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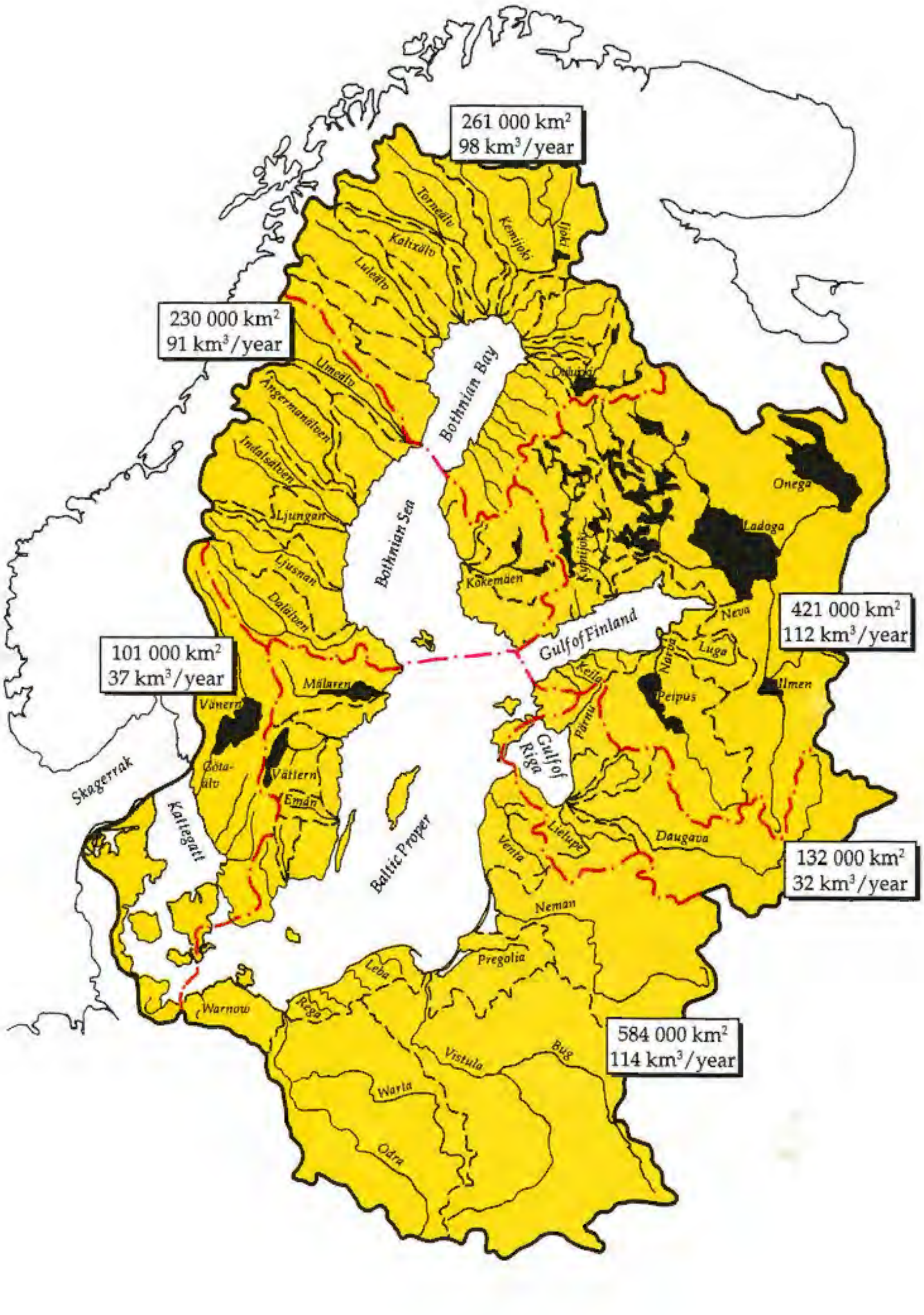

HYDROLOGY OF THE BALTIC BASIN

Inflow of fresh water from rivers and land for the period 1950 - 1990

Sten Bergström and Bengt Carlsson

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Abstract

A data base of monthly inflow of fresh water from rivers and land to the Baltic Sea and its subbasins is created. The data base covers the period 1950 - 1990 and is based on observations from the national hydrological services of the surrounding countries.

The main features of the data base are presented including river flow of selected rivers and total inflow to the Baltic Sea and its subbasins. Long term, seasonal and short term variabilities are analysed and the effects of hydropower development are identified. An earlier data base by Mikulski (1982) is used for comparison and extension of the record to cover the period 1921 - 1990.

It is concluded that the variability of inflow is great and that the decade 1981 - 1990 is the wettest in 70 years. The increase in runoff is mainly due to increasing river flow during the cold seasons. The effects of hydropower development are noticeable in the records for the Bothnian Bay and the Bothnian Sea.

Key words

Baltic hydrology, fresh water runoff, runoff data base.

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1. INTRODUCTION

The water balance of the Baltic Sea is in focus due to a growing concern about the long term environmental deterioration of the system and its great economic and recreational importance. One important factor is the amount and variability of inflow of fresh water from the rivers and land areas into the sea. The river flow is highly variable over the year and there are great interannual variations as well. Rivers from different regions also carry different amounts of load to the system depending on the conditions in the catchments.

The water balance of the Baltic Sea has attracted the interest of many scientists since the beginning of the present century (Falkenmark and Mikulski, 1975). In recent times the compilation of river inflow by Mikulski has played a key role in this respect (Mikulski, 1970 and 1982). Mikulski's work has been used for water balance estimates presented by, for example; Falkenmark and Mikulski (1975 and 1988), Ehlin (1982), Henning (1988) and by the Helsinki commission (HELCOM, 1986).

Within the Swedish research programme "Large-scale Environmental Effects and Ecological Processes in the Baltic Sea" (Wulff, 1990) it was found necessary to establish an updated and more complete database on inflow from the drainage basin to the Baltic Sea system as a foundation for environmental studies and as input to oceanographic models. The responsibility for this work was given to the research team of the Swedish Meteorological and Hydrological Institute in 1990.

A great deal of the work had to be carried out with support from national institutes and colleagues of the countries surrounding the Baltic Sea. This was a complicated process, mainly due to the dramatic political changes which occurred in some of the countries at the same time. The political process has, however, not hindered the scientific exchange and we are happy to conclude that it was possible to collect the information needed.

The present report summarizes the work and describes the main features of the data collected thus far. The objective is to give an overview of inflow conditions and show some highlights. Emphasis is put on natural interannual variabilities, seasonalities and monthly variations, regional differences and changes of the inflow regimes caused by river regulation. Preliminary results have earlier been presented by Carlsson (1992).

2. THE BALTIC BASIN

The Baltic Sea is the largest brackish water body of the world with a total surface area of 377 400 km^2 and a corresponding volume of 21 200 km^3 (Sjöberg, 1992). It can be separated into the five subbasins; the Bothnian Bay, the Bothnian Sea, the Gulf of Finland, the Gulf of Riga, and the Baltic Proper (Figure 1). One sixth basin, the Danish Sounds and Kattegat, is normally not considered a part of the system but is included in this project due to its significance for the exchange of water of the Baltic Sea.

Figure 1. The drainage basin of the Baltic Sea, the Danish Sounds and Kattegat.

Nine countries share the shorelines of the Baltic Sea and its drainage basin includes territories from altogether thirteen countries. Several major cities are located within the basin and the total population amounts to more than 70 million (Wulff, 1992). The size of the total area is approximately 1 729 000 km^2 with a distribution over subbasins according to Table 1.

Table 1. Approximate sizes of land areas draining into the different subbasins of the Baltic Sea.

Subbasin	Size (km^2)
Bothnian Bay	261 000
Bothnian Sea	230 000
Gulf of Finland	421 000
Gulf of Riga	132 000
Baltic Proper	584 000
Danish Sounds and Kattegat	101 000
Total area	1 729 000

The hydrology of the Baltic Sea area is characterized by long cold winters in the north, with pronounced winter low flows and snowmelt peaks, and more variable flow regimes in the south. Several large rivers discharge their water into the Baltic Sea, the largest being river Neva with a mean annual flow of approximately 2 500 m^3/s. Other large rivers are shown in Table 2. As can be seen from the table their specific runoff is highly variable.

Table 2. The ten largest rivers of the Baltic Sea system, the Danish Sounds and Kattegat, their approximate drainage area, mean annual and specific runoff during 1950 - 1990.

River	Drainage area (km^2)	Mean annual runoff (m^3/s)	Specific runoff ($l/(s \cdot km^2)$)
Neva	281 000	2 460	8.8
Vistula	194 400	1 065	5.5
Daugava	87 900	659	7.5
Neman	98 200	632	6.4
Odra	118 900	573	4.8
Kemijoki	51 400	562	11.0
Göta älv	50 100	574	11.5
Ångermanälven	31 900	489	15.0
Luleälven	25 200	486	19.0
Indalsälven	26 700	443	16.5

There are several large lakes in the area, the largest being Lake Ladoga in Russia. The lakes have strong influence on the dynamics of the rivers as they damp the fluctuations in runoff. They also effect the water balance of catchment as they cause increased evaporation.

Some of the rivers are subjects to river regulation, mostly for hydropower production. This is particularly pronounced in the northern rivers and results in a redistribution in time of the river flow as water is stored during spring, summer and autumn for use in winter.

3. PREPARATION OF THE DATA BASE

The collection of a data base of monthly river flow was a major undertaking of the project. It was made possible by contributions from national institutes and colleagues in the countries of the area. At present the data base covers the time period 1950 - 1990 and consists of data from altogether some 200 river flow stations, most of them near the mouth of the rivers. The catchment areas of these stations represent 86 % of the total drainage basin. A more detailed picture of the data coverage is given in Table 3.

Table 3. Areal coverage of river flow data for the subbasins of the Baltic Sea system, the Danish Sounds and Kattegat used in the present study.

Subbasin	Data coverage (%)
Bothnian Bay	87
Bothnian Sea	84
Gulf of Finland	93
Gulf of Riga	66
Baltic Proper	80
Danish Sounds and Kattegat	96
Total area	86

Runoff from areas not covered by measurements, mostly coastal areas located between major rivers, has been estimated by the use of calculations of specific runoff for neighbouring stations which were considered representative. This means that a large amount of effort had to be put into mapping of the watersheds of individual rivers. For Denmark this work had already been carried out (Höybye, 1991) and the results were made available to the present project. More details about the preparation of the data base can be found in the work by Carlsson (1992).

The result of the preparatory phase of the project was one data base of monthly discharge from a large number of rivers and one that covers monthly runoff from the total area of the drainage basin. This means that contributions from local areas near the coast are also accounted for as well as direct discharge of groundwater although there might be some problems with the timing of contributions from larger aquifers. The latter is considered a minor problem as the dominating part of inflow is conveyed via rivers.

The data were stored as monthly mean values of runoff in m^3/s. This is the generally used hydrological dimension and will be used in most of the presentations in this report. One km^3/year corresponds to 31.71 m^3/s.

4. RIVER FLOW

The average runoff in the ten largest rivers were presented in Table 2. A sample of monthly records of river flow for the period 1950 - 1990 from the data base is shown in Appendix 1. These graphs illustrate the great variability and some individual features for specific rivers. River Neva, for example, shows a more damped pattern than most other rivers. This is an effect of the large lakes in its basin.

The record from river Vistula caused some concern as it gave the impression of a change in the regime during the last decade. As an upstream station did show the same tendency the data were accepted for this analysis.

Many of the rivers discharging into the Baltic Sea are subjects to river regulations, mostly for hydroelectric power production. This means that large volumes of water are stored from spring, summer and autumn to be used for production in winter. This is particularly pronounced for Sweden where some of the rivers can store a substantial part of the annual runoff. This part is defined as the "degree of regulation" and is summarized for Sweden in Table 4.

The effects of river regulation on streamflow can be dramatic as shown in Figure 2 which shows regulated and reconstructed natural discharge in the lower parts of river Luleälven in northern Sweden. The short term irregularities are caused by short term regulations to meet the day to day fluctuations in power demand. Short term regulations can not be detected by a database based on monthly averages.

Table 4. Degree of regulation for the most developed Swedish rivers. The figure shows the percentage of the mean annual runoff that can be stored in the system (Swedish Power Association, 1992).

