AMOUNT OF WATER, ENERGY AND HEATING THAT IS BROUGHT BY ESTONIAN RIVERS TO THE BALTIC SEA.

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CONTENT

ABSTRACT

This work was done in the framework of the Baltic Sea Experiment (BALTEX) and has the following objectives:

- to provide on estimation of long-term amount of water, energy and heat input by Estonian rivers to the Baltic Sea;
- to create an approximate model for long-term conveyance of water, energy and heat input as a basis for every year estimation of such input to the Baltic Sea;
- to use this model and its results as a basis for future suspention, hydrochemical and biological input estimation.

1. METHODOLOGY

Basically, the applied method can be identified as the **area-separation method**.
It is described as the following:

- the coastline of Estonia with the three main islands (Saaremaa, Hiiumaa and Muhu) has been divided into sections so that each one is not more than 10-20 km;
- for each section the number of crossing streams (rivers, springs and channels) and their catchment area in the very mouth have been estimated in accordance with the "List of Estonian rivers and their watersheds" (Arukaevu,1980);
- for each stream the slope size, long-term month water discharge, water velocity and temperature have been estimated using existing maps, observation data, results of field hydrographical investigations and descriptions of thermo- and water regimes;
- for each section (plot) of coastline the total catchment area, water, energy and heat input have been obtained;

- for Finnish and Riga Bay sections the total amount of catchment area, water, energy and heat input from Estonia to the Baltic Sea have been obtained.

The number of coastline sections is 97 cuts for the whole of Estonia and islands. The coastline of Finnish Bay catchment was divided into 30 plots. All other 67 plots belong to Riga Bay coastline (fig.1).

The total list of streams from 79 820 km² including the Narva river contains 184 rivers, springs and drainage channels which flow over the Estonian coastline (Estonian area is equal to 45 215 km²) to the Baltic Sea. The catchment area of the smallest stream is equal to 2 km².

The total catchment area of Estonian rivers belonging to the Finnish Bay is equal to 64 817 km² including the Narva river (56 225 km²), this amounts to 81.2% of the Estonian portion in the Baltic Sea watershed. This total watershed belongs to 61 streams.

The total catchment area of Riga Bay amounts to 15 003 km² which is equal to 18.8% of total catchment area. The correlation between the Finnish and Riga watersheds without the Narva river's catchment is 36.4% and 63.6% respectively.

2. THE WATER INPUT ESTIMATION

The water volume is a basis for energy and heat amounts, so this must be considered first.

The long-term (1961-90) water volume per month (m³) was obtained for every plot (section) by the following equations:

$$Wp = t \cdot Qp,$$
$$Qp = SumQi,$$
$$Qi = Fi \cdot Mg \text{ or } Fi \cdot Mu,$$

where Wp - amount of water per month, m³;
t - amount of seconds in the month;
Qp - total discharge of all rivers crossing any plot subline, m³/s;
Qi - water discharge of any river crossing plot subline, m³/s;
Fi - catchment area of any river crossing plot subline, km²;
Mg - specific discharge of gauged river, $m^3 \cdot s^{-1} \cdot km^{-2}$;
Mu - specific discharge of unknown river, $m^3 s^{-1} \cdot km^{-2}$.

The specific yield for the very mouth of gauged rivers was assumed as the same for downstream gauged portion of any river due to absence of M = f(F) ratio as a rule on this part of Estonia (Eipre,1972). To obtain the specific yield of unknown or partially known rivers the analogy and regression method was used.

Amount of water, energy and heating that is brought by Estonian rivers to the Baltic Sea

The total year mean discharge is equal to 580 m^3/s, the Finnish Bay portion composes 442 m^3/s (with the Narva river) and 76.9 m^3/s (without the Narva river), which are the 78% and 37% of total Estonian discharge to the Baltic Sea; the Riga Bay portion amounts to 138 m^3/s (22% and 63% respectively).

The Finnish Bay coast is characterised by more or less equal water volume along its line (excluding the Narva river). There are two large water issues on the Riga Bay coast - Kasari and Pärnu rivers.

The correlation between total water volumes from two examined watersheds (1961-90) is just the same as between their catchment areas (fig.2).

