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INFLOW OF RIVER WATER TO THE BALTIC SEA IN THE PERIOD 1951-1960

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The inflow of river water to the Baltic Sea is evaluated for the period 1951–60. A proposal is made for a re-evaluation of the estimates for earlier periods and for future computations on a continuous basis.

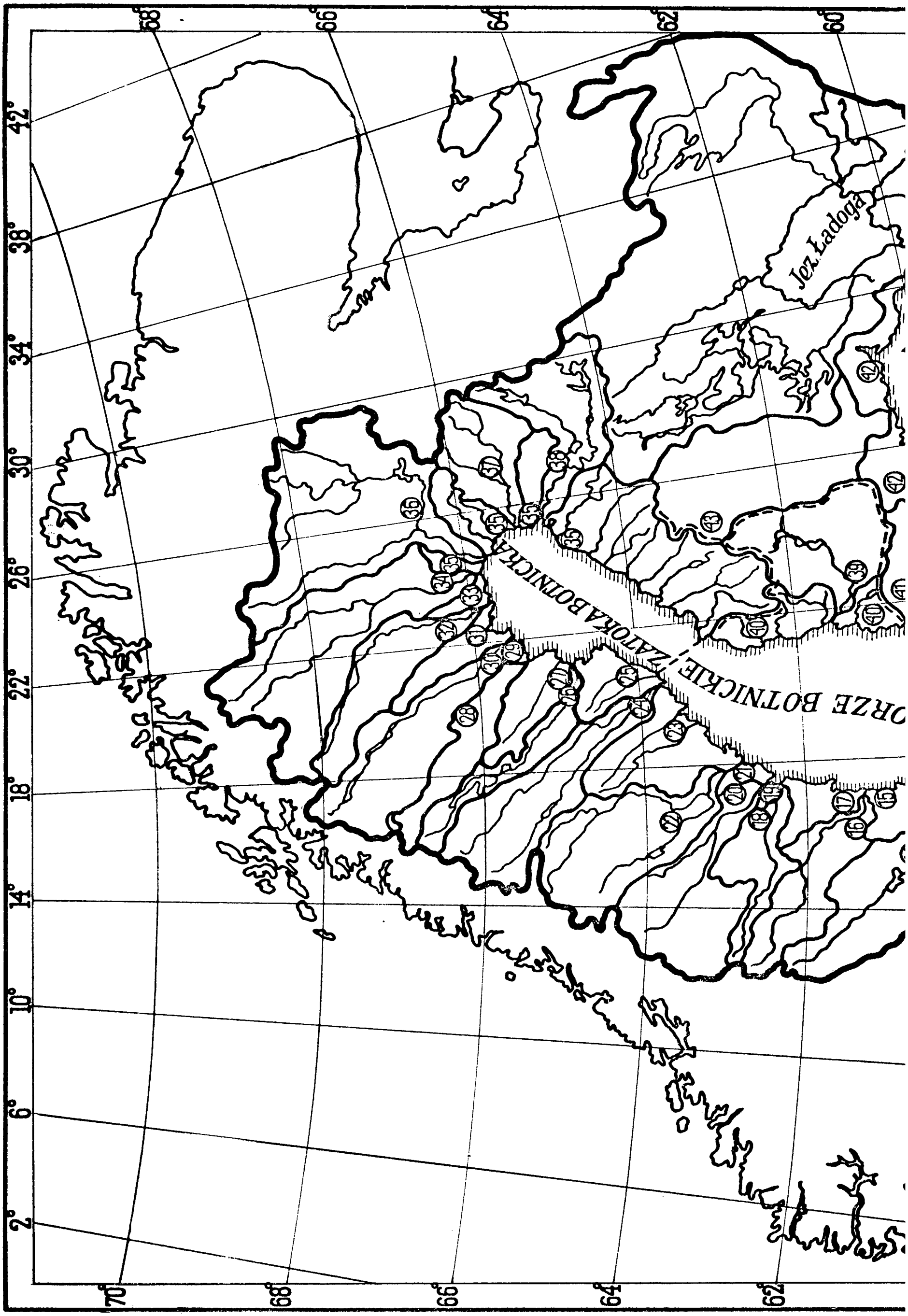
The water balance of the Baltic Sea was the object of discussions already half a century ago (Spethmann 1933, Witting 1918), but the initiation of scientific research was a result of the Hydrologic Conferences of the Baltic States. At the third conference in 1930, Rundo (1936) presented a report on "Determination of the inflow of river waters to the Baltic" in which he requested the hydrographic institutions to undertake systematic investigations on the volume of water discharging into the Baltic Sea. A resolution stressing the necessity of research into all elements of the water balance was agreed upon; but only at the fifth conference in 1936 was the decision taken to collect the balance data for the period 1921–1930. Some tentative balance sheets (Rundo 1936, Schulz 1938, Slaucitajs 1938) were subsequently elaborated. Further work was impeded by the outbreak of World War II and it was only several years later that the first water balance studies of the Baltic appeared, based on measurements and computated data (Brogmus 1952, Simojoki 1949, Wüst 1952, Wyrtki 1954). Most authors pointed out the difficulties in the determination of river outflow owing to lack of measurement and observation material, and Wüst (1952) stressed the necessity of further systematic balance investigations for proper evaluation of inadequately determined elements and for the study of the seasonal variation of the water circulation.

