5. Methodology and Results

5.1 Temperature and Salinity Dynamics: 1961-1999

The raw data on the CD-ROM was used to construct a time series of temperature and salinity variations from 1961 to 1999 (Figures 4 and 5, respectively). Figure 4 presents the annual anomalies of temperature for the depths 0-65 m, 0-15 m, and 50-65 m. Figure 5 shows the annual anomalies for salinity for the depths 10-65 m, 10-15 m, and 50-65 m. These depths were chosen because they describe, in sufficient detail, temperature and salinity variations along the vertical. When describing salinity variations, no consideration has been given to the surface layer due to strong effects by river discharge and ice melt. The diagram of salinity anomaly variations shows two distinct time spans: 1961-1975, where the salinity anomaly is positive; and 1976-1997, where the salinity anomaly is negative.

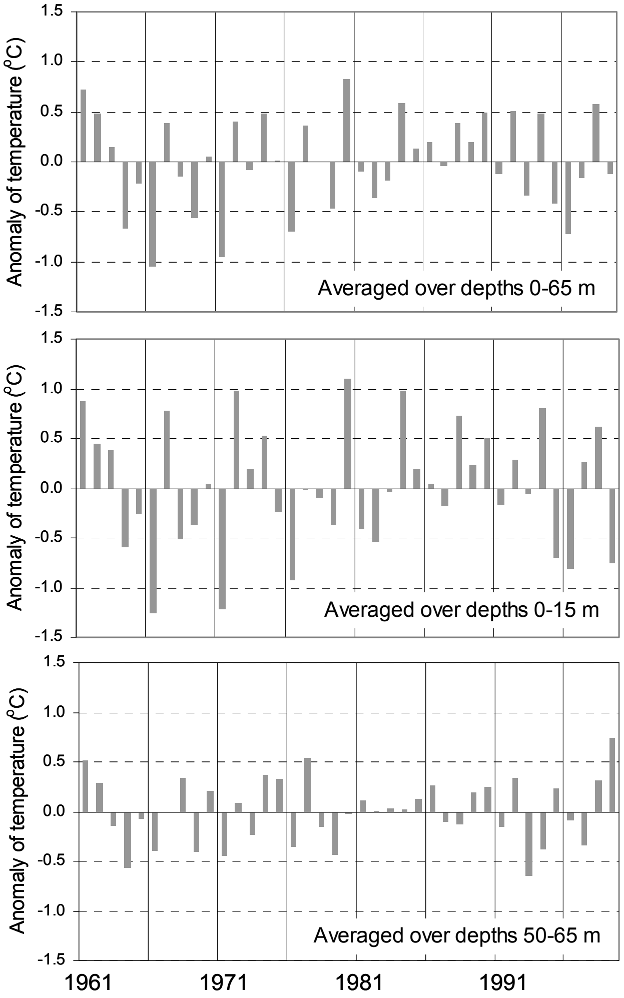


Figure 4. Time series of annual temperature anomalies for 1961-1999.

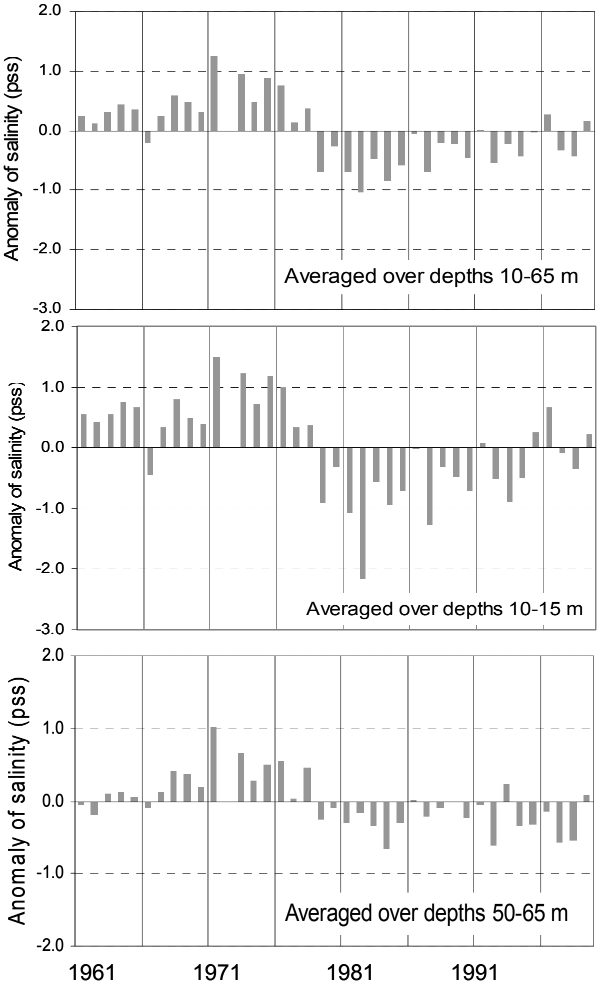


Figure 5. Time series of annual salinity anomalies for 1961 – 1999.

The algorithm used to construct the time series (Figures 4 and 5) was the following:

- Long-term temperature, $T_{j,k}$, and salinity, $S_{j,k}$, means (climatic normal) are calculated by month (*j*) and level (*k*). Table 4 presents these values for 12 months and for levels 0 m, 5 m, 10 m, 15 m, 25 m, 50 m, and 65 m.
- Monthly mean deviations of temperature, $T_k(N)$, and salinity, $S_k(N)$, are computed for the given year (N) and level (k).
- $T(N)$ and $S(N)$ means are calculated for multiple layers.

Table 4. Climatological means for each month and each level for temperature and salinity.

(a) Temperature

Depth (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	-0.98	-0.80	-0.55	-0.65	3.41	10.98	14.78	13.77	9.31	5.02	1.96	-0.05
5	-0.92	-0.68	-0.68	-0.76	2.03	7.60	13.19	13.51	9.32	5.09	2.01	0.05
10	-0.86	-0.65	-0.66	-0.76	1.06	5.51	11.26	12.04	8.93	5.13	2.22	0.18
15	-0.76	-0.48	-0.44	-0.63	0.34	3.43	8.62	9.75	8.26	4.83	2.37	0.58
25	-0.50	0.15	-0.23	-0.48	-0.33	0.96	4.02	4.81	5.31	4.18	2.61	0.95
50	0.02	0.25	-0.23	-0.58	-0.64	-0.17	0.53	1.35	1.97	1.87	2.51	1.60
65	0.08	0.18	-0.27	-0.60	-0.66	-0.24	0.39	1.17	1.72	1.65	2.29	1.33