The month distribution (fig.3) of water volume shows that total flow to the Finnish Bay is very regulated by Peipsi lake (Narva river) and redistributed by karst events from the March-May to May-July periods.

3. THE ENERGY INPUT ESTIMATION

The long-term (1961-90) monthly water kinetic energy (work, J) which is carried out through every section was obtained in accordance with (Shahhov,1980) by the following equation:

$$Ep = t \cdot d \cdot g \cdot Sum(Qi \cdot I \cdot L),$$

where Ep - amount of energy carried out by rivers crossing any plot subline, J;

- I - water surface slope on the river mouth, ‰;
- d - specific water density (=1000), kg/m^3;
- g - specific gravitation factor (=9.8), m/s^2;
- L - length of the river plot which is quantitatively equal to the water velocity, m.

The slope size was defined by map for river plot which has the largest discharge (in the borders of rounding). For each month the same slope was used independent of the sea level. For unknown rivers the water velocity was obtained from the V = f(I) ratio that was built using known river data.

The total amount of energy that was obtained during the 1961-90 period is equal to 1 867 GJ. Without the Narva river this amounts to 1 833 GJ. The energy which is brought by Narva river is so little (0.4%) due to its slope size in the very mouth of river. This is 0.00002, other rivers have 0.001-0.006 range of the slope size. So the mean correlation between Finland Bay and Riga Bay portions are 78% and 22% independent of that if Narva river is taking into account or not.

In spite of the very small slope of Narva river the majority of rivers belonging to the Finland Bay have a far larger slope size than Riga Bay rivers due to near coastal landforms. So the Finland Bay rivers bring out to the Baltic Sea more energy than Riga Bay rivers (fig.4).

The month distribution of energy input has just the same correlation between Finnish and Riga portions of energy either if Narva is taken into account or not. On the October-April period the Finland Bay portion amounts to 73-78%, and on the May-September period it is characterised by 83-87% of total energy that is brought to the Baltic Sea.

4.THE HEAT INPUT ESTIMATION

The long-term (1961-90) mean input of heat (Hp, J) per month over any coastline section was obtained in accordance with (Vikulina,1972) by the following equation:

$$Hp = 4{,}19 \cdot t \cdot c \cdot d \cdot Sum(Qi \cdot Ti),$$

where Hp - amount of heating that is brought by rivers crossing any plot subline, J or $kg \cdot m^2 \cdot s^{-2}$;

Ti - month mean of water temperature of calculated stream, °C;

c - specific heat of water, $m^2 \cdot s^{-2} \cdot °C^{-1}$;

d - water density, (=1000) kg/m^3;

4,19 - the ratio between calories and joules (1cal = 4,19J).

To use this equation for total heat estimation the following conditions were assumed:

- the density of water is taken to be equal to 1000 kg/m^3 independently on water temperature;
- the specific heat of water is equal to 2095 $m \cdot s^{-2} \cdot °C^{-1}$ for any water temperature;
- 0°C volume of the water temperature was assumed as 0.01°C;
- the sea level fluctuation and heat changing from sea were not taken into account.

The water temperature for unknown rivers was taken by analogy.

Due to absence of daily and monthly database for water temperature the long-term monthly means were used and so decadely amounts of heat input have not been obtained.

The total heat input from Estonia to the Baltic Sea amounts to 271 351 $\cdot 10^{12}$ J and to 79 382 $\cdot 10^{12}$J per year with Narva river and without respectively. Distribution of heat input along coastline of Estonia is very similar to the water distribution. Correlation between Finnish and Riga Bay portions is equal to 76% and 24%, if the Narva river is taken in account, and 40% and 60% without Narva r.

Monthly distribution of the total heat input to the Baltic Sea (fig.5) shows that without Narva river heating the portion of Finnish Bay amounts to the largest value (59%) in February and the smallest one (33%) in April, October and November. In the warm months the rivers of Riga Bay are heated more than those of Finnish Bay due to their more southern location.

RESULTS

The approximate model for the long-term water, energy and heat input from Estonia to the Baltic Sea was considered.

For the first time the total long-term (1961-90) water, energy and heat input have been obtained.