This work was taken over and continued by the Conference of Baltic Oceanographers. At the fifth conference in 1966, the Polish participants (Lisitzin 1966) reported the computation results on inflow of river waters from Polish territory during the period 1951–1960, pointing out the necessity of continuous estimates of river inflow to and the water balance of the Baltic, and they also presented their recomputations on the basis of homogenous observations. Their recommendation was accepted by the Conference, and the collection of data was undertaken by Poland. Because all the Baltic countries were favourable to the project, it was possible to collect complete data on stream-flow discharges into the whole Baltic basin for the period 1951–1960.

The data supplied by the different Baltic countries were used to prepare a chart of the Baltic Basin, giving special consideration to the major catchment areas gauged by hydrological stream flow stations (Fig. 1) and containing a list of inflow volumes from them. The total Baltic Basin covers an area of 1.649.500 km^2, a value which does not differ much from that given by Brogmus (1.634.000 km^2). The following regions of the Baltic have been used in the present paper: Gulf of Bothnia (Zatoka Botnicka) and Bothnian Sea (Morze Botnickie), Gulf of Finland (Zatoka Fińska), Gulf of Riga (Zat. Ryska), and the rest being called the Central Baltic. The area and storage volume of these regions were taken after Witting (1918) with later alterations by Slaucitajs (1938).

The volume of the inflow of river water was calculated from the discharges of the major rivers at their mouths. The inflow from ungauged basins was estimated using unit flow values in neighbouring basins. The basin areas and the river flow volumes are given in Table 1.