(b) Salinity

Depth (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	20.51	19.62	17.64	14.99	18.50	22.21	23.34	24.32	24.98	25.60	26.08	25.84
5	26.17	26.27	25.67	25.63	24.49	24.05	24.38	24.79	25.39	25.93	26.54	26.74
10	26.65	26.60	26.00	26.20	25.47	24.87	24.96	25.21	25.64	26.06	26.63	26.74
15	27.11	27.42	27.38	27.40	26.84	26.08	25.84	25.89	26.09	26.38	26.75	27.02
25	27.37	27.61	27.80	27.91	27.68	27.12	26.88	26.76	26.79	26.90	27.03	27.21
50	27.82	28.05	28.41	28.48	28.46	28.08	27.93	27.75	27.68	27.76	27.78	27.78
65	28.02	28.32	28.63	28.67	28.54	28.31	28.05	27.93	27.88	27.87	27.79	27.97

5.2 Temperature Optima for Zooplankton Species

The temperature optimum for zooplankton species, x, is the temperature range within which the abundance of x reaches its maximum value. Let $T(x)$ be the temperature optimum for zooplankton species, x. The current study considers $T(x)$-values for two reasons: (1) because the quantitative description of the relationship between environmental conditions and zooplankton abundance forms a basis for providing control criteria for data quality and control; (2) $T(x)$-values allow us to formulate hypotheses for which a confirmation or refutation will provide a better understanding of the mechanism of environmental effects on the annual dynamics of zooplankton development and will serve as criteria for quality control of hydrobiological data. These hypotheses will be considered in the next section.

A T(x)-value is calculated based on multiple samples, any of which is characterized by information about its species composition, abundance, and temperature and salinity at different depths. Let the number of these samples be n. The computing algorithm for T(x) is as follows:

1. For layer, h, within which zooplankton sample, i, is taken, the value of $T_h(x)$ is calculated as:

$$T_h(x) = \frac{\sum_{i=1}^{n} T_{h,i} \bullet A_{h,i}(x)}{\sum_{i=1}^{n} A_{h,i}(x)}$$

where:

$T_h(x)$ is the temperature optimum for zooplankton species, x, in layer, h;
$T_{h,i}$ is the mean temperature of layer, h, and sample, i;
$A_{h,i}(x)$ is the abundance of zooplankton species, x, in layer, h, and sample, i; and
n is the total number of samples.

1. A $T_h(x)$-value is calculated for three layers: $h_1 = 0\text{-}10$ m, $h_2 = 10\text{-}25$ m, and $h_3 = 25\text{-}65$ m. The temperature optimum for layer, h_o (surface-bottom), has been calculated based on $T_{h1}(x)$, $T_{h2}(x)$, and $T_{h3}(x)$ values:

$$T_{ho}(x) = \frac{[T_{h1}(x) + T_{h2}(x) + T_{h3}(x)]}{3}$$

2. The temperature optima of zooplankton species, T(x), as listed in Table 3, are calculated by averaging the temperature optima for all its ontogenetic stages. In accordance with the $T_{ho}(x)$-values, the entire set of species is divided into the two categories, K_1 and K_2. The temperature optimum for the species set, K_1, lies in the range of 1.5^o to 4.1^o C, and K_2 - in the range of 8.1^o to 12.8^o C (Figure 6). The difference of the temperature optimum between these two categories is about 4^o C. Therefore, zooplankton species of the first category, K_1, are considered to be cold-water species and of the second category, K_2, – warm-water species. *Polychaeta* are the only intermediate group, probably, due to the diversity of species in this group.

During the year the ratio between the abundances of cold-water and warm-water species does not remain constant. In winter, the abundances are very similar; in spring, the cold-water species predominate; in summer and especially autumn, the warm-water species compose the major part of the total population abundance.

Based on multiple samples collected during the period 1963-1998 of continuous observations, Figure 6 shows the correspondence between zooplankton condition and water temperature on a climatic time scale. We plan to use these features to verify methods for the quality control of biological data for the White Sea. The results of this study and experience gained will make it possible to improve the technique of data quality control for other Arctic regions as well.

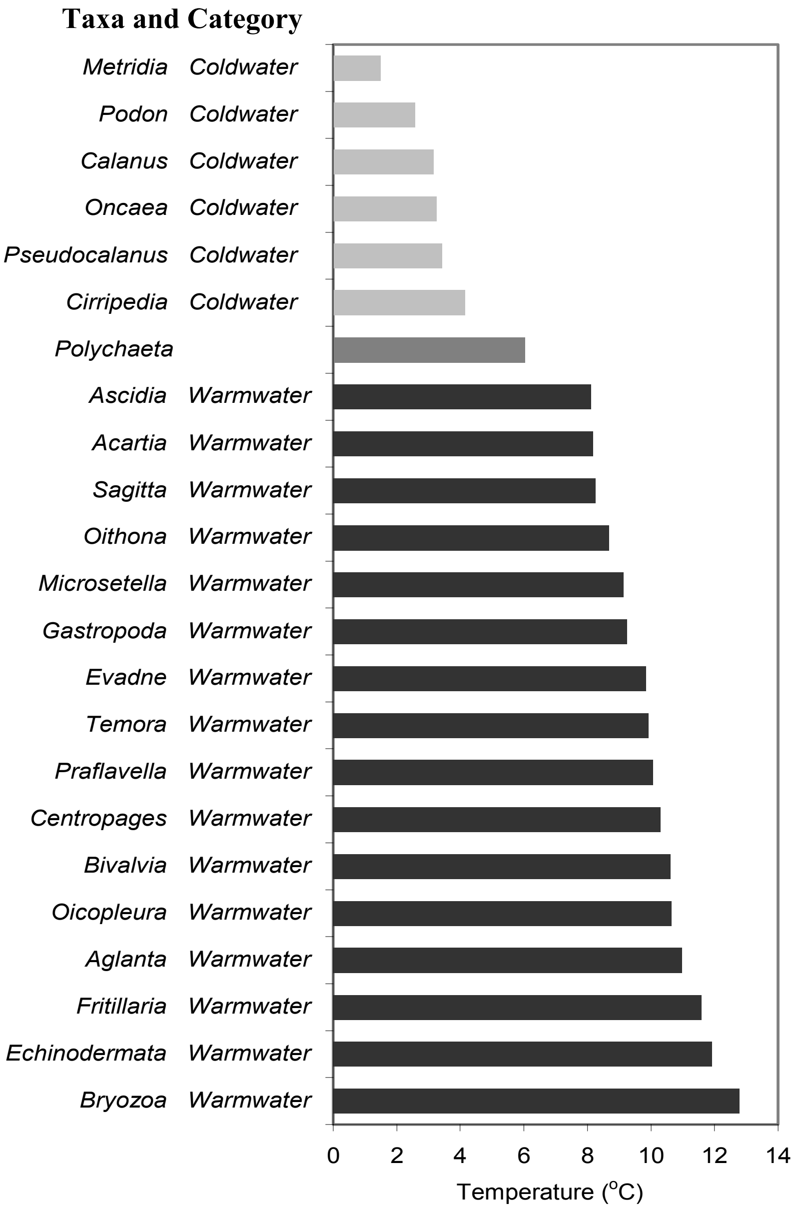


Figure 6. Correspondence between peak of zooplankton abundance and water temperature, T*(x)*.