Year mean of water input to the Baltic Sea is equal:

to the Finnish Bay:

with the Narva r. - 13 947 mln.m^3,

without the Narva r. - 2 425 mln.m^3,

to the Riga Bay: - 4 343 mln.m^3,

total:

with the Narva r. - 18 290 mln.m^3,

without the Narva r. - 6 768 mln.m^3.

Year mean of kinetic energy input to the Baltic Sea is equal:

to the Finnish Bay:

with the Narva r. - 48 342 mln.J,

without the Narva r. - 47 213 mln.J,

to the Riga Bay: - 13 414 mln.J,

total:

with the Narva r. - 61 757 mln.J,

without the Narva r. - 60 628 mln.J.

Year mean of heat input from Estonian rivers to the Baltic Sea is equal:

to the Finnish Bay:

with the Narva r. - 220 781$\cdot 10^{12}$J,

without the Narva r. - 28 812$\cdot 10^{12}$J,

to the Riga Bay: - 50 570$\cdot 10^{12}$J,

total:

with the Narva r. - 272 351$\cdot 10^{12}$J,

without the Narva r. - 79 382$\cdot 10^{12}$J.

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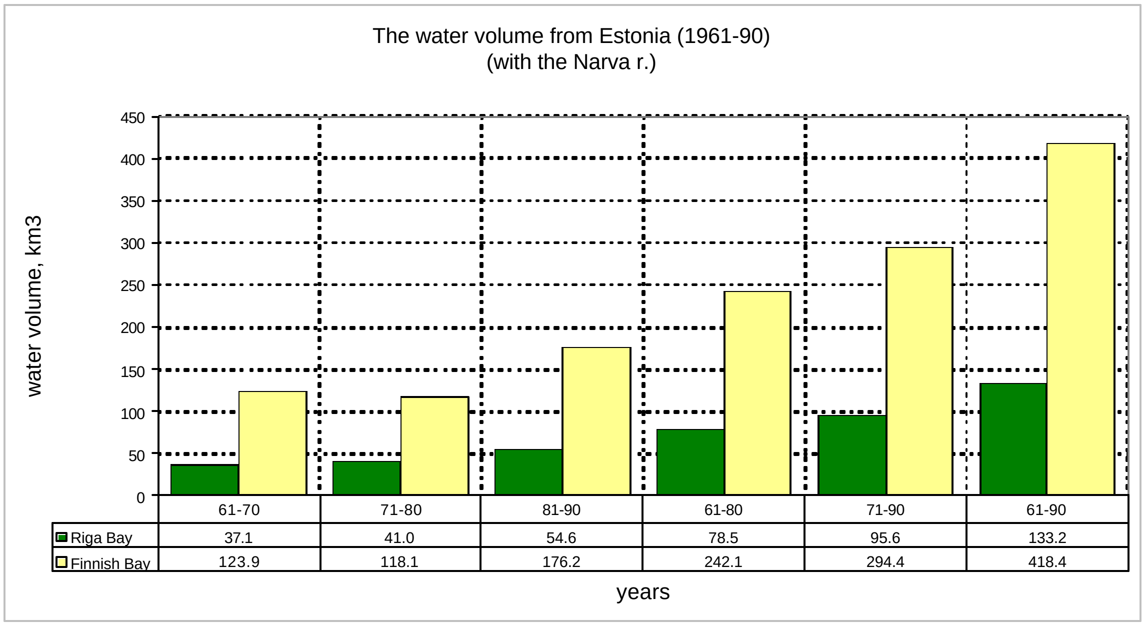
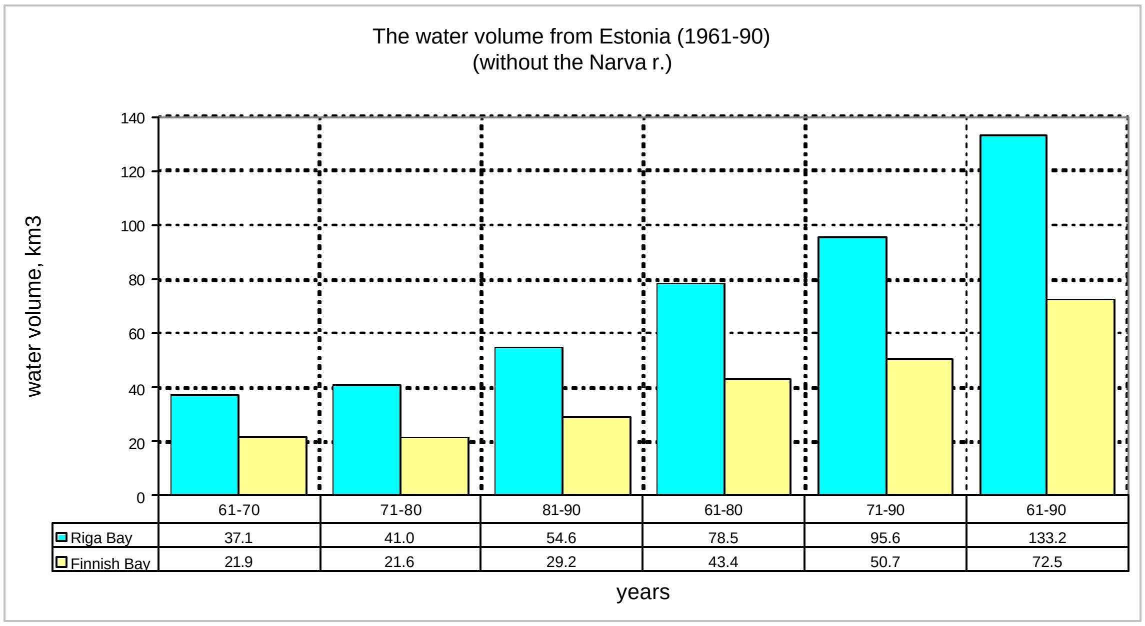