The unit discharge for the Gulf of Bothnia and the Bothnian Sea is as high as 12 l/sec/km^2. The total annual inflow to the Gulf of Bothnia is 185 km^3, corresponding to a water layer of 180 cm in the Gulf and to 2.8 per cent of the water volume in the Gulf of Bothnia. The largest inflow is received by the Gulf of Finland, mainly through the Neva. Although runoff in the basin is somewhat below 9 l/sec/km^2, the total inflow reaches 118 km^3, giving a 400-cm water layer and over 10 per cent of the water volume of the Gulf. Relatively large amounts of water are received by the Gulf of Riga (32 km^3 inflow corresponding a 200-cm water layer); and although runoff is less than 8 l/sec/km^2, it fills, due to its relatively small storage volume, at an annual rate of 6.5 per cent. The remaining central part of the Baltic has a much smaller inflow of river water; the runoff of this basin hardly reaches 5.7 l/sec/km^2. Although this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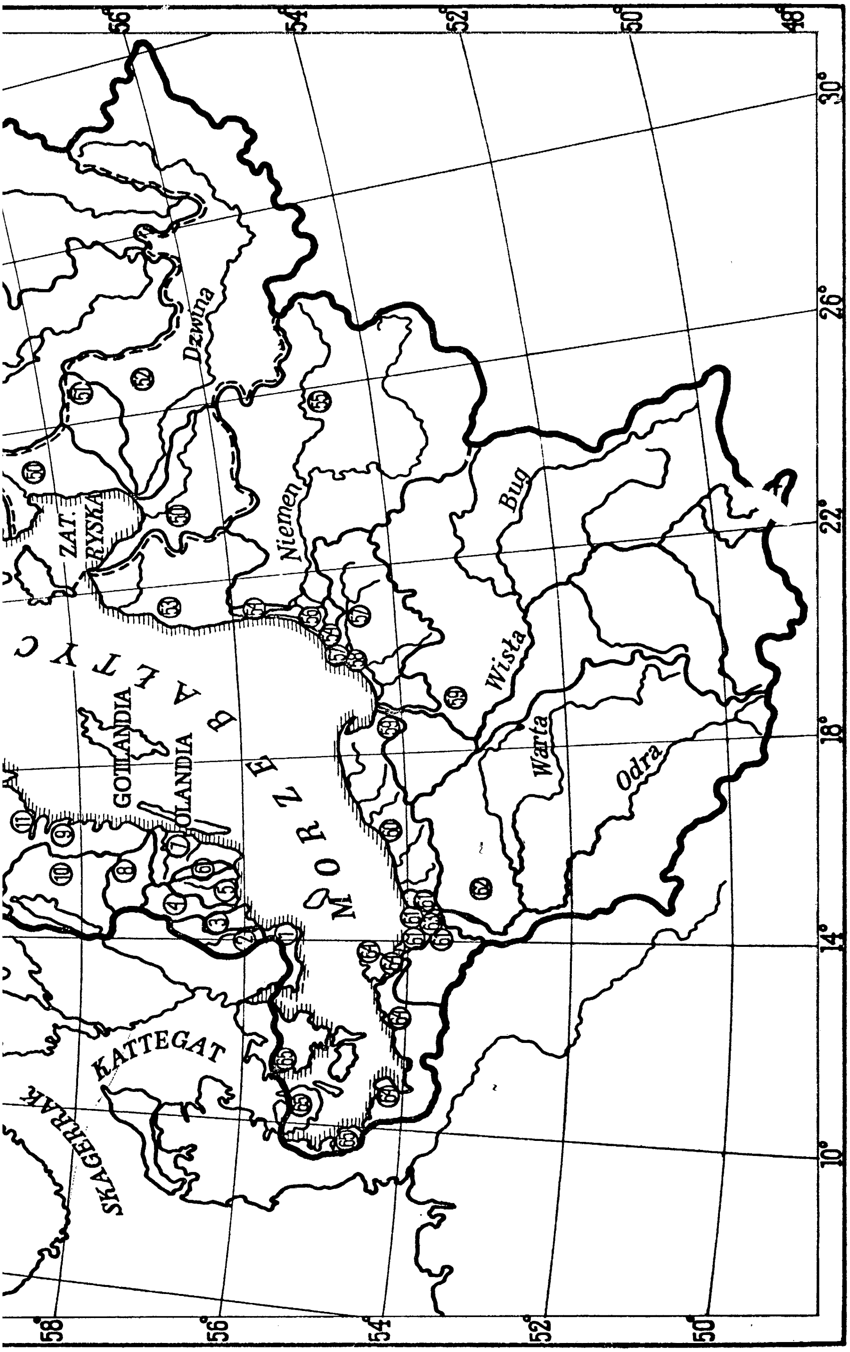

Fig. 1.
Baltic drainage basins. For translation of the names given on the map, see Fig. 2. For river names, see Table 1.