5.3 Main Concept and Problem Statements

One of the goals of this study is the quantitative description of environmental effects on zooplankton development. Let us consider the possibility of using T(x)-values to solve this problem. Parameter T(x) determines the temperature value favorable for zooplankton reproduction (Marshall, Orr, 1955; Waterman, 1960). This allows us to formulate the following two statements:

Statement 1: In the years with negative temperature anomaly, the duration of the period favorable for reproduction of cold-water zooplankton species of category, K_1, is extended and for warm-water zooplankton species of category, K_2, it is shortened (warm-water species are inhibited). The years with positive temperature anomalies tend to reverse this effect.

Statement 2: Inhibition of warm-water species of category, K_2, can cause a reduction in the average abundance or change the duration of the intensive reproduction period or species concentration in warm upper layers. Inhibition of cold-water species can cause a reduction in abundance and concentration in deeper water layers.

Statements 1 and 2 form a basis for the formulation and solution of problems to estimate water temperature effects on zooplankton development. This study defines the problems as follows:

Problem 1: To isolate zooplankton species most sensitive to variations in water temperature.

The definition of this problem may be extended to include the case of salinity to describe the environmental conditions:

Problem 2: To isolate zooplankton species most sensitive to variations in water salinity.

5.4 Algorithm and Results

Let us consider the algorithm for solving Problem 1. It is as follows:

- The long-term (climatic) annual mean cycle of changes in the abundance of zooplankton species, x - C_x(Climatic) - is calculated for the entire observation period based on multiple samples for every zooplankton species, x.

- In accordance with the value of annual temperature anomalies (Figure 4), a set of years is divided into years with a positive temperature anomaly, (A_{T+}), and the years with a negative temperature anomaly, (A_{T-}).
  (A_{T+}) = {1970, 1974, 1984, 1985, 1986, 1990, and 1998}
  (A_{T-}) = {1964, 1966, 1969, 1971, 1976, 1979, and 1996}
  The remaining years are those with a temperature anomaly around zero. Figure 7 shows the cycle of annual temperature variations for the sets of years A_{T+} and A_{T-} and the entire set of years.

- Annual cycles of abundance variations in zooplankton species from the database have been calculated for the set of years A_{T+} and A_{T-}. Let us designate these cycles for the zooplankton species, x, as $C_x(A_{T+})$ and $C_x(A_{T-})$, respectively.

- For every zooplankton species, the long-term mean cycle - C_x(Climatic) - has been compared with $C_x(A_{T+})$ and $C_x(A_{T-})$, respectively. According to Statement 2 the operation of comparison between these cycles consists of performing the comparison among the following characteristics of the annual cycle of zooplankton development:
  A) Annual average population abundance;
  B) Duration of the period of intensive reproduction;
  C) Structure of vertical zooplankton distribution.

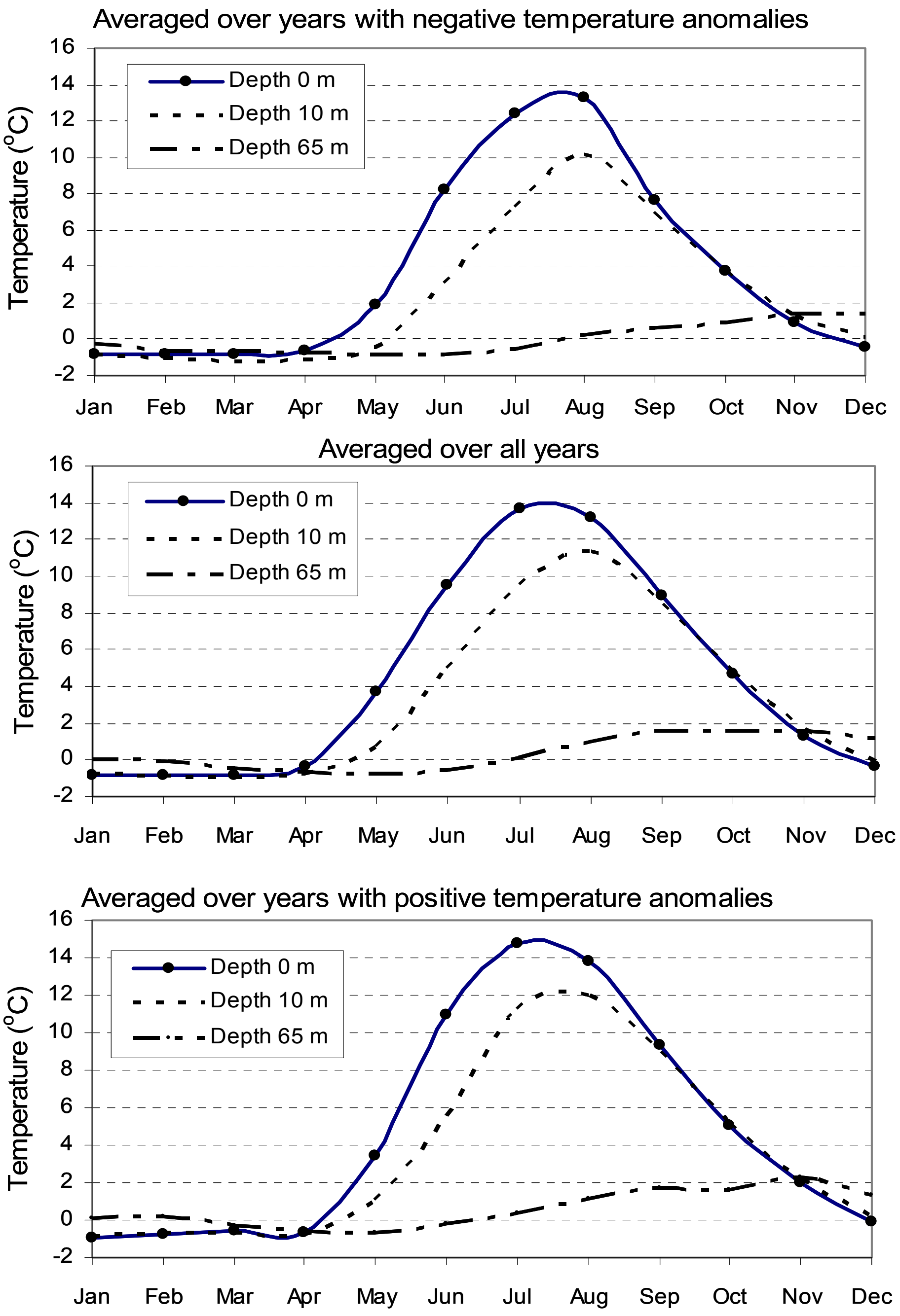


Figure 7. Climatological annual cycles of temperature.