	61-70	71-80	81-90	61-80	71-90	61-90
Riga Bay	37.1	41.0	54.6	78.5	95.6	133.2
Finnish Bay	123.9	118.1	176.2	242.1	294.4	418.4



	61-70	71-80	81-90	61-80	71-90	61-90
Riga Bay	37.1	41.0	54.6	78.5	95.6	133.2
Finnish Bay	21.9	21.6	29.2	43.4	50.7	72.5

Fig. 2. Decade water input from Estonian rivers to the Baltic Sea with and without the Narva River.

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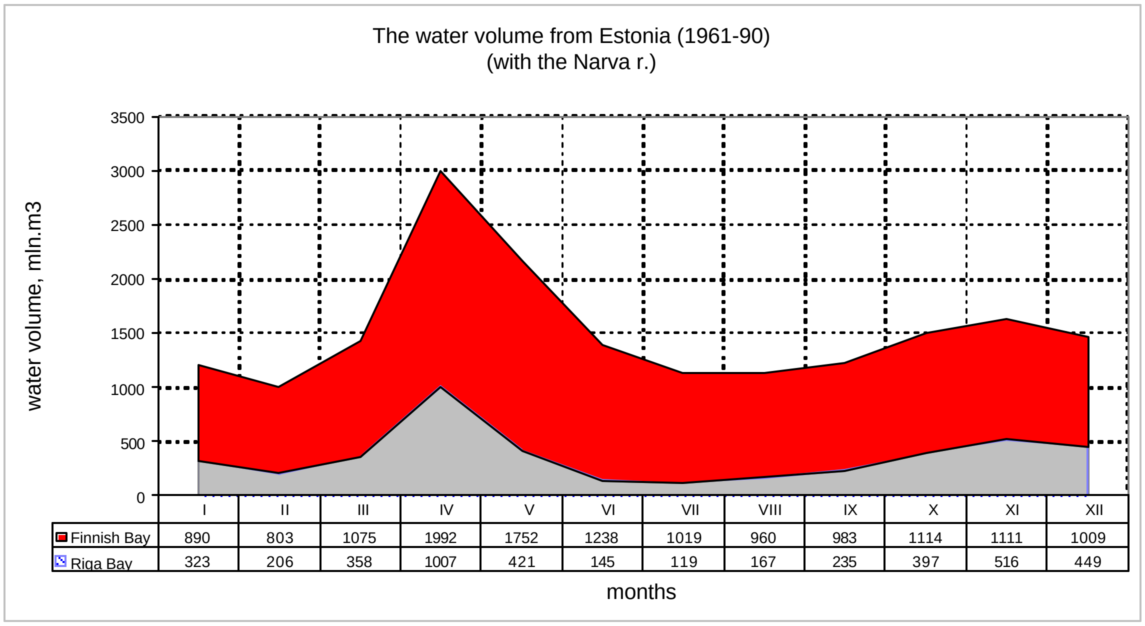
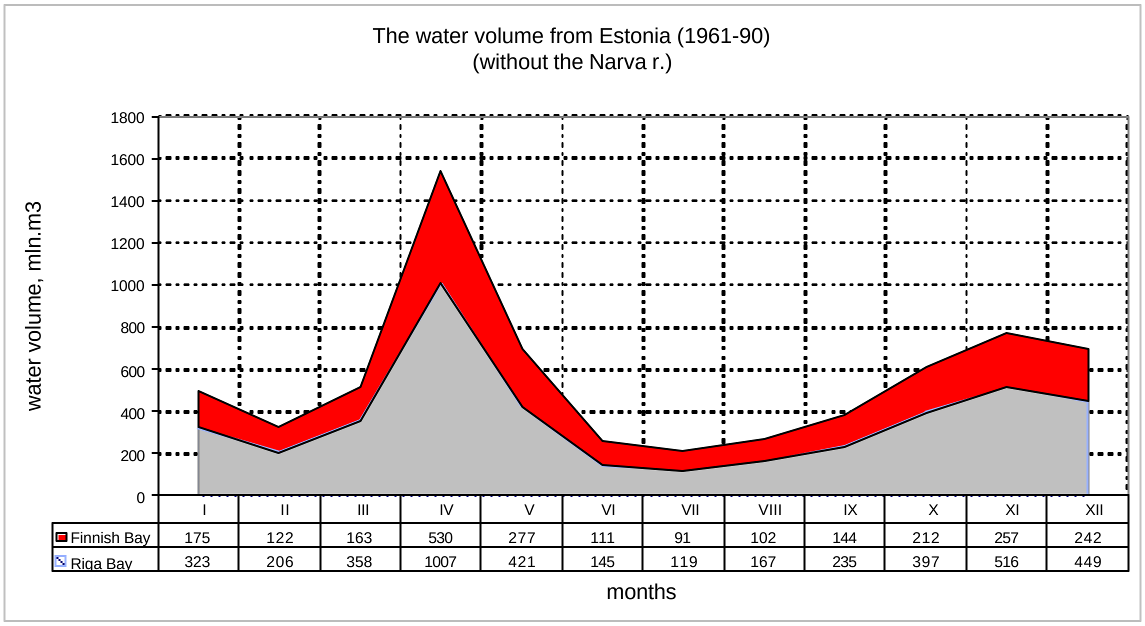


	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Finnish Bay	890	803	1075	1992	1752	1238	1019	960	983	1114	1111	1009
Riga Bay	323	206	358	1007	421	145	119	167	235	397	516	449



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Finnish Bay	175	122	163	530	277	111	91	102	144	212	257	242
Riga Bay	323	206	358	1007	421	145	119	167	235	397	516	449

Fig. 3 Monthly water input from Estonian rivers to the Baltic Sea with and without the Narva River.