Table 1.
River basin areas and discharges of stream flow into the Baltic Sea

Basin	No. of field	Area (km²)	Q (m³/sec)	q (l/sec km²)
		Gulf of Bothnia		
Umeälv-Skellefteälv	25	6.170	62	10.0
Skellefteälv	26	11.640	148	12.7
Skellefteälv-Piteälv	27	7.700	86	11.2
Piteälv	28	11.210	156	13.9
Piteälv-Luleälv	29	1.670	17	10.1
Luleälv	30	25.250	477	18.9
Luleälv-Kalixälv	31	6.360	64	10.0
Kalixälv	32	23.580	298	12.6
Kalixälv-Torneälv	33	2.000	22	11.0
Torneälv (Tornionjoki)	34	40.000	444	11.1
Tornionjoki-Merenkurkku	35	45.665	456	10.0
Kemijoki	36	51.400	581	11.3
Iijoki	37	14.385	181	12.6
Oulujoki	38	22.925	232	10.1
Total		269.955	3.224	11.8
		Bothnian Sea		
Norrtäljeån-Dalälven	13b	4.500	31	6.88
Dalälven	14	29.040	340	11.7
Dalälven-Ljusnan	15	5.040	43	8.53
Ljusnan	16	19.820	230	11.6
Ljusnan-Ljungan	17	5.380	50	9.29
Ljungan	18	12.840	131	10.2
Ljungan-Indalsälven	19	610	6	9.99
Indalsälven	20	26.740	420	15.7
Indalsälven-Ångermanälven	21	1.500	15	10.0
Ångermanälven	22	31.890	465	14.6
Ångermanälven-Umeälv	23	15.340	160	10.4
Umeälv	24	26.730	400	15.0
Merenkurkku-Lakalahti	40	13.385	119	8.88
Kokemäenjoki	39	27.100	224	8.26
Total		219.915	2.634	12.0
Bothnian Sea including Gulf of Bothnia		489.870	5.858	12.0

Table 1 continued

Basin	No. of field	Area (km^2)	Q (m^3/sec)	q ($l/sec\ km^2$)
		Gulf of Finland		
Hanko-Newa (Hanko-Neva)	42	19.460	189	9.71
Kymijoki	43	37.230	309	8.30
Newa (Neva)	44	281.100	2.600	9.25
Newa-Narwa (Neva-Narva)	45	4.310	43	10.0
Luga (Luga)	46	13.010	97	7.46
Narwa (Narva)	47	56.190	403	7.18
	48	9.690	97	10.0
Total		420.990	3.738	8.88
		Gulf of Riga		
Virtsu-Kalkasrags	50	34.160	256	7.50
Gauja	51	8.900	82	9.16
Dźwina (Daugava)	52	87.900	688	7.83
Total		130.960	1.026	7.89
		Central Baltic		
Öresund-Helgeån	1	1.890	16	8.46
Helgeån	2	4.780	55	11.5
Helgeån-Mörrumsån	3	1.460	13	8.90
Mörrumsån	4	3.380	27	7.99
Mörrumsån-Lyckebyån	5	3.140	22	7.00
Lyckebyån	6	850	6	7.06
Lyckebyån-Emån	7	4.730	33	6.98
Emån	8	4.460	31	6.95
Emån-Motalaström	9	6.180	37	5.99
Motalaström	10	15.470	97	6.27
Motalaström-Mälaren	11	7.450	49	6.58
Mälaren	12	22.600	173	7.65
Mälaren-Norrtäljeån	13[a]	1.900	13	6.88
Lakalathi-Hanko	41	9.780	91	9.30
Gulf of Finland-Gulf of Riga	49	4.000	40	10.0
Gulf of Riga-Kurishes Gulf	53	19.870	199	10.0
Direct basin of the Kurishes Gulf and the Baltic	54	2.150	21	10.0
Neman	55	98.200	674	6.86