River	Degree of regulation (%)
Luleälven	72
Skellefteälven	62
Umeälven	27
Umeälven excl. Vindelälven	52
Ångermanälven	43
Indalsälven	40
Ljungan	29
Ljusnan	22
Dalälven	26
Lagan	21
Göta älv	72
Klarälven	20

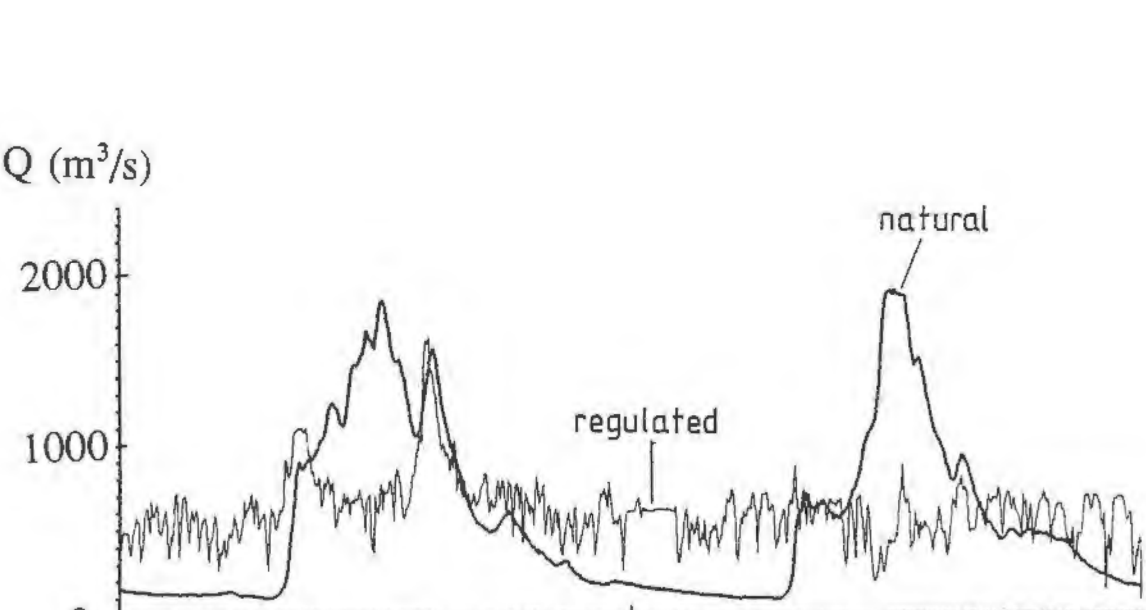

Figure 2. Comparison between the regulated river flow in lower Luleälven and reconstructed natural flow for the years 1989 and 1990. Daily values.

The long term effect of hydro power development is a successive change in runoff regimes and can be studied in more detail by a closer look at data from the individual rivers in Appendix 1. Most drastic is the record from river Luleälven (Figure 3) but tendencies can also be detected in rivers Ångermanälven and Kemijoki.

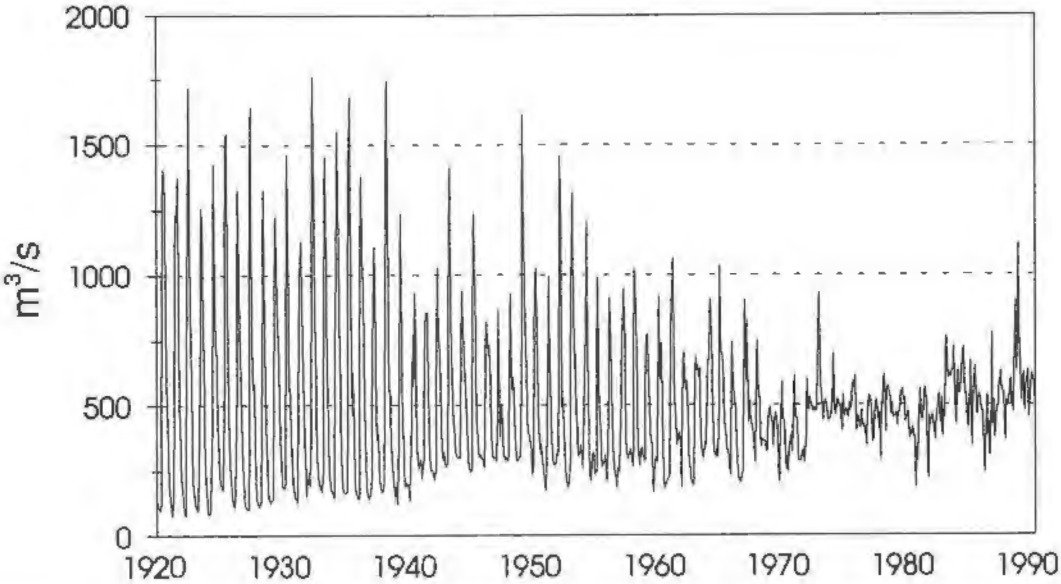

Figure 3. Monthly runoff record from lower river Luleälven for the period 1921 - 1990 illustrating the effect of hydropower development.

5. ANNUAL INFLOW TO THE BALTIC SEA

The total contribution of fresh water to the system and individual contributions to the subbasins for the whole period 1950 - 1990 are shown in Figure 4 and in Table 5.

The mean annual contribution to the Baltic Sea system, excluding the Danish Sounds and Kattegat is 14 151 m^3/s or 446 km^3/year for the period 1950 - 1990. The latter figure corresponds to a water body of 1.18 m covering the Baltic Sea and means that the total volume of water, 21 200 km^3, will be replaced in 48 years, if no mixing and other sources are considered.

As the flow of water through the Danish Sounds is going back and forth, typical flow rates in these sounds are about ten times the average inflow of fresh water from the surrounding rivers (Omstedt, 1990). The annual inflow of salt water is of the same order of magnitude as the contribution of fresh water, which means that the total annual outflow through the Danish Sounds is about twice the fresh-water contribution.

The figures can further be compared to the water exchange through the Danish Sounds during an episodic event which may be in the order of 100 km^3 during ten days. (See, for example, Franck and Matthäus, 1992.) Such an event occurs as an average approximately once in a ten year period. A stormy period in January 1993 led to an inflow of more than 100 km^3 of salt water from the Kattegat during 20 days (unpublished data from SMHI). A total river flow of 14 151 m^3/s is further comparable to that of a mighty river like the rivers Paraná, S:t Lawrence or Irrawaddy.

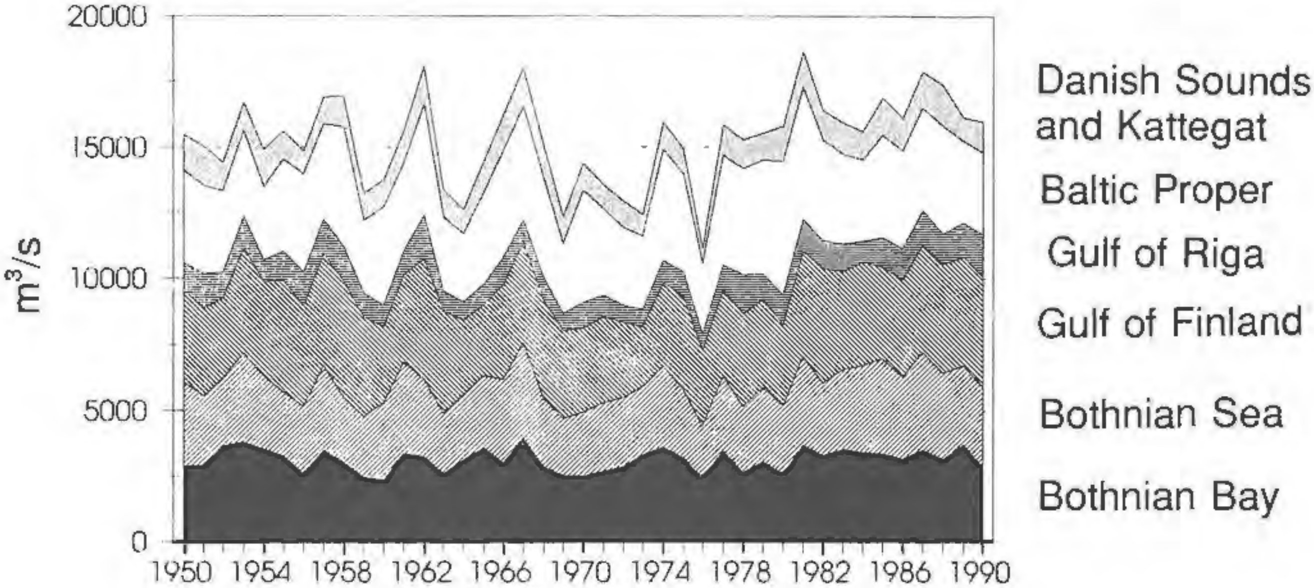

Figure 4. Total annual contribution of fresh water to the Baltic Sea system for the period 1950 - 1990 and separation into subbasins.

Table 5. Mean annual contribution of fresh water to the Baltic Sea system and its subbasins during the period 1950 - 1990.

Subbasin	M^3/s	$Km^3/year$
Bothnian Bay	3 104	98
Bothnian Sea	2 860	91
Gulf of Finland	3 556	112
Gulf of Riga	1 020	32
Baltic Proper	3 610	114
Danish Sounds and Kattegat	1 159	37
Total area	15 310	483

The estimates of fresh water inflow to the different basins of the Baltic Sea made by Mikulski (1982) offer an opportunity for comparison and extension of the records as they overlap the data base of the present project. Mikulski's estimates are based on a sample of 17 rivers and the time period is 1921 - 1975. The areal representation of the catchments of these rivers is 63 % of the total drainage area. In figure 5 is shown a composite presentation of the annual data from Mikulski and the present project covering the 70 years from 1921 to 1990. Corresponding data for the entire system per decade are shown in Table 6 of which Mikulski's data represent the period 1921 - 1950.

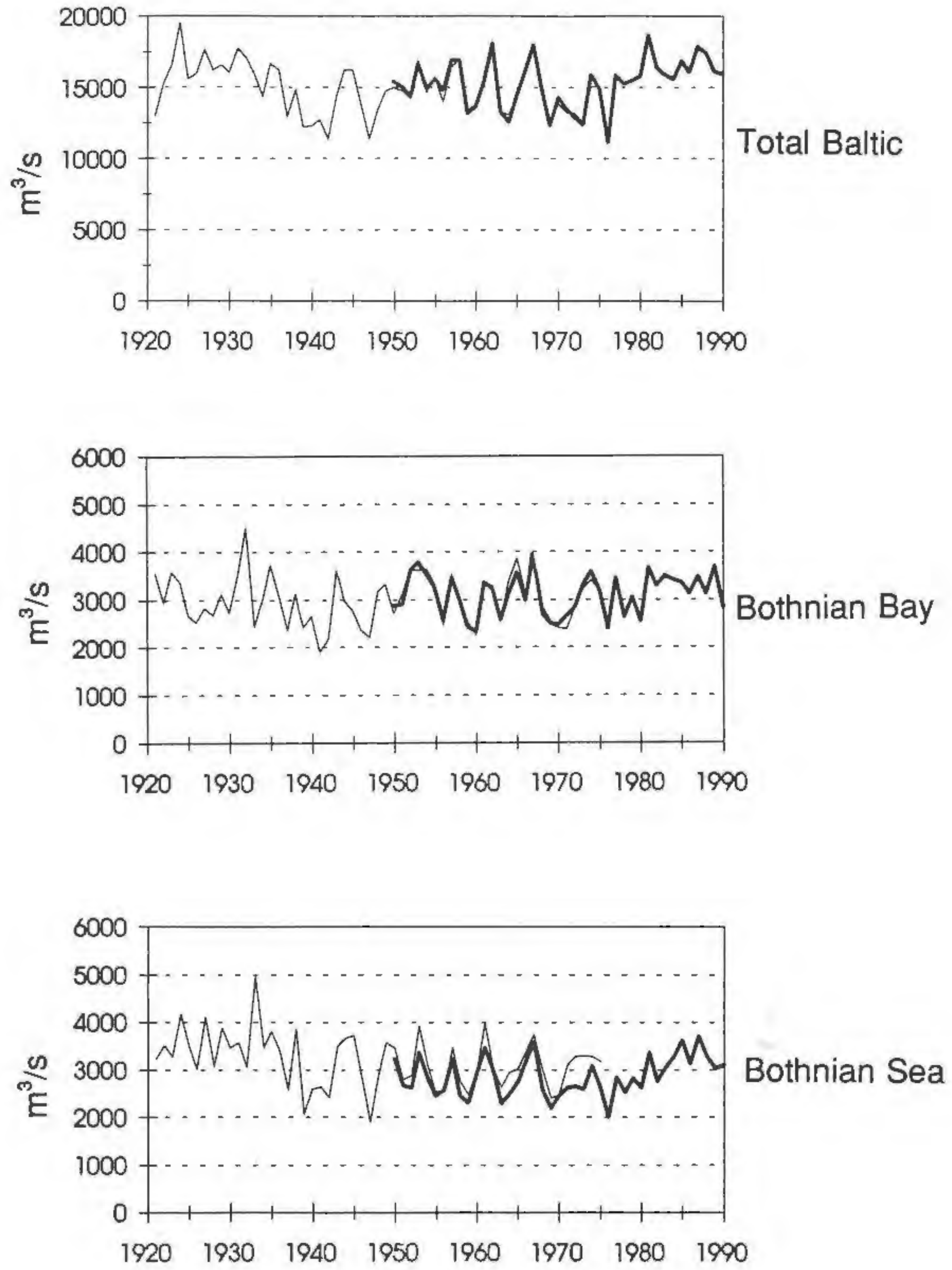

Figure 5. *Total annual contribution of fresh water (m^3/s) to the Baltic Sea system and its subbasins for 1921 - 1990 based on data from the present project (thick line) and Mikulski (1982) (thin line).*