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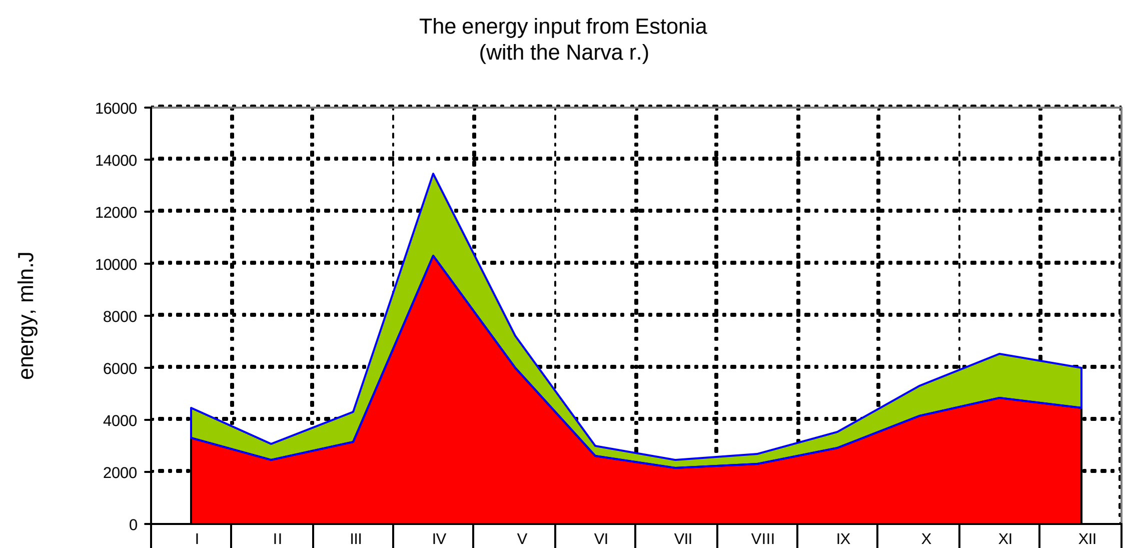
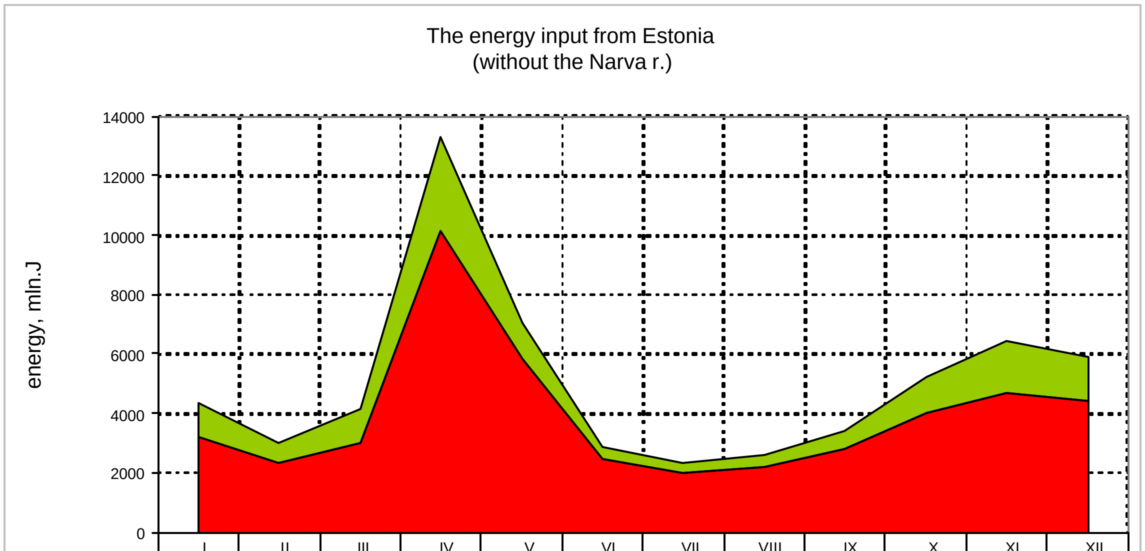


	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Riga Bay	1131	681	1150	3122	1212	373	303	424	626	1185	1696	1511
Finnish Bay	3304	2405	3102	10291	5986	2579	2110	2279	2889	4120	4803	4474



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Riga Bay	1131	681	1150	3122	1212	373	303	424	626	1185	1696	1511
Finnish Bay	3233	2338	3013	10148	5841	2469	2020	2195	2807	4032	4719	4398

Fig.4. Monthly distribution of energy input from Estonian rivers to the Baltic Sea with and without the Narva River.