Table 1 continued

Basin	No. of field	Area (km²)	Q (m³/sec)	q (l/sec km²)
Waters of the Kurishes Gulf	56	1.610	–	–
Taran-Vistula cape	57	23.600	117	4.95
Waters of the Vistula Gulf	58	840	–	–
Vistula	59	193.910	954	4.92
Vistula-Szczecin Gulf	60	17.240	142	8.43
Direct basin of the Szczecin Gulf and the Baltic	61	11.350	45	4.00
Odra	62	118.610	464	3.91
Waters of the Szczecin Gulf	63	910	–	–
Szczecin Gulf-Flensburg	64	16.960	68	4.00
Danish coast of the Baltic	65	10.410	51	4.90
Total		607.730	3.438	5.69
		Baltic Sea		
Gulf of Bothnia		269.955	3.224	11.8
Bothnian Sea		219.915	2.634	12.0
Gulf of Finland		420.990	3.738	8.88
Gulf of Riga		130.960	1.026	7.89
Central Baltic		607.730	3.438	5.69
Baltic Sea, Total		1.649.550	14.060	8.52

gives a water mass of 110 km³, the resulting layer in the sea is somewhat less than 50 cm and the water exchange is below 1 per cent.

Altogether the Baltic Sea received in the period 1951–1960 about 440 km³ of water (14.000 m³/sec), that is, 92 per cent of the amount obtained by the computations based upon data available at Fifth Hydrologic Conference of the Baltic States. This is equivalent to a 115-cm water layer in the sea, or 10 cm less than in previous computations. The annual discharge into the Baltic corresponds to 2 per cent of the total water volume. The lower values of river discharge presented here may be partly due to more accurate calculations, but are certainly mainly caused by the observed diminution of precipitation in the southern part of the basin. Studies recently made in Poland indicate that the discharge in the period 1951–1960 was several per cent below the long-term average. Compared

Table 2.
Annual exchange of river water in the Baltic Sea

Part of the Baltic Sea	Area (F, km^2)	Volume (V, km^3)	Inflow of river water			Exchange %
			m^3/sec	km^3	cm	
Gulf of Bothnia (including the Bothnian Sea)	103.600	6.500	5.858	184.8	178	2.8
Gulf of Finland	29.500	1.100	3.738	117.9	400	10.7
Gulf of Riga	16.700	500	1.026	32.4	194	6.5
Central Baltic	236.000	12.400	3.438	108.5	46	0.9
Baltic Sea	385.800	20.500	14.060	443.6	115	2.2

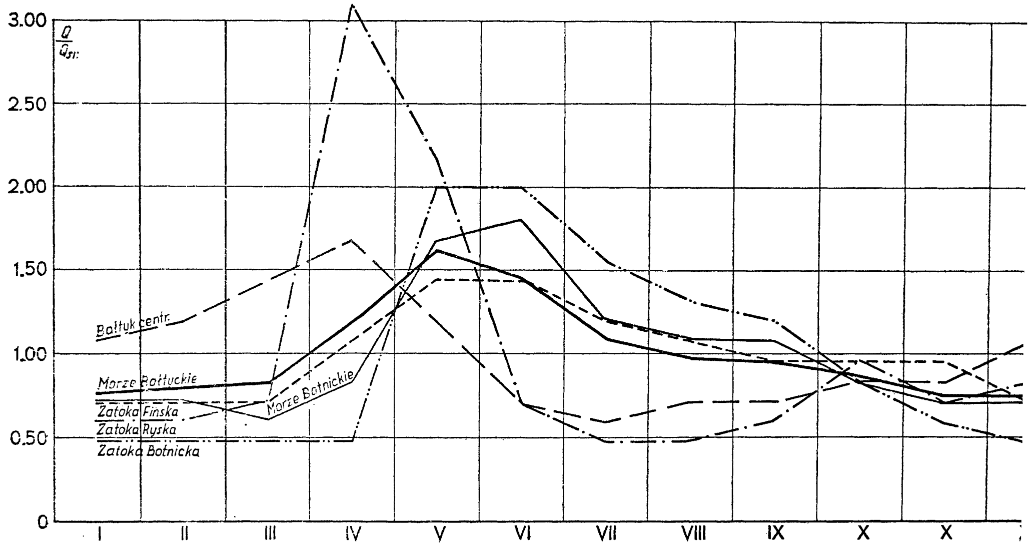

Fig. 2.