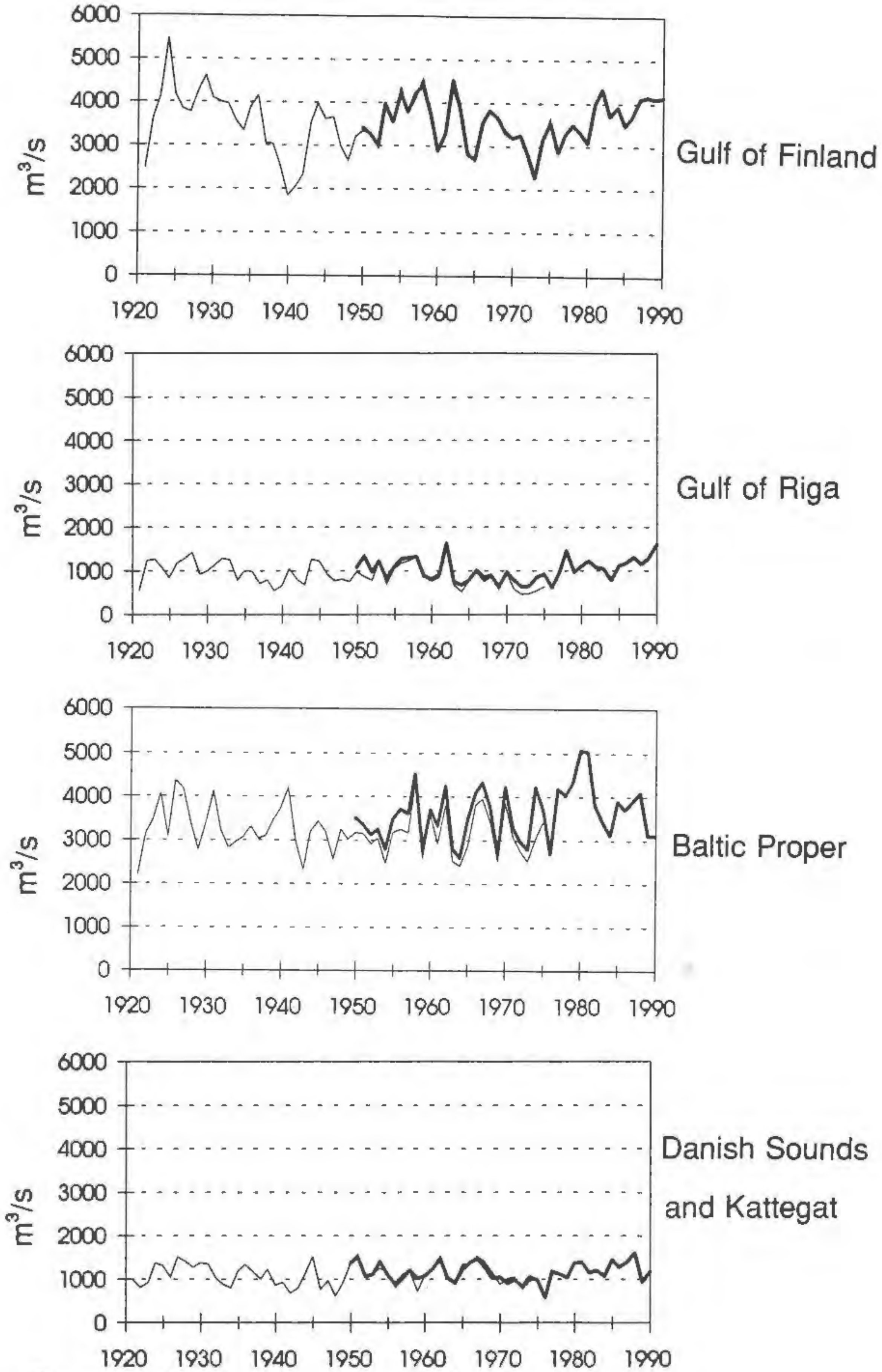

Figure 5. *Cont.*

Table 6. Average contribution and total volumes of fresh water to the Baltic Sea system and the Danish Sounds and Kattegat for each decade during the period 1921 - 1990. The period 1921 - 1950 is based on data from Mikulski (1982) and the period 1951 - 1990 is based on the present data base.

Decade	Average inflow (m^3/s)	Total volume (km^3)
1921-30	16 246	5120
1931-40	15 039	4740
1941-50	13 940	4400
1951-60	15 217	4800
1961-70	14 997	4730
1971-80	14 318	4520
1981-90	16 692	5260

Figure 5 shows that the estimates made by Mikulski are well in agreement with the present database for the whole system and for some of the basins. The greatest differences are found in the estimates of contributions to the Bothnian Sea and the Baltic Proper. These differences are due to different data coverage in two studies.

The long term inflow of fresh water to the total Baltic Sea shows a remarkable annual variability with high values in the beginning and end of the record. The last decade is the wettest of the whole period. 1924 is an outstanding wet year with a mean annual inflow of 19 500 m^3/s while the inflow during the driest year, 1976, is as low as 11 100 m^3/s.

The database can also be used to estimate the relative contributions from each one of the countries around the Baltic Sea. It is important to note, however, that the water that discharges into the sea from one country very well may have its origin in another country further upstream. It is thus more appropriate to say that the water reaches the Baltic sea via a particular country. Another problem is caused by rivers floating along the border lines between two countries, like the rivers Torneälven, Narva and Neman. In the following presentation the river flows of these are shared equally between the two countries. A summary of relative contributions via each country, under the assumptions given above, is given in Table 7.

Due to differences in specific runoff from different regions the relative contributions in Table 7 do not fully reflect the areal conditions. As can be seen in Figure 6 the specific runoff in Poland is only about half of that of northern Sweden. The highest specific rnnoff is found in the northwest of Sweden and in Norway were precipitation is high and evapotranspiration is low.

Table 7. Approximate relative contributions (%) to the Baltic Sea via different countries and distribution over each subbasin. Mean values for the period 1950 - 1990.

Country	Total basin	Both-nian Bay	Both-nian Sea	Gulf of Finland	Gulf of Riga	Baltic Proper	Danish Sounds and Kattegat
Sweden	35	10	16	-	-	3	6
Finland	16	10	3	3	-	-	-
Russia	22	-	-	19	-	3	-
Estonia	3	-	-	2	0.5	0.5	-
Latvia	7	-	-	-	6	1	-
Lithuania	2	-	-	-	-	2	-
Poland	12	-	-	-	-	12	-
Germany	1	-	-	-	-	1	-
Denmark	2	-	-	-	-	<0.5	2
Total	100	20	19	24	6.5	22.5	8

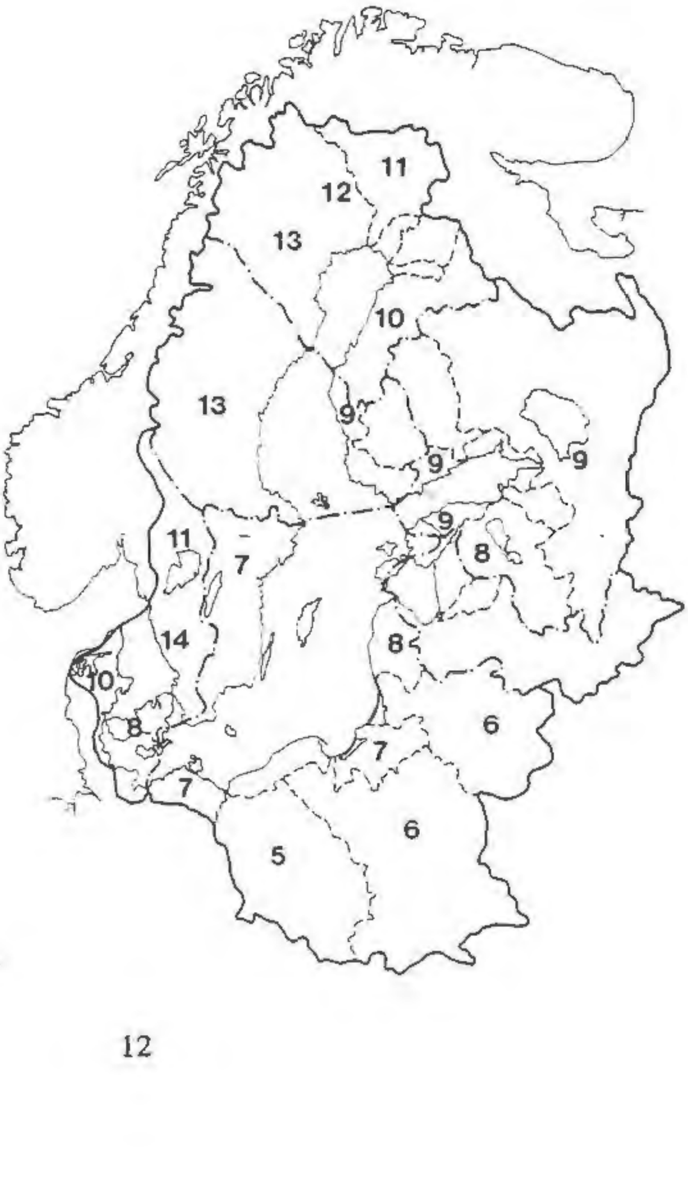

Figure 6. Approximate specific runoff $[l/(s \cdot km^2)]$ for different parts of the Baltic Sea drainage basin.

6. SEASONAL INFLOW TO THE BALTIC SEA

Seasonal inflow is of interest in environmental studies as the concentrations of nutrients in the rivers may vary considerably over the year due to biological activities and other conditions (see, for example, Taylor, 1987; Brandt, 1990). In particular are the nitrate concentrations in lake-rich systems low in summer. The dynamics in concentrations interact with river flow and has to be considered when estimating the total load to the coastal waters.

The seasonality of the inflow to the Baltic Sea system is illustrated as regimes in Figure 7 for the full system as well as for its subbasins. Time series of inflow to the total system for winter, spring, summer and autumn respectively are shown in Figure 8. In Appendix 2 the corresponding data for each one of the subbasins are presented.

Figure 7 shows that the hydrological regimes are highly variable for the different subbasins. The northern subbasins have a pronounced spring flood due to snowmelt and low winter runoff while winter runoff is gradually becoming more important further south in the drainage area and is dominating the contribution to the Danish Sounds and Kattegat.

From Figure 8 can be seen that the pronounced increase in runoff during the late 1980-ies is dominated by increasing winter flows with some influence from increased flows in spring and autumn. A closer look at the graphs in Appendix 2 reveals that the increase in winter runoff is a general tendency for all basins with the possible exception of the Gulf of Finland which shows a more irregular pattern. Increasing flows in February for the whole of Finland have previously been reported by Kuusisto (1992). The increase in winter inflow to the Gulf of Riga and some extreme winter flows into the Baltic Proper are remarkable. The regional inflow patterns are much more variable for the other seasons than the winters and can not be so easily generalized.

The increase in winter runoff is partly an effect of the recent mild winters with little or no accumulation of snow in the south. For the northern basins, the Bothnian Bay and the Bothnian Sea, there is also an effect of hydropower developments which result in increasing winter discharges and decreasing discharge other times of the year (see Section 4).