- The zooplankton species most sensitive to water temperature variations is considered to be the one displaying maximum discrepancy among one or more of the above characteristics A, or B, or C; between both C_x(Climatic) and $C_x(A_{T+})$; and between C_x(Climatic) and $C_x(A_{T-})$. To reveal these discrepancies, it is necessary to estimate the characteristics A, B, C. It is no problem to do this for A by using the available database, but more information is required to estimate B and C for the White Sea region in particular. Therefore, we limit this study to treat only the characteristic A. In this case, the designations given above mean the following:

- C_x(Climatic) is the mean annual zooplankton abundance for species, x, calculated for all years;
- $C_x(A_{T+})$ is the mean annual zooplankton species abundance, x, calculated for those years with a positive temperature anomaly;
- $C_x(A_{T-})$ is the mean annual zooplankton species abundance, x, calculated for those years with a negative temperature anomaly.

To solve Problem 2, we may use the algorithm for Problem1 but with the introduction of slight modifications. These modifications are as follows:

- The sets of years A_{T+} and A_{T-} are substituted with A_{S+} and A_{S-}, where A_{S+} and A_{S-} are the sets of years with positive and negative annual salinity anomalies (Figure 5):
  A_{S+} = {1963, 1964, 1965, 1967, 1968, 1969, 1970, 1971, 1973, 1974, 1975, 1976, 1978}
  A_{S-} = {1979, 1981, 1982, 1983, 1984, 1985, 1987, 1990, 1992, 1994, 1998}
  The remaining years are those with a salinity anomaly around zero. Figure 8 shows the cycle of annual salinity variations for the sets of years, A_{S+} and A_{S-}, and the total set of years.

- The mechanisms of salinity effects on plankton reproduction are studied but not in as great a detail as compared to those of water-temperature effects. It makes no sense to introduce *Salinity optimum of zooplankton species* by analogy with *Temperature optimum of zooplankton species* because the biological meaning of this concept is unknown. As a result, we cannot formulate Statement 1 and Statement 2 as has been done for Problem 1. However, it is still possible to identify zooplankton species most sensitive to salinity variations. In biological terms, Problem 1 differs considerably from Problem 2.

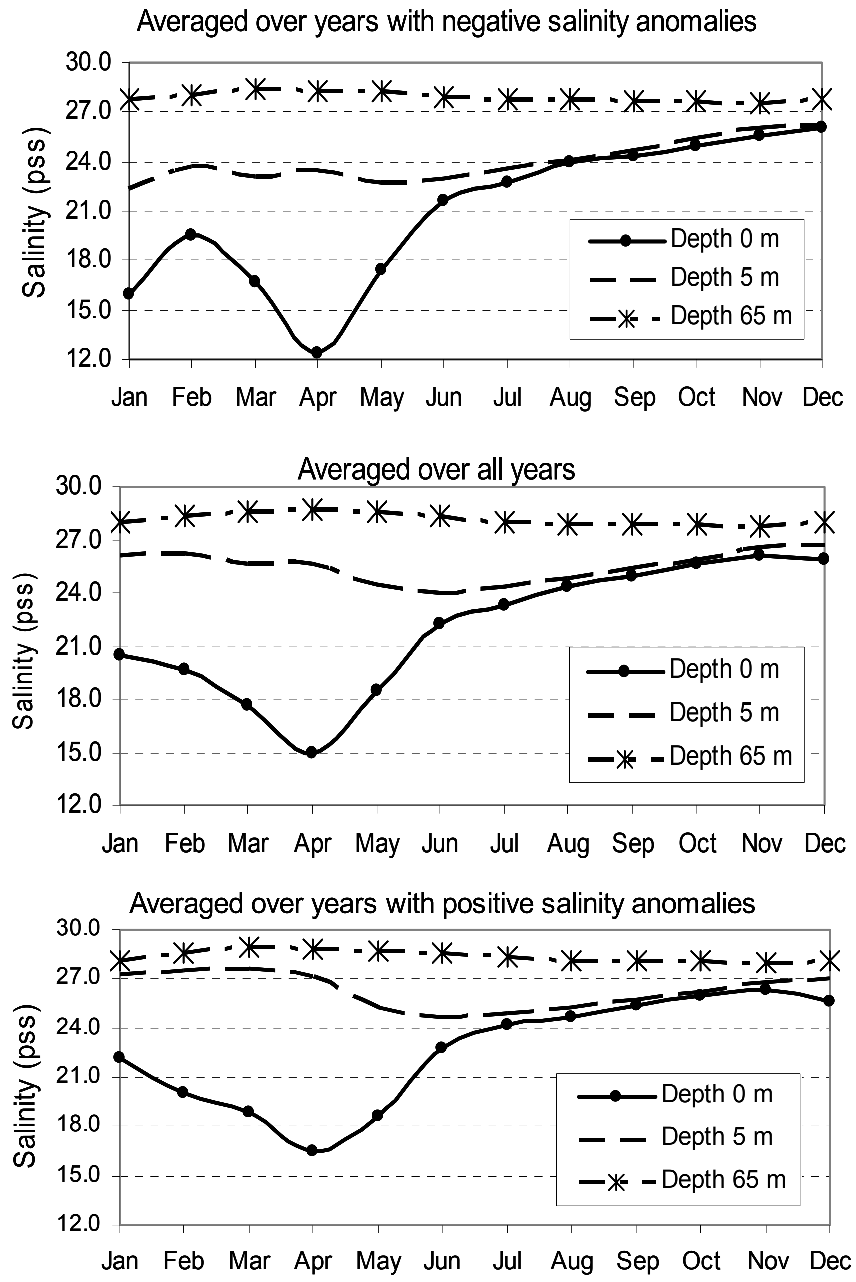
  Problem 1 is aimed at checking the hypotheses formulated as Statement 1 and Statement 2.

  Problem 2 is aimed at deriving information that may be useful when it is necessary to formulate hypotheses about salinity on the annual cycle of zooplankton development.