Seasonal variation of the inflow of river water to the Baltic basin.
Baltyk centr.: Central Baltic; Morze Baltyckie: the Baltic Sea; Zatoka Finska: Gulf of Finland; Morze Botnickie: Bothnian Sea; Zatoka Ryska: Gulf of Riga; Zatoka Botnicka: Gulf of Bothnia.

with the interwar period, the decrease was 5 per cent for the Vistula and 10 per cent for the Odra (Stachy 1968).

It is only now possible to evaluate the seasonal variation of river inflow to different Baltic regions (Table 3). Among other features, attention should be given to the delay of maximum inflow (meltwater) and its shift in a north-eastern direction. The inflow of meltwater causes the highest runoff in the western part of the Baltic as early as March, in the central part in April. In the Gulf of Riga the maximum is shifted to May. The Gulf of Finland is characterized by uniform maximum inflow in May and June. In the Bothnian Sea and the Gulf of Bothnia the situation is approximately similar, though a considerable part of the maximum inflow occurs there as late as July. The inflow minimum, which in the central part of the Baltic occurs in summer (July-August), shifts in the northern part to fall and winter (November-March). This shift of the inflow produces a more uniform supply of river water to the sea. Therefore the outflow of spring water from the Baltic to the North Sea starts first in the central part of the Baltic and then from the Gulf of Finland and the Gulf of Bothnia (Fig. 2).

Table 3.
Seasonal variation of river inflow to the Baltic Sea (%)

Part of the Baltic Sea	Area (km^2)	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Gulf of Bothnia (including the Bothnian Sea)	489.870	5	5	4	5	16	16	12	10	10	7	5	5
Gulf of Finland	420.990	6	6	6	9	12	12	10	9	8	8	8	6
Gulf of Riga	130.960	5	5	6	26	18	6	4	4	5	8	6	7
Central Baltic	607.730	9	10	12	14	9	6	5	6	6	7	7	9
Baltic Sea	1.649.550	6	7	7	10	14	12	9	8	8	7	6	6
km^3		27	31	31	44	62	53	40	35	35	31	27	27

Taking into consideration the whole Baltic Sea, we observe the greatest inflow of stream water in spring (April-June) with a maximum in May (14 per cent). Minimum inflow, amounting to 50 per cent of the maximum values, occurs in winter (November-January), i. e. at the period of dominant sea storms. The foregoing allows some conclusions of a general nature.

1. The water balance of the Baltic has to be up-dated by a recomputation of all its components for a uniform balance period. The calculations should be based on morphometric data and a detailed hydrographic division of the whole basin.

2. The magnitudes of water exchange between sea and atmosphere (precipitation and evaporation) must re-evaluated and a method developed for their continuous determination.

3. Continuous information on the volume of the inflow of river water to the Baltic and to its separate regions has to be secured as well as data on the mean sea-level.

4. Reliable estimations of the inflow volume of ocean water to the Baltic are required for an effective study of the balance period, and procedures should be developed for continuous determination of its magnitude.

5. Since the water balance of the Baltic forms the basis for all future research, it must be determined continuously by estimation of its components from data supplied by all the Baltic countries.

6. The work requires distribution of the tasks among the countries and a single centre for the collection and co-ordination of the whole material.

The realization of these proposals is necessary for further research of the Baltic, as planned in the program for the Baltic Year, and for the full and rational economic utilization of this sea.

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