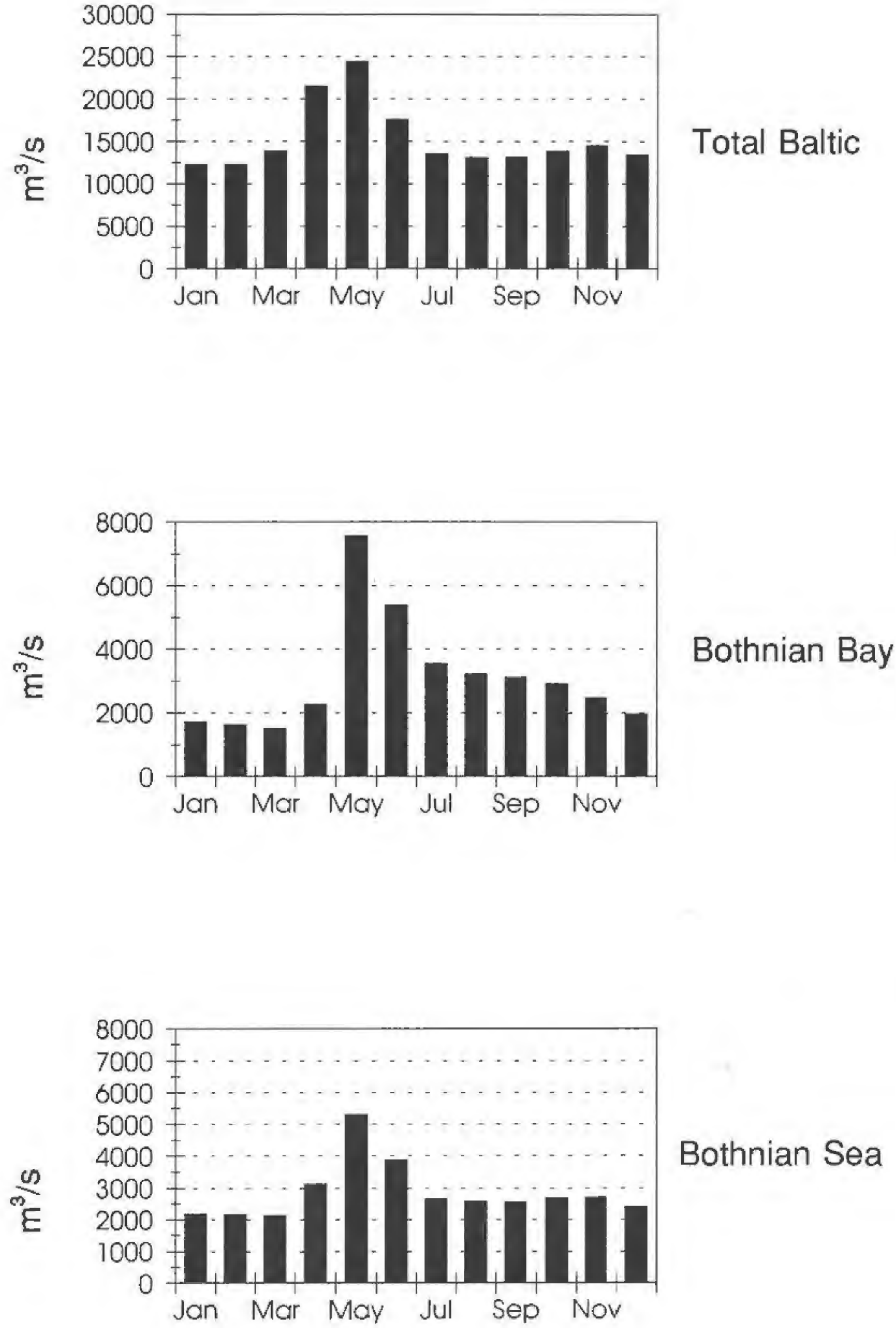

Figure 7. Monthly means of runoff showing the hydrological regime of the Baltic Sea and its subbasins from the period 1950-90.

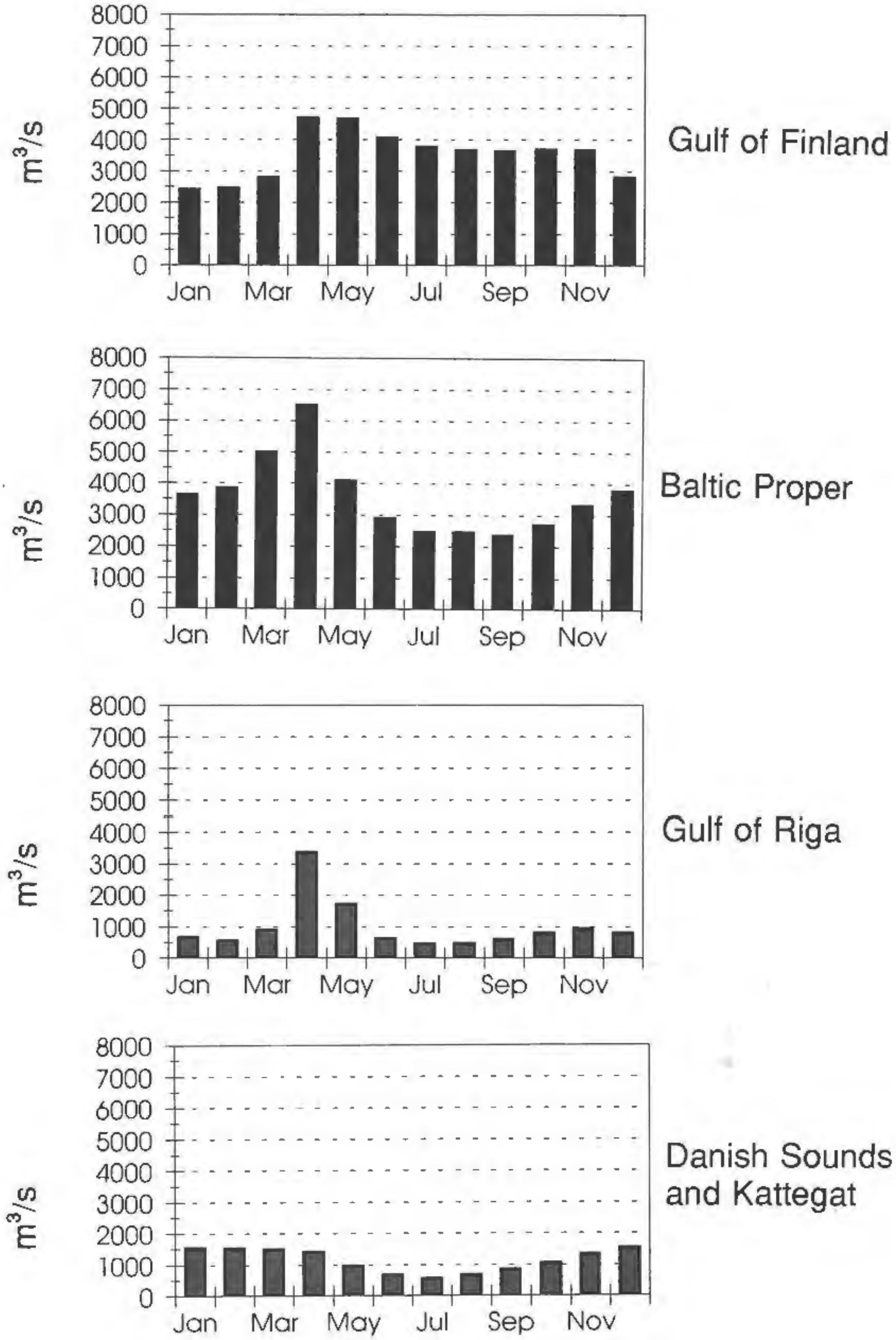

Figure 7. *Cont.*

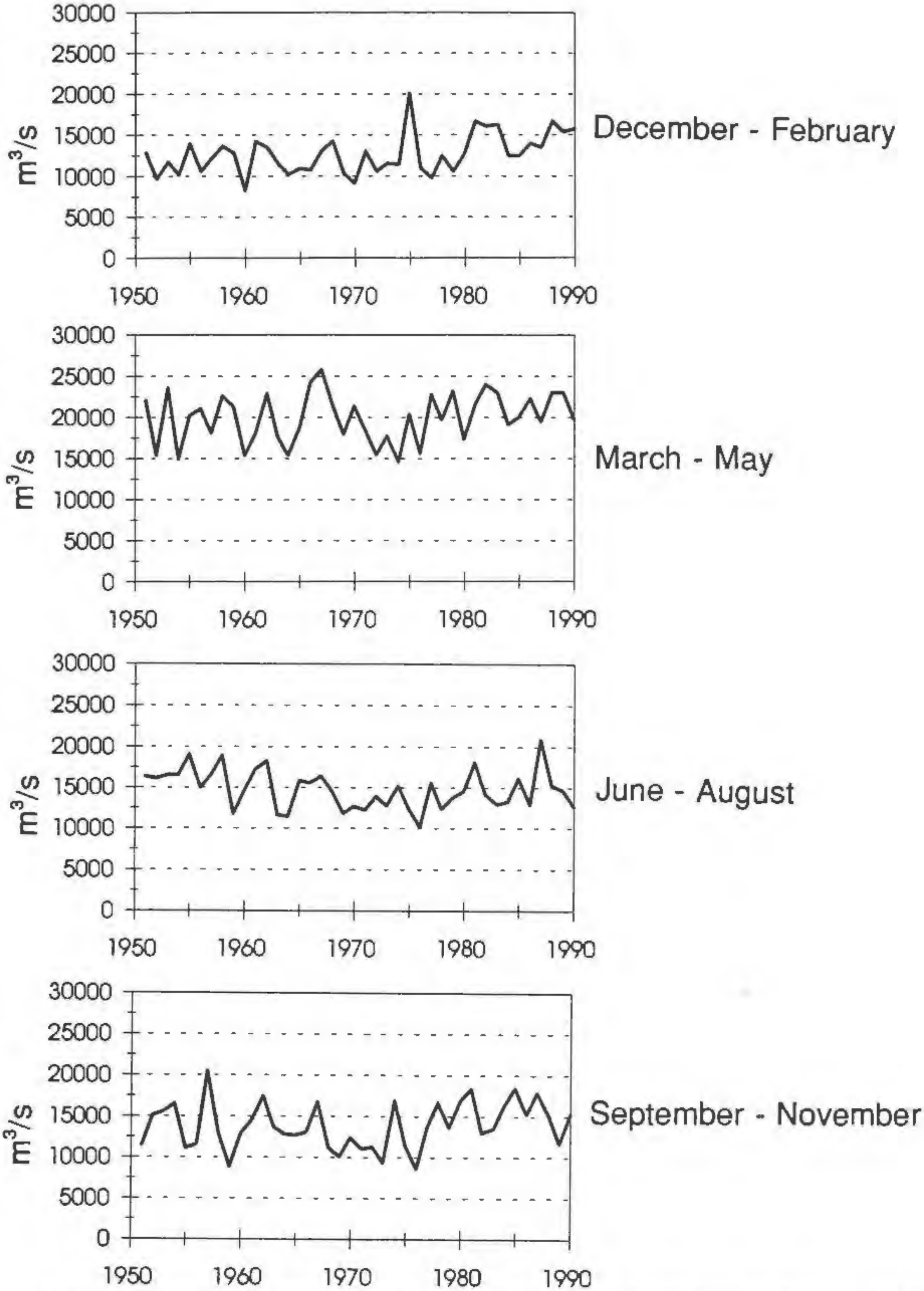

Figure 8. Seasonal contribution of fresh water to the Baltic Sea for the period 1951 - 1990. Annual means. Corresponding graphs for each subbasin are shown in Appendix 2.

7. MONTHLY INFLOW AND EXTREMES

Monthly values is the highest resolution which can be analysed with the present data base. This is a relevant resolution if extreme values from larger areas are of interest and can also, to some degree, help detecting the effects of river regulation. Figure 9 is a presentation of monthly data for the period 1950 - 1990 for the full system and its subbasins. Monthly and annual extremes are summarized in Table 8.