- The following zooplankton characteristics are calculated:
  - $C_x(A_{S+})$ is the mean annual abundance of zooplankton species, x, calculated for those years with a positive salinity anomaly;
  - $C_x(A_{S-})$ is the mean annual abundance of zooplankton species, x, calculated for those years with a negative salinity anomaly.

- The zooplankton species most sensitive to changes in water salinity is considered to be the one showing a maximum discrepancy between C_x(Climatic) and $C_x(A_{S+})$ and between C_x(Climatic) and $C_x(A_{S-})$.

The values of characteristics C_x(Climatic), $C_x(A_{T+})$, $C_x(A_{T-})$, and C_x(Climatic) and $C_x(A_{S+})$, $C_x(A_{S-})$ are presented in Table 5 and Table 6, respectively. For convenience of comparison of changes in mean annual abundances for different zooplankton species the characteristics $C_x(A_{T+})$, $C_x(A_{T-})$, $C_x(A_{S+})$, $C_x(A_{S-})$ are calculated in percentage of C_x(Climatic). These values are shown in Table 7 and Table 8, respectively. As seen in Table 7, a temperature


Averaged over years with negative salinity anomalies

Averaged over all years

Averaged over years with positive salinity anomalies

Figure 8. Climatological annual cycles of salinity.

anomaly of any sign causes a reduction in zooplankton abundance. This statement is valid for all zooplankton species from the database. During anomalous years, the total abundance of all zooplankton species is 15% relative to C_x(Climatic). For the zooplankton species most sensitive to temperature variations, the abundance decreases to 7-10% (Figure 9). This result refutes Statement 1 and Statement 2 and makes it necessary to continue studies both in terms of collecting data and developing the methods for data analysis.

Zooplankton response to changing salinity is very diverse as compared to zooplankton response to temperature variations. These diversities are divided into four categories, as can be seen in Table 8:

1. Category A includes the zooplankton species that increase their mean annual abundance as compared to C_x(Climatic) in the years with positive salinity anomaly and decrease it in the years with negative salinity anomaly.

2. Category B includes the zooplankton species that decrease their mean annual abundance as compared to C_x(Climatic) in the years with positive salinity anomaly and increase it in the years with negative salinity anomaly.

3. Category C includes the zooplankton species that increase their abundance with salinity anomaly deviation either to positive or negative values.

4. Category D includes the zooplankton species that, in practice, retain their abundance with salinity anomaly deviations from the long-term mean to positive or negative values.

Table 5. Annual abundance (#/m^3) with respect to temperature anomalies

		Annual abundance, #/m^3		
Zooplankton taxa	**Category**	Averaged over all years, C_x	Averaged over years with positive temperature anomalies, $C_x(T+)$	Averaged over years with negative temperature anomalies, $C_x(T–)$
ACARTIA LONGIREMIS Cop	Warmwater	4644	379	748
ACARTIA LONGIREMIS FemaleCop 6	Warmwater	2060	283	311
ACARTIA LONGIREMIS Juv	Warmwater	3318	283	550
ACARTIA LONGIREMIS MaleCop 6	Warmwater	1034	163	150
ACARTIA LONGIREMIS Naup	Warmwater	380	39	101
AGLANTHA DIGITALE	Warmwater	2243	190	215
ASCIDIA Larvae	Warmwater	30	18	0
BIVALVIA Larvae	Warmwater	4621	988	678
BRYOZOA Larvae	Warmwater	802	131	142
CALANUS GLACIALIS Cop 1	Coldwater	729	138	72
CALANUS GLACIALIS Cop 2	Coldwater	631	135	43
CALANUS GLACIALIS Cop 3	Coldwater	841	131	105
CALANUS GLACIALIS Cop 4	Coldwater	1196	151	206
CALANUS GLACIALIS Cop 5	Coldwater	239	24	34
CALANUS GLACIALIS MaleCop 6	Coldwater	10	0	1
CALANUS GLACIALIS FemaleCop 6	Coldwater	126	14	12
CALANUS GLACIALIS Naup	Coldwater	3993	440	286
CENTROPAGES HAMATUS Cop	Warmwater	2712	547	225
CENTROPAGES HAMATUS FemaleCop 6	Warmwater	774	143	88
CENTROPAGES HAMATUS Juv	Warmwater	2092	551	312
CENTROPAGES HAMATUS MaleCop 6	Warmwater	1249	234	138
CENTROPAGES HAMATUS Naup	Warmwater	269	74	44
CIRRIPEDIA Naup	Coldwater	1835	340	244
ECHINODERMATA Larvae	Warmwater	1876	306	288
EVADNE NORDMANNI	Warmwater	6910	1348	1153
FRITILLARIA BOREALIS	Warmwater	8877	1563	924
GASTROPODA Larvae	Warmwater	5319	717	913
METRIDIA LONGA Cop 1	Coldwater	640	35	45
METRIDIA LONGA Cop 2	Coldwater	732	26	70
METRIDIA LONGA Cop 3	Coldwater	792	54	108
METRIDIA LONGA Cop 4	Coldwater	418	33	80
METRIDIA LONGA Cop 5	Coldwater	233	29	44
METRIDIA LONGA FemaleCop 6	Coldwater	187	30	22
METRIDIA LONGA MaleCop 6	Coldwater	225	26	24
METRIDIA LONGA Naup	Coldwater	1063	138	111
MICROSETELLA NORVEGICA	Warmwater	827	159	142
MICROSETELLA NORVEGICA Cop	Warmwater	4340	583	1315
MICROSETELLA NORVEGICA Juv	Warmwater	246	32	59
MICROSETELLA NORVEGICA Naup	Warmwater	362	21	90
OICOPLEURA VANHOFFENIS.csv	Coldwater	211	12	7
OITHONA SIMILIS Cop	Warmwater	144309	21518	22068
OITHONA SIMILIS FemaleCop 6	Warmwater	57647	9486	8242
OITHONA SIMILIS Juv	Warmwater	6685	735	1423
OITHONA SIMILIS MaleCop 6	Warmwater	11546	1673	1646
OITHONA SIMILIS Naup	Warmwater	1789	173	548
ONCAEA BOREALIS Cop	Coldwater	5159	346	1726
ONCAEA BOREALIS FemaleCop 6	Coldwater	14169	1335	2201
ONCAEA BOREALIS MaleCop 6	Coldwater	3725	112	1169
PARAFAVELLA DENTICULATA	Warmwater	2540	427	292
PODON LEUCKARTI	Warmwater	2126	389	272
POLYCHAETA Larvae		2779	496	368
PSEUDOCALANUS MINUTUS Cop 1	Coldwater	16520	2367	2263
PSEUDOCALANUS MINUTUS Cop 2	Coldwater	20428	3345	2690
PSEUDOCALANUS MINUTUS Cop 3	Coldwater	44648	7959	6276
PSEUDOCALANUS MINUTUS Cop 4	Coldwater	29144	4250	4108
PSEUDOCALANUS MINUTUS Cop 5	Coldwater	26420	3055	3170
PSEUDOCALANUS MINUTUS FemaleCop 6	Coldwater	7672	966	1258
PSEUDOCALANUS MINUTUS MaleCop 6	Coldwater	1500	88	346
PSEUDOCALANUS MINUTUS Naup	Coldwater	19759	2326	3997
SAGITTA ELEGANS	Warmwater	1402	239	119
TEMORA LONGICORNIS Cop	Warmwater	9576	3233	485
TEMORA LONGICORNIS FemaleCop 6	Warmwater	5161	1488	419
TEMORA LONGICORNIS Juv	Warmwater	6229	2063	492
TEMORA LONGICORNIS MaleCop 6	Warmwater	5475	1425	467
TEMORA LONGICORNIS Naup	Warmwater	1166	223	216