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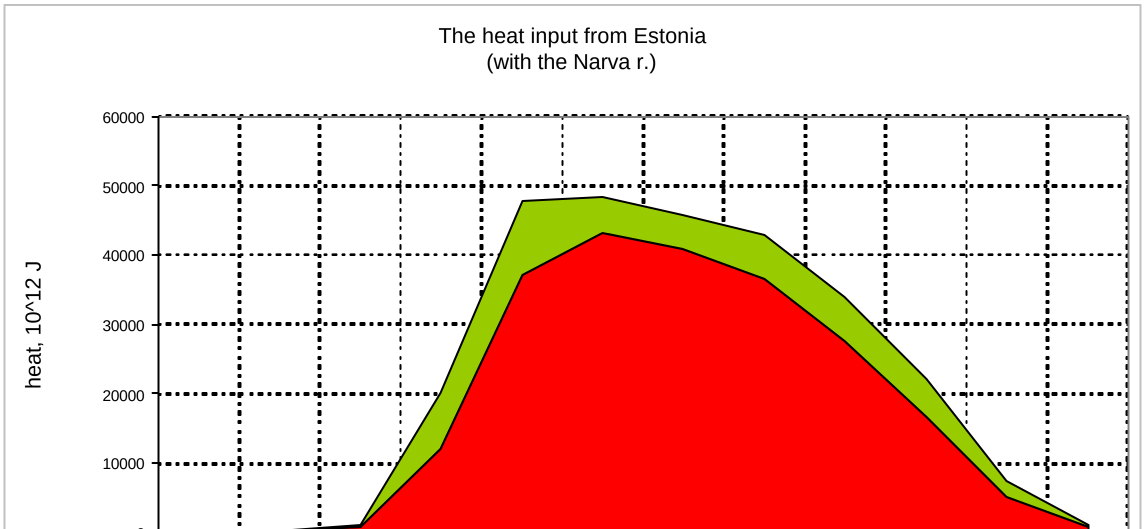
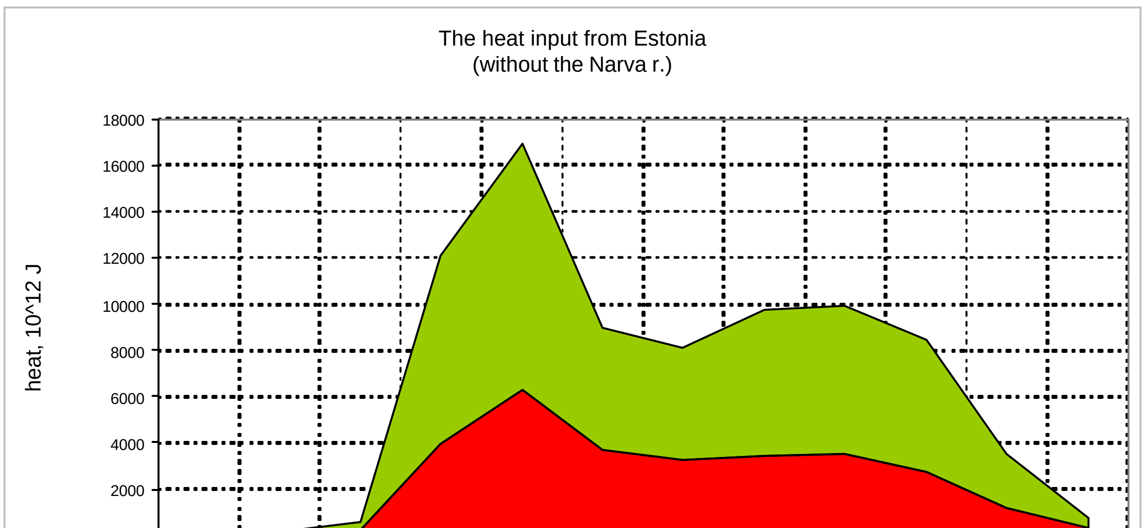


	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Riga Bay	83	52	327	8088	10689	5347	4814	6307	6400	5692	2357	415
Finnish Bay	226	218	812	11925	37150	43104	40820	36526	27605	16580	5106	709



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Riga Bay	83	52	327	8088	10689	5347	4814	6307	6400	5692	2357	415
Finnish Bay	76	75	239	3964	6268	3668	3291	3448	3502	2777	1170	334

Fig. 5. Monthly distribution of heat input from Estonia to the Baltic Sea with and without the Narva River.