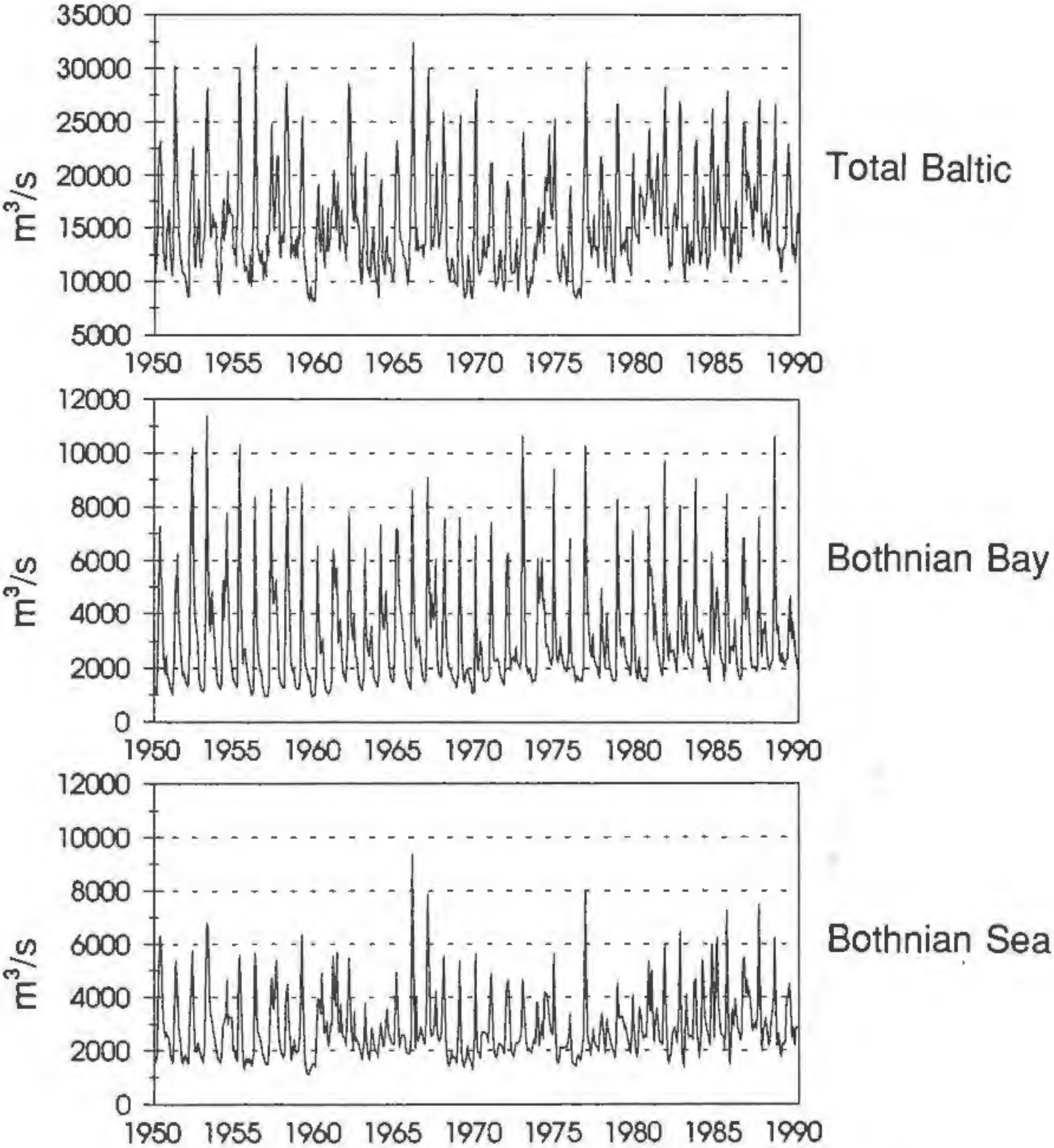

Figure 9. Monthly contributions of fresh water to the Baltic sea and its subbasins for the period 1950 - 1990.

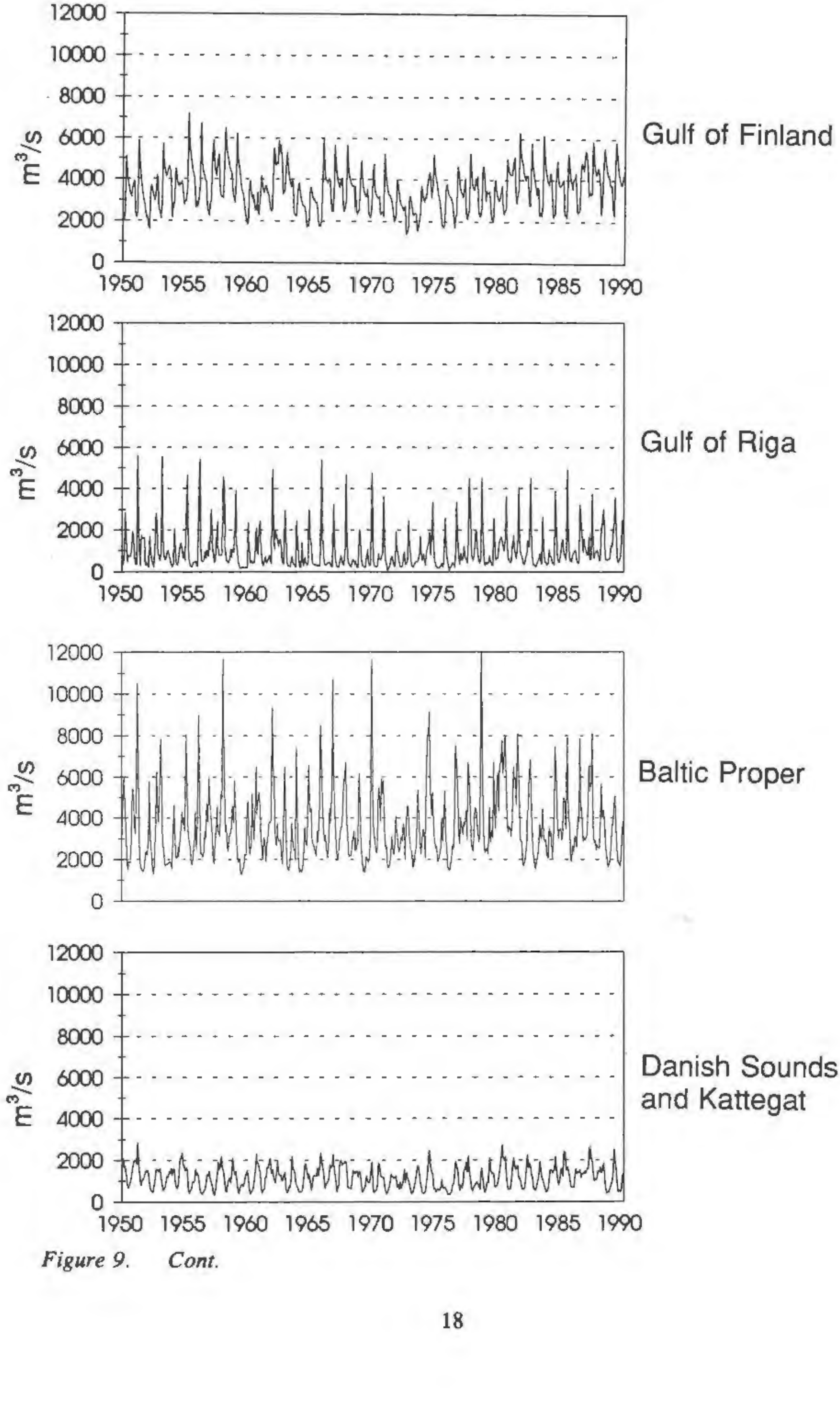

Figure 9. *Cont.*

Table 8. Annual and monthly extreme mean inflows to the Baltic Sea and its sub-basins during 1950 - 1990 (m^3/s).

	Highest annual	Year	Lowest annual	Year	Highest monthly	Date	Lowest monthly	Date
Total system	18 660	1981	11 132	1976	32 411	May -66	7 635	Dec -59
Bothnian Bay	3 940	1967	2 326	1960	11 380	May -53	910	Jan -57
Bothnian Sea	3 711	1987	1 992	1976	9 391	May -66	1 100	Oct -59
Gulf of Finland	4 521	1962	2 267	1973	7 194	May -55	1 405	Jan -73
Gulf of Riga	1 654	1962	629	1976	5 593	Apr -51	162	Feb -60
Baltic Proper	5 072	1981	2 602	1964	12 167	Apr -79	1 276	Oct -59
Danish Sounds and Kattegat	1 607	1988	571	1976	2 841	Mar -51	309	Jul -57

The maximum recorded monthly average contribution of fresh water to the system occurred in May 1966 and was 32 411 m^3/s which corresponds to a volume of 87 km^3. It would cause a raise in the sea level of 23 cm if other factors are disregarded.

A closer look at the annual values in Figure 5 and the monthly values in Figure 9 give no indication of a change in the pattern of extremes. They seem to be fairly randomly distributed over the analysed period. There are, however, clear signs of effects of river regulation in the monthly data for the Bothnian Bay and a the Bothnian Sea. The effects show up as increasing base flow levels over time.

8. DISCUSSION

The inflow to the Baltic Sea system from surrounding land areas is highly variable. The specific runoff is highest in the northwest and lowest in the south. This results in higher relative contributions from Sweden and Finland than could be anticipated by analysis of land areas alone.

The lowest and highest annual values of the Baltic Sea system differ from the mean value by -27 % and +22 % respectively during the period 1950 - 1990. The last decade is the wettest period during 70 years but another wet period, of almost the same magnitude, is found between 1921 and 1930. The increase in runoff during the 1980-ies is mainly due to wetter conditions during the cold seasons, which amplifies the transport of nutrients from non-point sources to the system.

The short term variability of inflow has a random character and no obvious trends in extremes can be detected. The effects of hydropower development is, however, noticeable in the inflow data for the Bothnian Bay and the Bothnian Sea.

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We would also like to thank our national contacts Dr. Lemmelä, Prof. Shiklomanov, Dr. Roosaare, Dr. Zaharchenko, Dr. Niemirycz and Prof. Lundager Jensen.

Finally we would like to remind everyone of the tremendous work by devoted hydrologists and observers in all surrounding countries which is the foundation for our present knowledge of the inflow of fresh water to the Baltic Sea.

REFERENCES

Brandt, M. (1990). Simulation of Runoff and Nitrate Transport from Mixed Basins in Sweden. Nordic Hydrology, 21, pp. 13 - 34.

Carlsson, B. (1992). Fresh-water runoff to the Baltic Sea from surrounding land areas (In Swedish with English abstract). Nordic Hydrological Conference, Alta 1992. Nordisk Hydrologisk Program NHP-rapport Nr. 30.

Ehlin, U. (1981). Hydrology of the Baltic Sea. in: The Baltic Sea by A. Voipio (Editor), Elsevier Oceanography Series, 30, pp. 123 - 134, Amsterdam.

Falkenmark, M. and Mikulski, Z. (1975). The Baltic Sea - A semi-enclosed sea, as seen by the hydrologist. Nordic Hydrology, 6, pp. 115 - 136.

Falkenmark, M. and Mikulski, Z. (1988). The Baltic Sea as an example: hydrological conditions as a determinant of the ecosystem in a semi-enclosed sea. Nature and resources, Vol. XXIV, No.1.

Franck, H., and Matthäus, W. (1992). Sea level conditions associated with major Baltic inflow. Beitr. Meereskd., Berlin, 63, 65 - 90.

HELCOM (1986). Water Balance of the Baltic Sea. Baltic Sea Environment Proceedings, No. 16, Helsinki.

Henning, D. (1988). Evaporation, water and heat balance of the Baltic Sea. Estimates of short and long-term totals. Meteorol. Rdsch., 41, 33 - 53.

Höybye, J. (1991). Ferskvandstilströmning til danske farvande 1990. Hedeselskabet, Fagdatacenter for hydrometriske data. Slagelse, Denmark.

Kuusisto, E. (1992). Runoff from Finland in the period of 1931 - 1990. Aqua Fennica, 22, 1, pp. 9 - 22.

Mikulski, Z. (1970). Inflow of river waters to the Baltic Sea in 1961 - 1970. Nordic Hydrology, 4, pp. 216 - 227.

Mikulski, Z. (1982). River inflow to the Baltic Sea 1921 - 1975. Polish Academy of Sciences, Polish national Committee of the IHP, University of Warsaw, Faculty of Geography and Regional Studies.

Omstedt, A. (1990). Modelling the Baltic Sea as thirteen subbasins with vertical resolution. Tellus, 42 A, 286 - 301.

Sjöberg, B. (editor) (1992). Sea and coast. The National Atlas of Sweden. Almqvist & Wiksell International, Stockholm.