Table 6. Annual abundance (#/m^3) with respect to salinity anomalies

Zooplankton taxa	**Annual abundance, #/m^3**		
	Averaged over all years, C_x	Averaged over years with positive salinity anomalies, $C_x(S+)$	Averaged over years with negative salinity anomalies, $C_x(S–)$
ACARTIA LONGIREMIS Cop	4644	7796	3611
ACARTIA LONGIREMIS FemaleCop 6	2060	2646	2426
ACARTIA LONGIREMIS Juv	3318	7129	2777
ACARTIA LONGIREMIS MaleCop 6	1034	1651	1393
ACARTIA LONGIREMIS Naup	380	1221	435
AGLANTHA DIGITALE	2243	7897	1111
ASCIDIA Larvae	30	26	210
BIVALVIA Larvae	4621	5812	4824
BRYOZOA Larvae	802	1636	1161
CALANUS GLACIALIS Cop 1	729	532	3118
CALANUS GLACIALIS Cop 2	631	607	1741
CALANUS GLACIALIS Cop 3	841	910	1496
CALANUS GLACIALIS Cop 4	1196	983	1871
CALANUS GLACIALIS Cop 5	239	161	411
CALANUS GLACIALIS MaleCop 6	10	32	19
CALANUS GLACIALIS FemaleCop 6	126	143	207
CALANUS GLACIALIS Naup	3993	2795	9949
CENTROPAGES HAMATUS Cop	2712	2243	3650
CENTROPAGES HAMATUS FemaleCop 6	774	601	1096
CENTROPAGES HAMATUS Juv	2092	2657	2557
CENTROPAGES HAMATUS MaleCop 6	1249	1298	1732
CENTROPAGES HAMATUS Naup	269	538	426
CIRRIPEDIA Naup	1835	2026	2467
ECHINODERMATA Larvae	1876	4856	814
EVADNE NORDMANNI	6910	5940	6435
FRITILLARIA BOREALIS	8877	8264	12045
GASTROPODA Larvae	5319	5255	4720
METRIDIA LONGA Cop 1	640	998	569
METRIDIA LONGA Cop 2	732	714	731
METRIDIA LONGA Cop 3	792	840	904
METRIDIA LONGA Cop 4	418	604	495
METRIDIA LONGA Cop 5	233	300	316
METRIDIA LONGA FemaleCop 6	187	210	270
METRIDIA LONGA MaleCop 6	225	235	326
METRIDIA LONGA Naup	1063	2268	1886
MICROSETELLA NORVEGICA	827	877	1968
MICROSETELLA NORVEGICA Cop	4340	7455	3735
MICROSETELLA NORVEGICA Juv	246	492	1137
MICROSETELLA NORVEGICA Naup	362	983	1031
OICOPLEURA VANHOFFENIS.csv	211	397	263
OITHONA SIMILIS Cop	144309	153596	149145
OITHONA SIMILIS FemaleCop 6	57647	51694	66332
OITHONA SIMILIS Juv	6685	12655	9898
OITHONA SIMILIS MaleCop 6	11546	10239	14906
OITHONA SIMILIS Naup	1789	4496	1603
ONCAEA BOREALIS Cop	5159	9974	4089
ONCAEA BOREALIS FemaleCop 6	14169	17111	11758
ONCAEA BOREALIS MaleCop 6	3725	8609	2934
PARAFAVELLA DENTICULATA	2540	3624	6351
PODON LEUCKARTI	2126	2487	2734
POLYCHAETA Larvae	2779	2940	4390
PSEUDOCALANUS MINUTUS Cop 1	16520	17014	30251
PSEUDOCALANUS MINUTUS Cop 2	20428	19309	31886
PSEUDOCALANUS MINUTUS Cop 3	44648	33467	62923
PSEUDOCALANUS MINUTUS Cop 4	29144	25372	33506
PSEUDOCALANUS MINUTUS Cop 5	26420	21099	26363
PSEUDOCALANUS MINUTUS FemaleCop 6	7672	7266	8736
PSEUDOCALANUS MINUTUS MaleCop 6	1500	2182	2128
PSEUDOCALANUS MINUTUS Naup	19759	28491	19417
SAGITTA ELEGANS	1402	1330	1884
TEMORA LONGICORNIS Cop	9576	10200	13507
TEMORA LONGICORNIS FemaleCop 6	5161	4415	7258
TEMORA LONGICORNIS Juv	6229	9212	5767
TEMORA LONGICORNIS MaleCop 6	5475	5776	6501
TEMORA LONGICORNIS Naup	1166	2343	990

