, pointed out that the survival rate of the crab larvae which molted from the first to the second zoea stage reached 95 percent.

If it is possible to cultivate the crab zoea to the megalops stage with 50 percent survival of the young, the problem of practical realization of crab acclimatization to the Barents Sea can be considered solved. Successful experiments performed by Kurata (1959, 1960, 1960a), permit us to hope for such a high survival rate.

The problem of transportation of crab young to the Barents Sea and releasing them there is not without interest. Marukawa (1933) believes that death of the larvae fromthe time of hatching until the megalops stage amounts to 96.5 percent. Therefore, the survival of 2-5-year old crabs is close to 100 per cent, and, therefore, putting a single young crab specimen into the Barents Sea is equivalent to putting approximately 50,000 specimens of larvae there. The introduction of young in a quantity of 50,000-100,000 specimens per year might be very effective.

In order to throw light on problems of crab migrations and the boundaries of their distribution in the Barents Sea in the next three-five years, it is necessary to introduce 1,000-4,000 specimens of

*[For the explanation of this term see middle of the next page]

labeled adult crabs into this sea.

Along with the biological substantiation, development of a method of collecting and transporting the crabs has been begun. In 1960, Yu. Ya. Misharev transported 30 crabs (males) from Vladivostok to Moscow with the aim of elucidating the possibility of transporting them in a live state. The duration of the transportation was 38 hours. Twenty two crabs were brought there alive.

In October 1960, workers of the Central Commercial Acclimatization Station brought nine living females and 6,020,000 Kamchatka crab eggs to the Murmansk Marine Biological Institute. The duration of the transportation of the females was 128 hours; of the eggs, 147 hours. Further observations on the material brought were made by a worker of the Murmansk Marine Biological Institute, N. A. Zubkova. During the entire winter of 1960/61 the crabs were in a running-water aquarium; they moved about actively, took nourishment and cared for their eggs. In January 1961 the fully developed larvae began to hatch out; in February the crabs began to molt normally. The eggs (in bunches), brought to the Murmansk Marine Biological Institute and placed in apparatuses of the Chalikov type set up in Dal'nezelenetskiy Zaliv [gulf], died one and a half months after the beginning of "post-incubation" ("post-incubation" means incubation of the fertilized eggs after transportation) because of imperfection of the incubation apparatus. In March-April 1961, the experimental work was continued. On 16 April, 15 adult Kamchatka crabs (eight females and five males) and two male blue crabs were brought to the Murmansk Marine Biological Institute. One hundred and three two-year olds and 2,2000,000 berries were also brought there. Seven females and three males of the Kamchatka crabs were released in the sea. A special center was organized for post-incubation of the eggs. Of the 2,000,000 berries placed in apparatuses of the Weiss type, 1,600,000 larvae hatched out. Of this number, 1,500,000 larvae were released in the Barents Sea and in Dal'nezelenetskiy Zaliv, and 100,000 larvae were given to the Murmansk Marine Biological Institute for the performance of cultivation experiments. Five spawners left in the MMBI aquarium and five two-year olds showed the same good survival as the crabs brought in October 1960 had shown.

In August-September 1961, in Ussuriyskiy Zaliv on beds of Ahnfeltia, the young of the Kamchatka crab were collected; these were brought to the Barents Sea in two batches and released in Bol'shaya Volokovaya Bay. In all, 2470 yearlings and 7500 underyearlings were released.

Conclusions

1. An analysis of certain aspects of the biology of commercial crabs and the basic conditions of their existence in the Barents Sea shows the great likelihood of survival of crabs in this Sea.

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2. The possibility of collection and transportation of the crabs in mass numbers and at all stages of development has been proved for practical purposes(this applies to the eggs, the young and the spawners).

3. Observations made at tho MMBI aquarium indicate the fact that the crabs can adapt themselves to many new abiotic factors of the Barents Sea.

4. The experiments performed provide the opportunity of initiating the acclimatization of the Kamchatka crab to the Barents Sea on a broad, commercial scale.

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