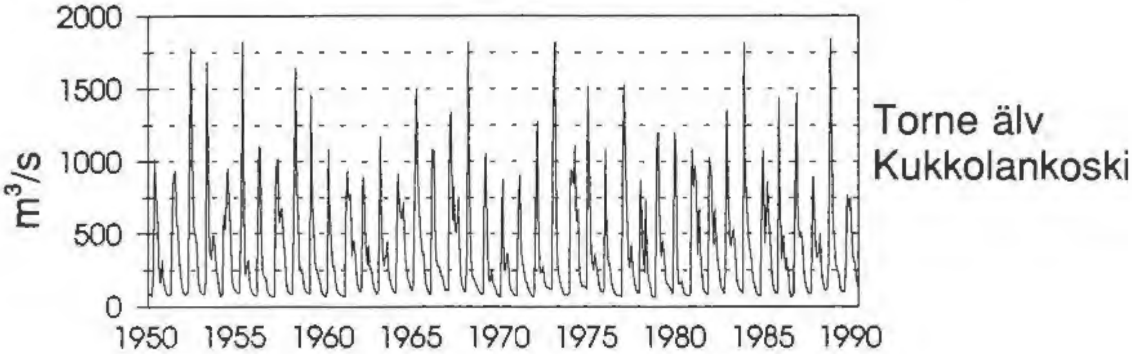
Swedish Power Association (1992). Some facts about Sweden and its electric power 1992. Information brochure.

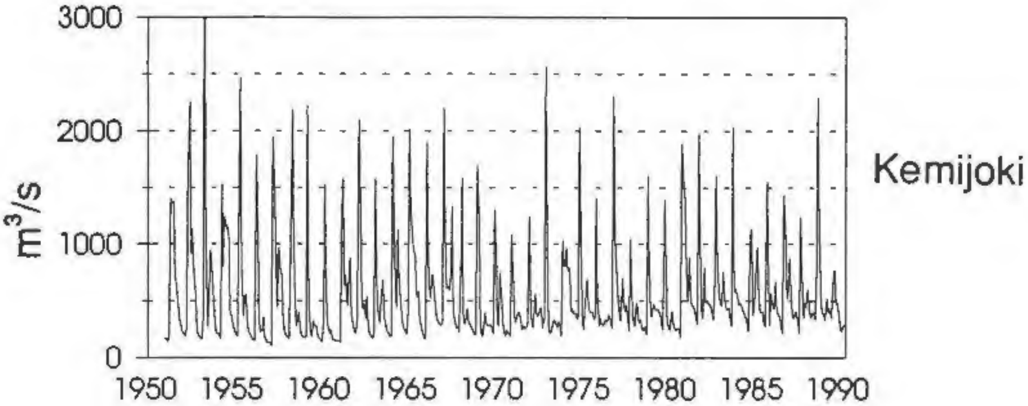
Taylor, R. (1987). Factors forming the level and dynamics of nutrient runoff from an agricultural watershed. Pol. Arch. Hydrobiol. 34, 3, pp. 285 - 295.

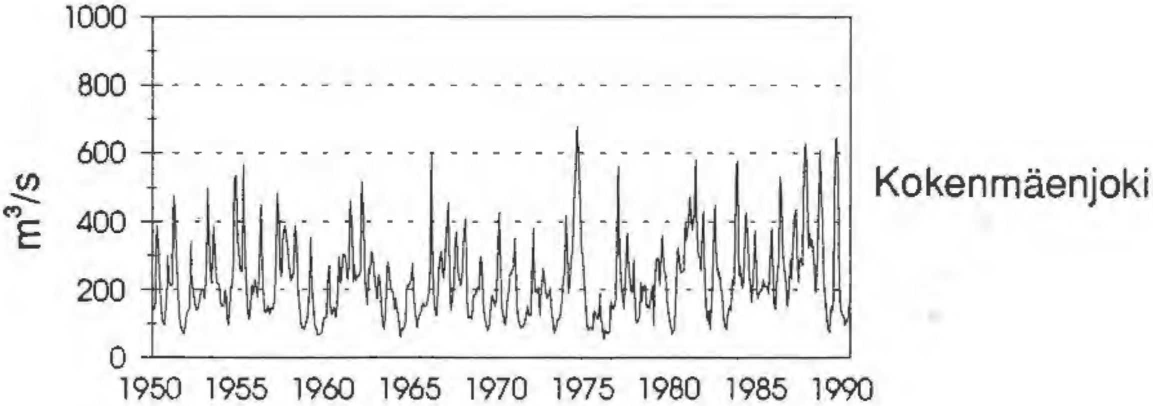
Wulff, F. (editor) (1990). Large-scale Environmental Effects and Ecological Processes in the Baltic Sea. Research Programme for the Period 1990 - 1995 and Background Documents. Swedish Environmental Protection Agency, Report 3849, Solna.

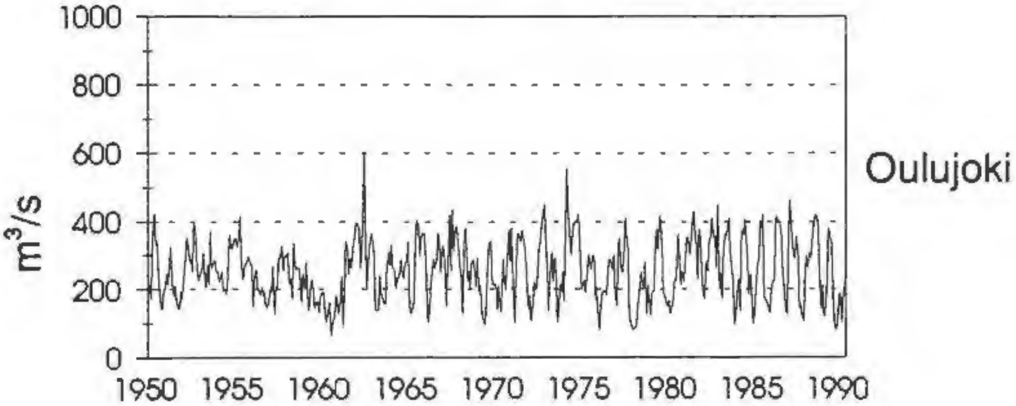
Wulff, F. (1992). Östersjön - ett annorlunda hav. In: Östersjön - ett hav i förändring. Swedish Natural Science Research Council, yearbook 1992.

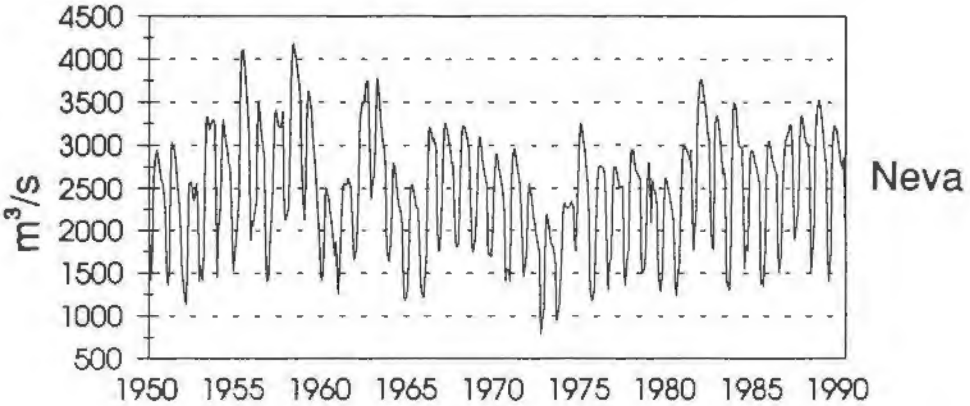
Examples of monthly streamflow in rivers in the Baltic Basin for the period 1950 - 1990

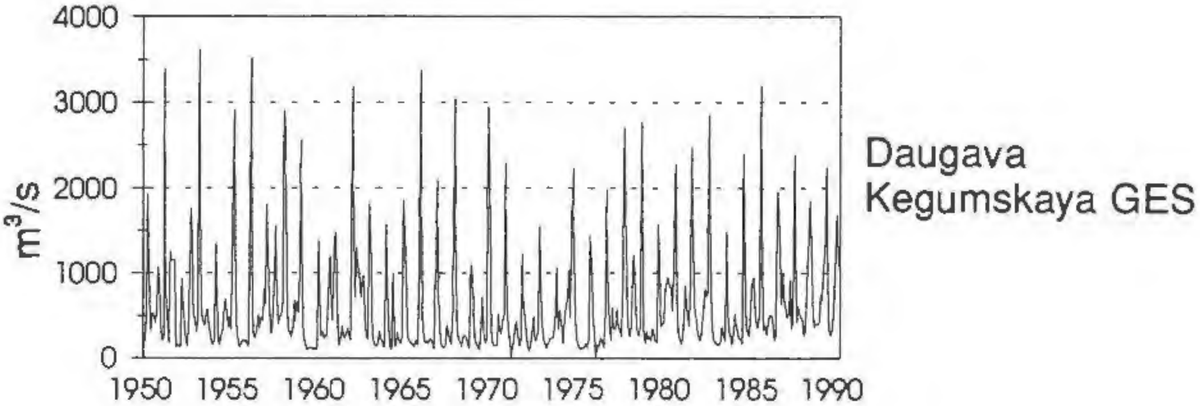









m3/s
4500
4000
3500
3000
2500
2000
1500
1000
500
1950 1955 1960 1965 1970 1975 1980 1985 1990
Neva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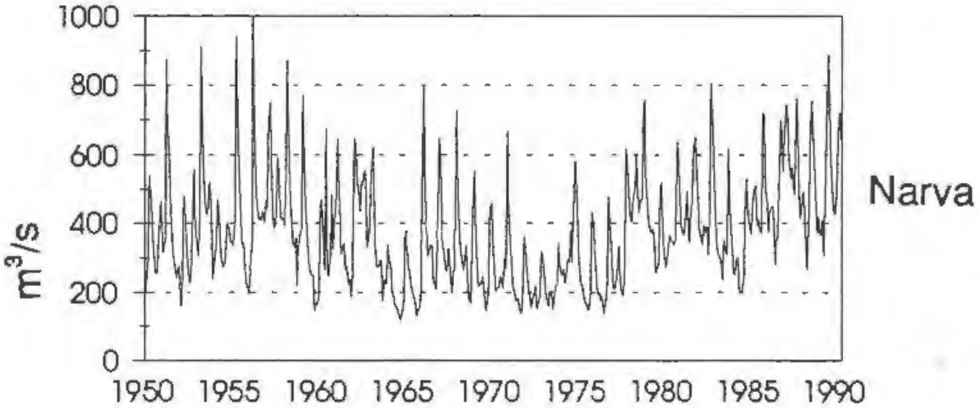
Daugava
Kegumskaya GES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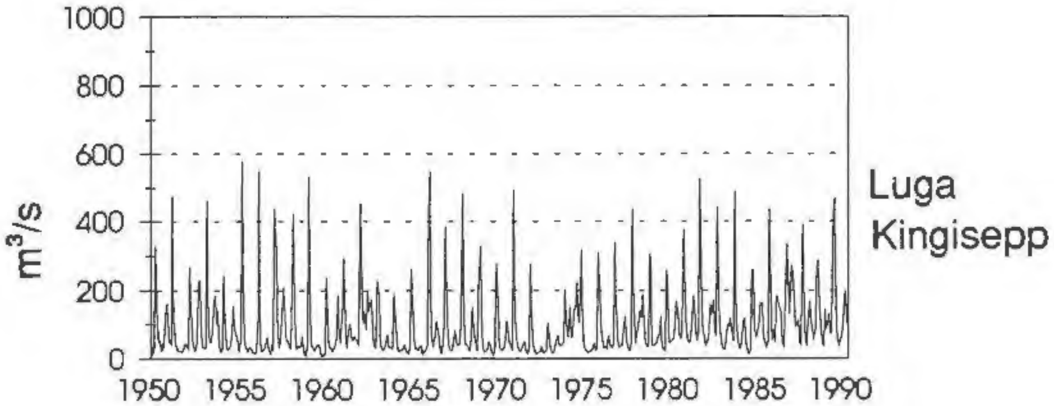
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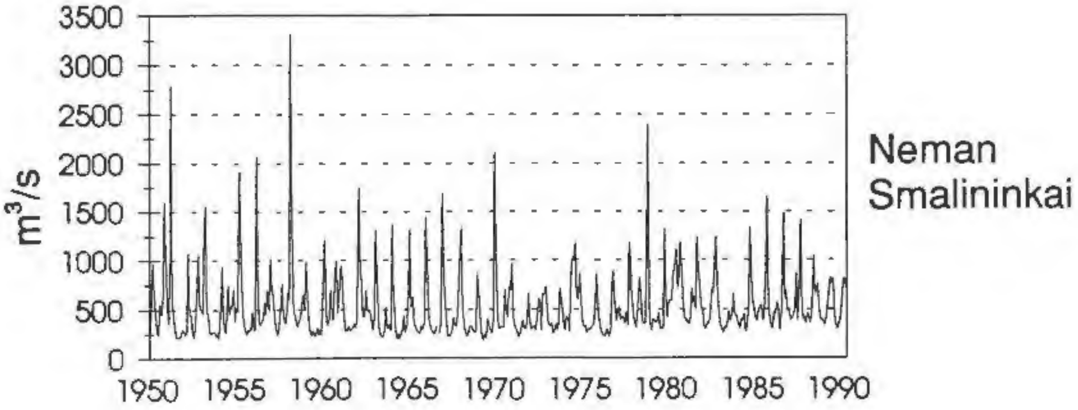
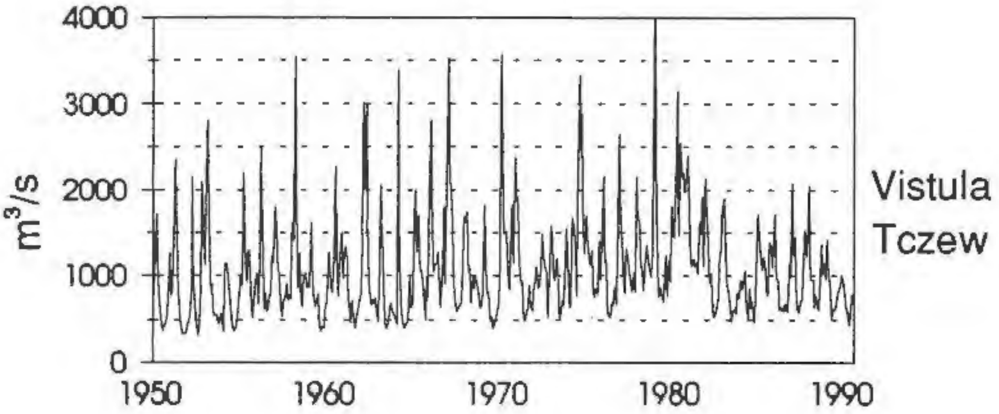
Luga
Kingisepp