Table 7. Annual abundance (%) with respect to temperature anomalies

		Annual abundance, %	**Annual abundance, % (relative to all years)**	
Zooplankton taxa	**Category**	Averaged over all years, C_x	Averaged over years with positive temperature anomalies, $C_x(T+)$	Averaged over years with negative temperature anomalies, $C_x(T-)$
ACARTIA LONGIREMIS Cop	Warmwater	100	8	16
ACARTIA LONGIREMIS FemaleCop 6	Warmwater	100	14	15
ACARTIA LONGIREMIS Juv	Warmwater	100	9	17
ACARTIA LONGIREMIS MaleCop 6	Warmwater	100	16	15
ACARTIA LONGIREMIS Naup	Warmwater	100	10	27
AGLANTHA DIGITALE	Warmwater	100	8	10
ASCIDIA Larvae	Warmwater	100	59	1
BIVALVIA Larvae	Warmwater	100	21	15
BRYOZOA Larvae	Warmwater	100	16	18
CALANUS GLACIALIS Cop 1	Coldwater	100	19	10
CALANUS GLACIALIS Cop 2	Coldwater	100	21	7
CALANUS GLACIALIS Cop 3	Coldwater	100	16	12
CALANUS GLACIALIS Cop 4	Coldwater	100	13	17
CALANUS GLACIALIS Cop 5	Coldwater	100	10	14
CALANUS GLACIALIS MaleCop 6	Coldwater	100	5	12
CALANUS GLACIALIS FemaleCop 6	Coldwater	100	11	10
CALANUS GLACIALIS Naup	Coldwater	100	11	7
CENTROPAGES HAMATUS Cop	Warmwater	100	20	8
CENTROPAGES HAMATUS FemaleCop 6	Warmwater	100	18	11
CENTROPAGES HAMATUS Juv	Warmwater	100	26	15
CENTROPAGES HAMATUS MaleCop 6	Warmwater	100	19	11
CENTROPAGES HAMATUS Naup	Warmwater	100	27	16
CIRRIPEDIA Naup	Coldwater	100	19	13
ECHINODERMATA Larvae	Warmwater	100	16	15
EVADNE NORDMANNI	Warmwater	100	20	17
FRITILLARIA BOREALIS	Warmwater	100	18	10
GASTROPODA Larvae	Warmwater	100	13	17
METRIDIA LONGA Cop 1	Coldwater	100	6	7
METRIDIA LONGA Cop 2	Coldwater	100	4	10
METRIDIA LONGA Cop 3	Coldwater	100	7	14
METRIDIA LONGA Cop 4	Coldwater	100	8	19
METRIDIA LONGA Cop 5	Coldwater	100	13	19
METRIDIA LONGA FemaleCop 6	Coldwater	100	16	12
METRIDIA LONGA MaleCop 6	Coldwater	100	12	11
METRIDIA LONGA Naup	Coldwater	100	13	10
MICROSETELLA NORVEGICA	Warmwater	100	19	17
MICROSETELLA NORVEGICA Cop	Warmwater	100	13	30
MICROSETELLA NORVEGICA Juv	Warmwater	100	13	24
MICROSETELLA NORVEGICA Naup	Warmwater	100	6	25
OICOPLEURA VANHOFFENIS.csv	Coldwater	100	6	3
OITHONA SIMILIS Cop	Warmwater	100	15	15
OITHONA SIMILIS FemaleCop 6	Warmwater	100	16	14
OITHONA SIMILIS Juv	Warmwater	100	11	21
OITHONA SIMILIS MaleCop 6	Warmwater	100	14	14
OITHONA SIMILIS Naup	Warmwater	100	10	31
ONCAEA BOREALIS Cop	Coldwater	100	7	33
ONCAEA BOREALIS FemaleCop 6	Coldwater	100	9	16
ONCAEA BOREALIS MaleCop 6	Coldwater	100	3	31
PARAFAVELLA DENTICULATA	Warmwater	100	17	11
PODON LEUCKARTI	Warmwater	100	18	13
POLYCHAETA Larvae		100	18	13
PSEUDOCALANUS MINUTUS Cop 1	Coldwater	100	14	14
PSEUDOCALANUS MINUTUS Cop 2	Coldwater	100	16	13
PSEUDOCALANUS MINUTUS Cop 3	Coldwater	100	18	14
PSEUDOCALANUS MINUTUS Cop 4	Coldwater	100	15	14
PSEUDOCALANUS MINUTUS Cop 5	Coldwater	100	12	12
PSEUDOCALANUS MINUTUS FemaleCop 6	Coldwater	100	13	16
PSEUDOCALANUS MINUTUS MaleCop 6	Coldwater	100	6	23
PSEUDOCALANUS MINUTUS Naup	Coldwater	100	12	20
SAGITTA ELEGANS	Warmwater	100	17	9
TEMORA LONGICORNIS Cop	Warmwater	100	34	5
TEMORA LONGICORNIS FemaleCop 6	Warmwater	100	29	8
TEMORA LONGICORNIS Juv	Warmwater	100	33	8
TEMORA LONGICORNIS MaleCop 6	Warmwater	100	26	9
TEMORA LONGICORNIS Naup	Warmwater	100	19	19

Table 8. Annual abundance (%) with respect to salinity anomalies

Zooplankton taxa	**Annual Abundance, %**	**Annual Abundance, % (relative to all years)**		**Category**
	Averaged over all years, C_x	Averaged over years with positive salinity anomalies, $C_x(S+)$	Averaged over years with negative salinity anomalies, $C_x(S-)$	
ACARTIA LONGIREMIS Cop	100	168	78	A
ACARTIA LONGIREMIS FemaleCop 6	100	128	118	C
ACARTIA LONGIREMIS Juv	100	215	84	A
ACARTIA LONGIREMIS MaleCop 6	100	160	135	C
ACARTIA LONGIREMIS Naup	100	321	114	C
AGLANTHA DIGITALE	100	352	50	A
ASCIDIA Larvae	100	85	700	B
BIVALVIA Larvae	100	126	104	C
BRYOZOA Larvae	100	204	145	C
CALANUS GLACIALIS Cop 1	100	73	427	B
CALANUS GLACIALIS Cop 2	100	96	276	
CALANUS GLACIALIS Cop 3	100	108	178	C
CALANUS GLACIALIS Cop 4	100	82	156	B
CALANUS GLACIALIS Cop 5	100	67	172	B
CALANUS GLACIALIS MaleCop 6	100	302	182	C
CALANUS GLACIALIS FemaleCop 6	100	113	164	C
CALANUS GLACIALIS Naup	100	70	249	B
CENTROPAGES HAMATUS Cop	100	83	135	B
CENTROPAGES HAMATUS FemaleCop 6	100	78	142	B
CENTROPAGES HAMATUS Juv	100	127	122	C
CENTROPAGES HAMATUS MaleCop 6	100	104	139	C
CENTROPAGES HAMATUS Naup	100	200	158	C
CIRRIPEDIA Naup	100	110	134	C
ECHINODERMATA Larvae	100	259	43	A
EVADNE NORDMANNI	100	86	93	
FRITILLARIA BOREALIS	100	93	136	
GASTROPODA Larvae	100	99	89	D
METRIDIA LONGA Cop 1	100	156	89	A
METRIDIA LONGA Cop 2	100	98	100	D
METRIDIA LONGA Cop 3	100	106	114	C
METRIDIA LONGA Cop 4	100	145	118	C
METRIDIA LONGA Cop 5	100	128	135	C
METRIDIA LONGA FemaleCop 6	100	112	144	C
METRIDIA LONGA MaleCop 6	100	104	145	C
METRIDIA LONGA Naup	100	213	177	C
MICROSETELLA NORVEGICA	100	106	238	C
MICROSETELLA NORVEGICA Cop	100	172	86	A
MICROSETELLA NORVEGICA Juv	100	200	462	C
MICROSETELLA NORVEGICA Naup	100	272	285	C
OICOPLEURA VANHOFFENIS.csv	100	188	125	C
OITHONA SIMILIS Cop	100	106	103	D
OITHONA SIMILIS FemaleCop 6	100	90	115	B
OITHONA SIMILIS Juv	100	189	148	C
OITHONA SIMILIS MaleCop 6	100	89	129	B
OITHONA SIMILIS Naup	100	251	90	A
ONCAEA BOREALIS Cop	100	193	79	A
ONCAEA BOREALIS FemaleCop 6	100	121	83	A
ONCAEA BOREALIS MaleCop 6	100	231	79	A
PARAFAVELLA DENTICULATA	100	143	250	C
PODON LEUCKARTI	100	117	129	C
POLYCHAETA Larvae	100	106	158	C
PSEUDOCALANUS MINUTUS Cop 1	100	103	183	C
PSEUDOCALANUS MINUTUS Cop 2	100	95	156	
PSEUDOCALANUS MINUTUS Cop 3	100	75	141	B
PSEUDOCALANUS MINUTUS Cop 4	100	87	115	B
PSEUDOCALANUS MINUTUS Cop 5	100	80	100	
PSEUDOCALANUS MINUTUS FemaleCop 6	100	95	114	D
PSEUDOCALANUS MINUTUS MaleCop 6	100	145	142	C
PSEUDOCALANUS MINUTUS Naup	100	144	98	
SAGITTA ELEGANS	100	95	134	
TEMORA LONGICORNIS Cop	100	107	141	C
TEMORA LONGICORNIS FemaleCop 6	100	86	141	B
TEMORA LONGICORNIS Juv	100	148	93	A
TEMORA LONGICORNIS MaleCop 6	100	105	119	
TEMORA LONGICORNIS Naup	100	201	85	A