3500
3000
2500
2000
1500
1000
500
0
m³/s
1950 1955 1960 1965 1970 1975 1980 1985 1990
Neman
Smalininkai


4000
3000
2000
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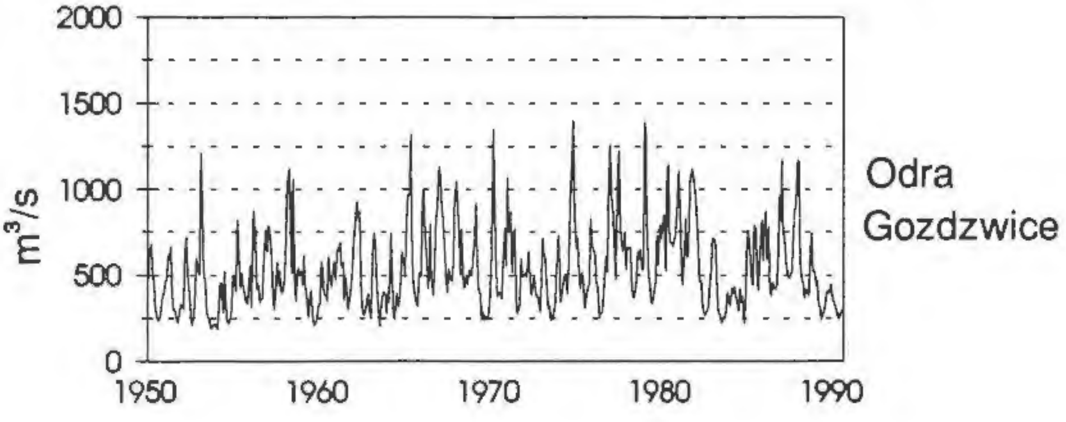
m³/s
1950 1960 1970 1980 1990
Vistula
Tczew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1500
1000
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0
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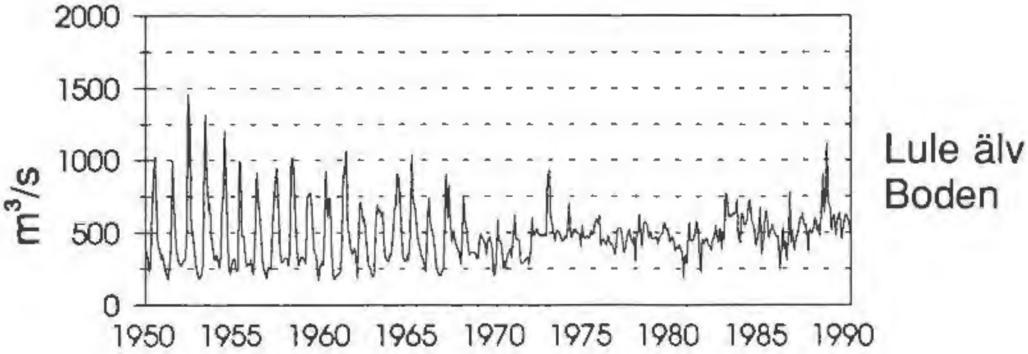
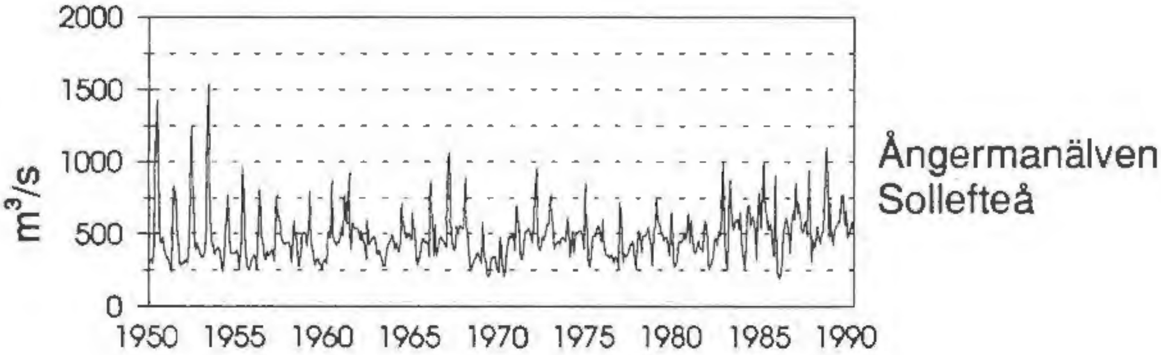
1950 1960 1970 1980 1990
Odra
Gozdzwice


2000
1500
1000
500
0
m³/s
1950 1955 1960 1965 1970 1975 1980 1985 1990
Lule älv
Boden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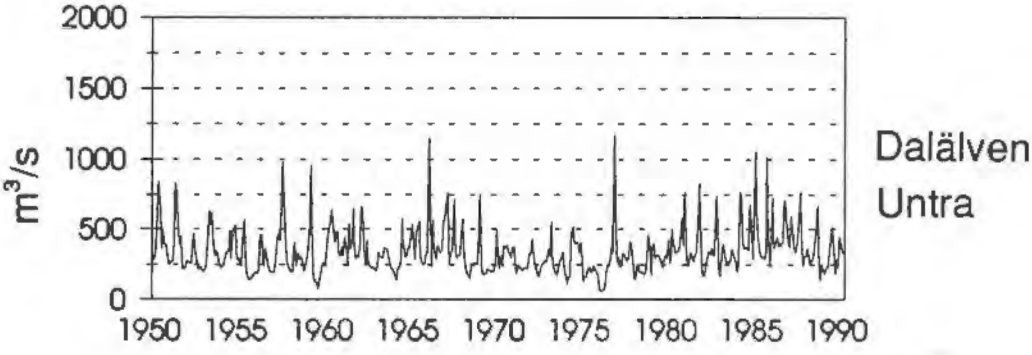
m³/s
1950 1955 1960 1965 1970 1975 1980 1985 1990
Ångermanälven
Sollefteå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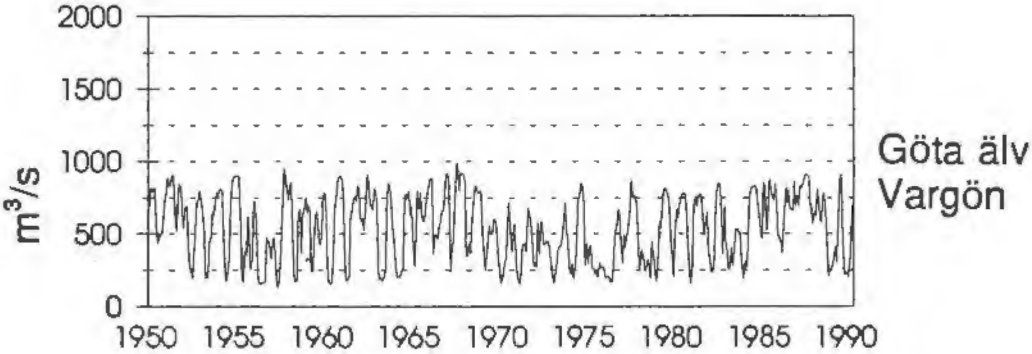
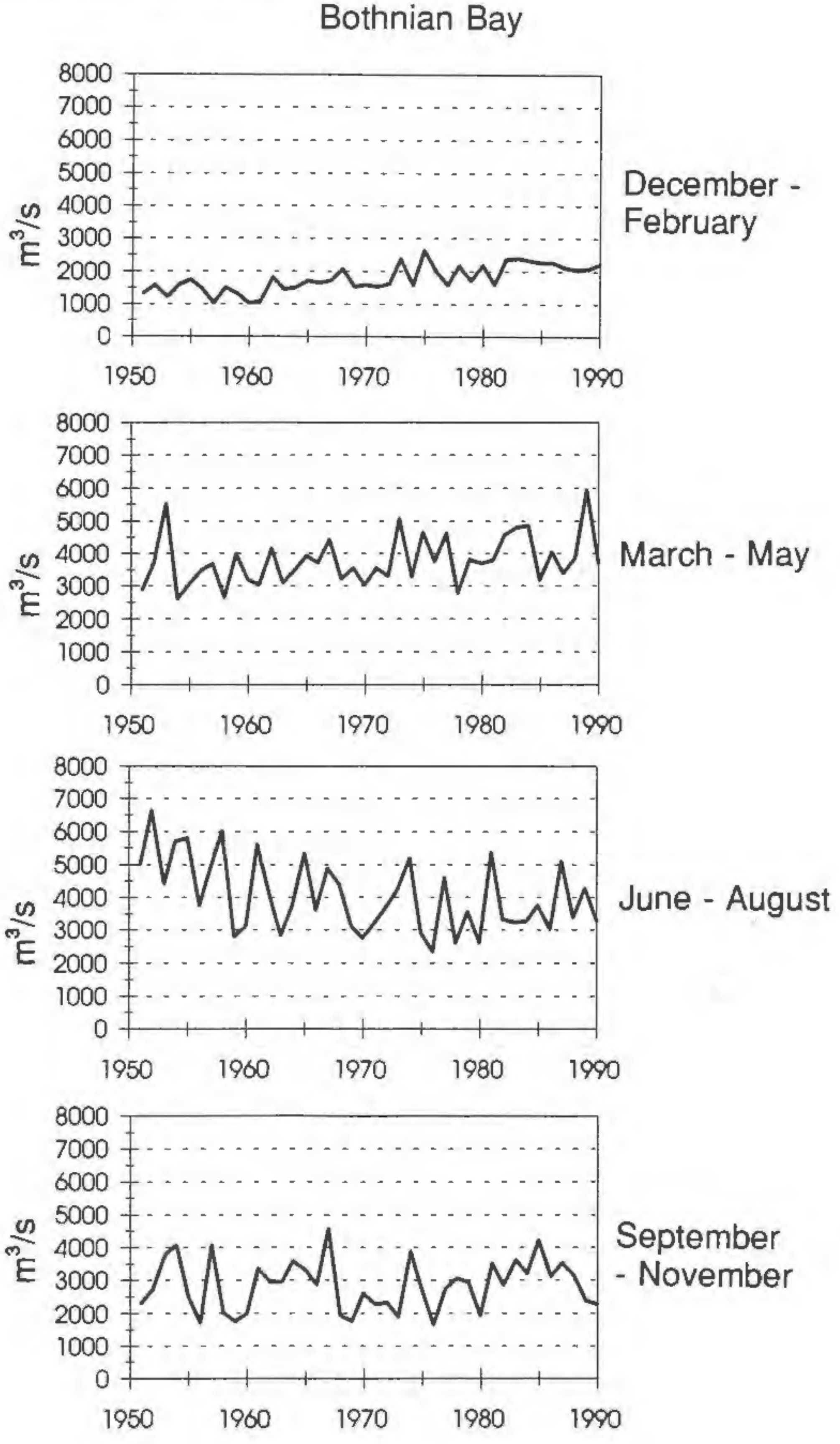
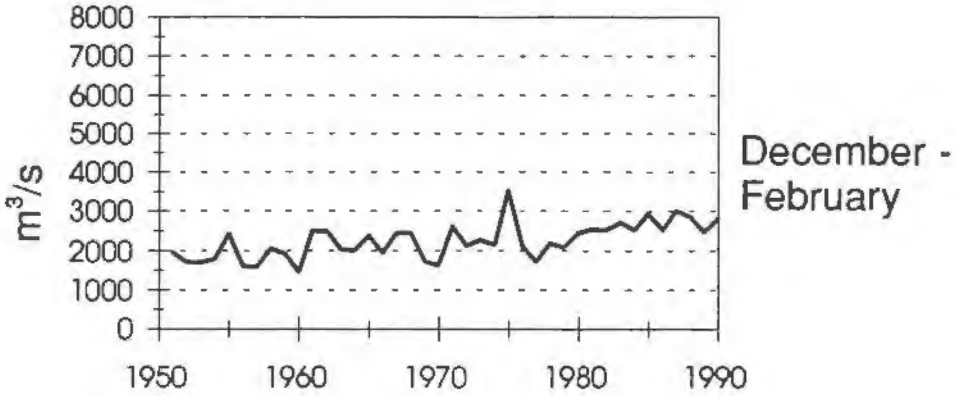
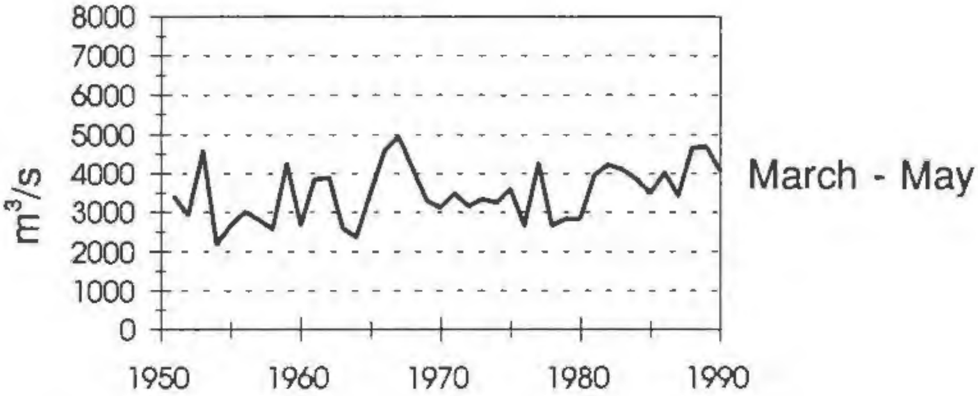