Figure 9 shows the diagrams of the abundance dynamics for those zooplankton species that considerably change their mean annual abundances with temperature and salinity deviation from the long-term mean. As seen, temperature and salinity variations cause a 10- to 12-fold and 1.5- to 4.3-fold change, respectively, in zooplankton abundance. This leads us to the conclusion that in the White Sea region under consideration, zooplankton is more sensitive to temperature rather than salinity variations. Zooplankton species *CALANUS GLACIALIS Naup.* is most sensitive to changes both in temperature and salinity.

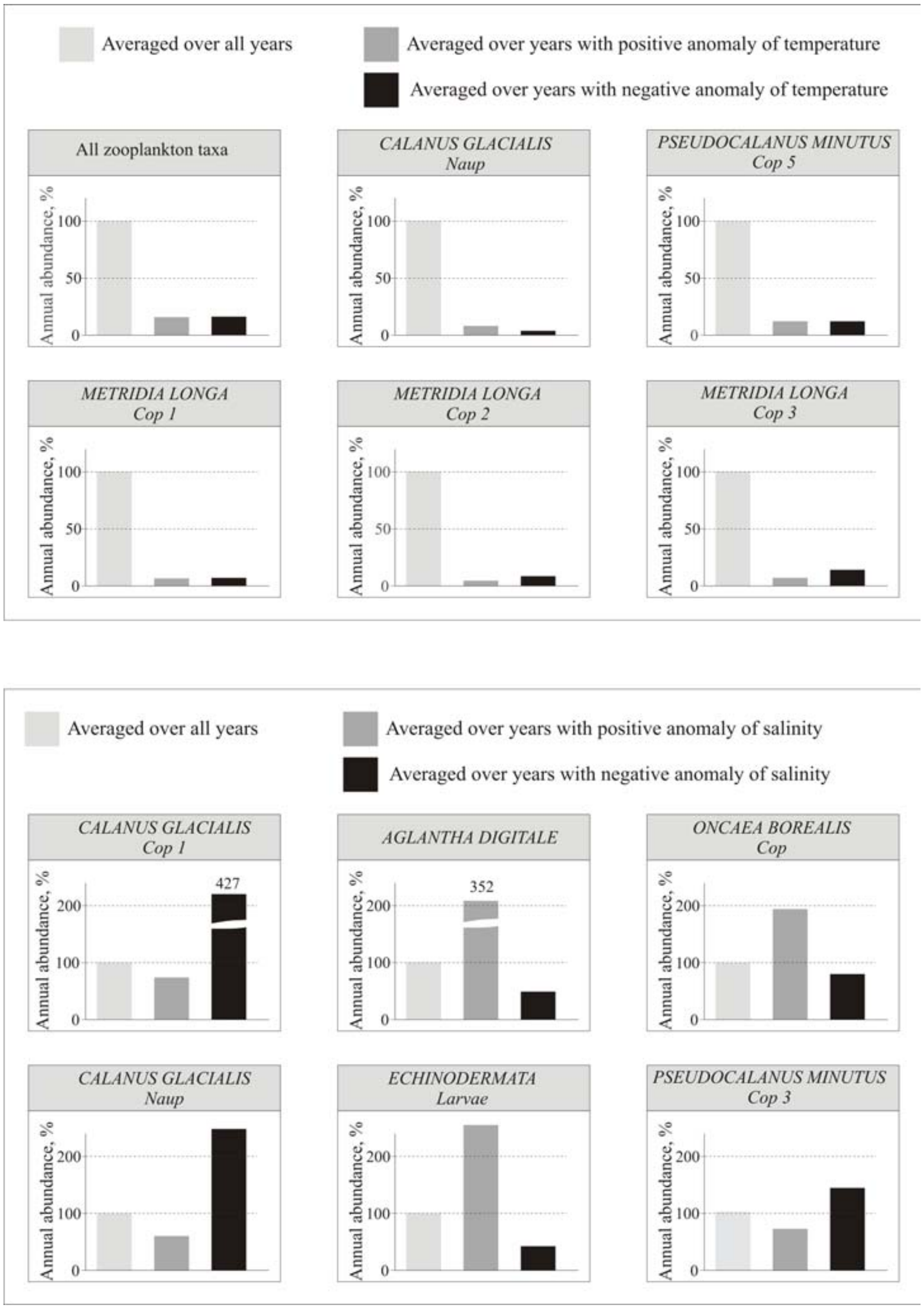


Figure 9. The effect of temperature and salinity variations on zooplankton abundance.