2000
1500
1000
500
0
m³/s
1950 1955 1960 1965 1970 1975 1980 1985 1990
Göta älv
Vargön

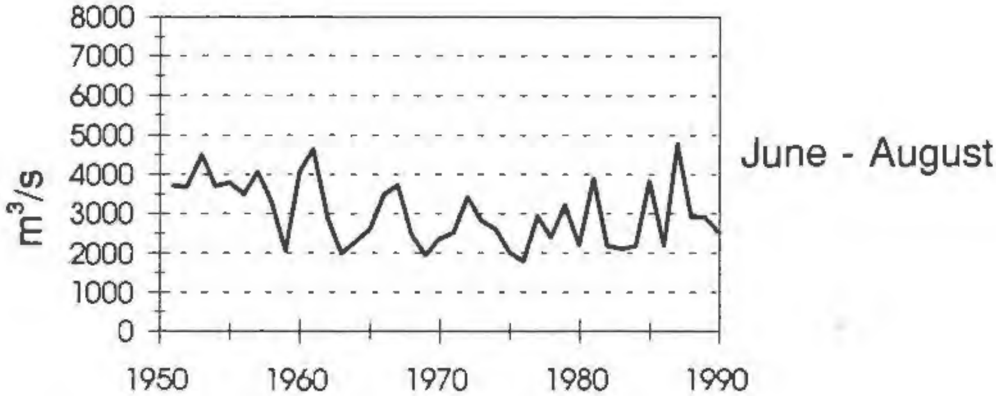
Seasonal contributions to the subbasins of the Baltic Sea for the period 1951 - 1990 **APPENDIX 2**

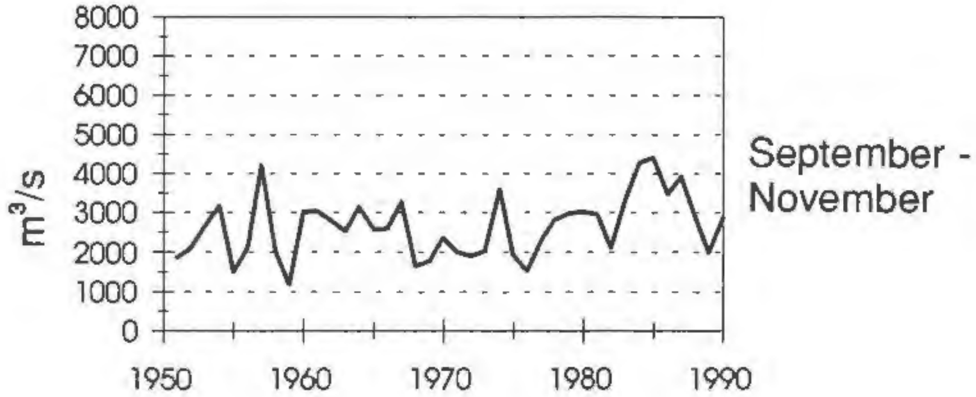


Bothnian Sea

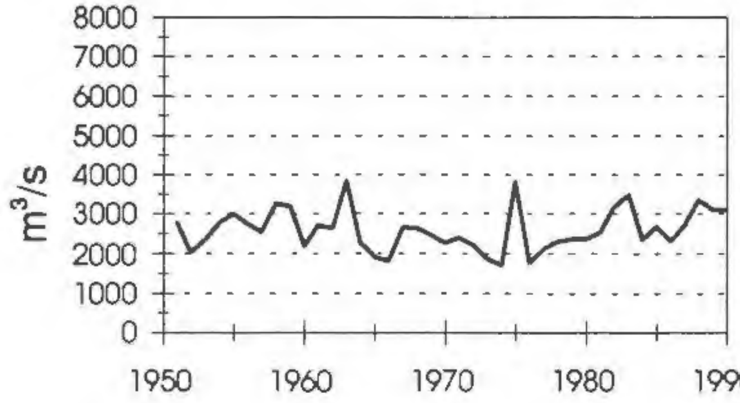




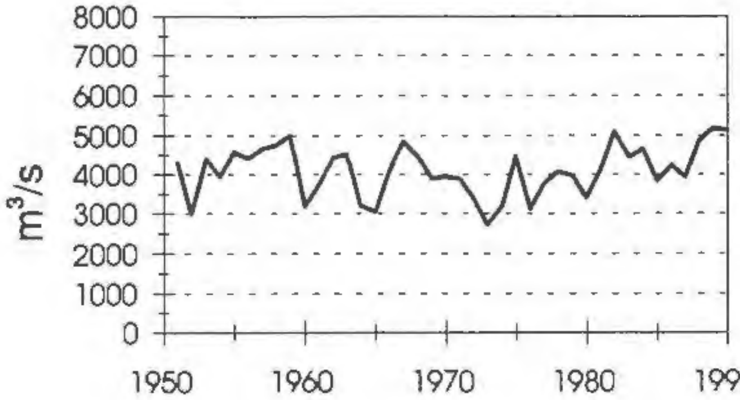




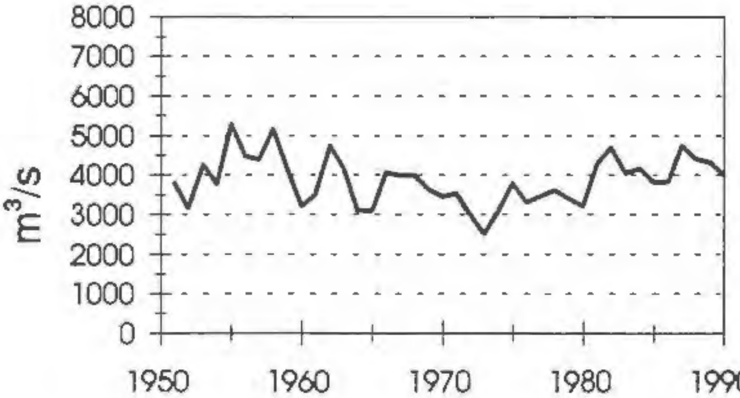
Gulf of Finland



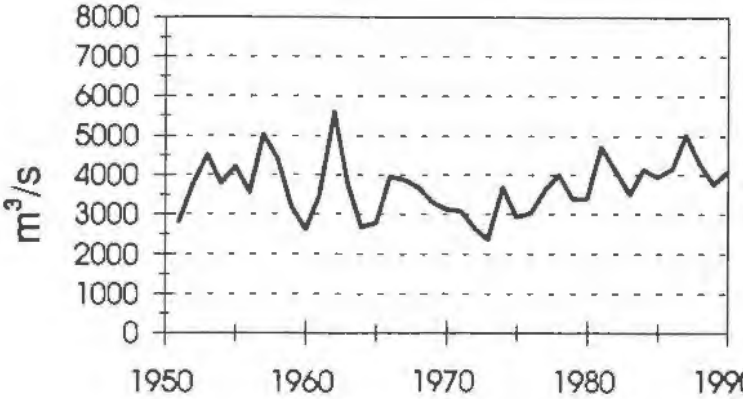
December - February



March - May

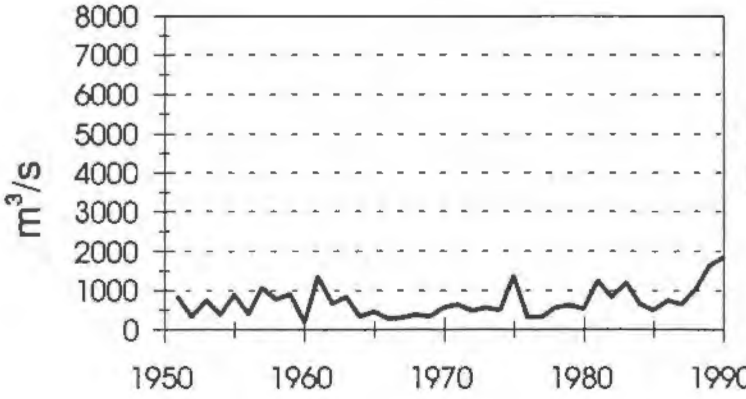


June - August

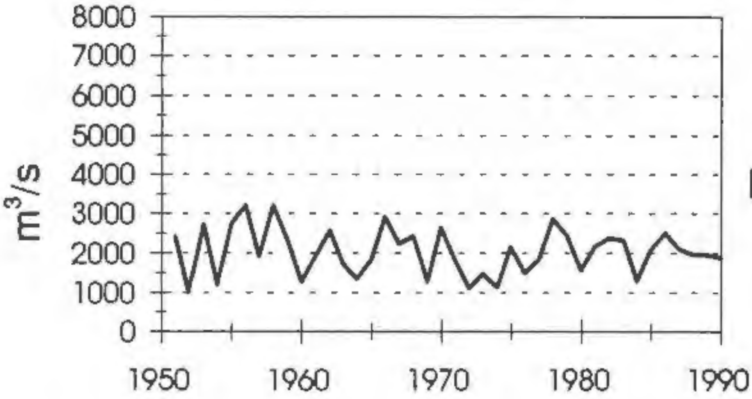


September - November

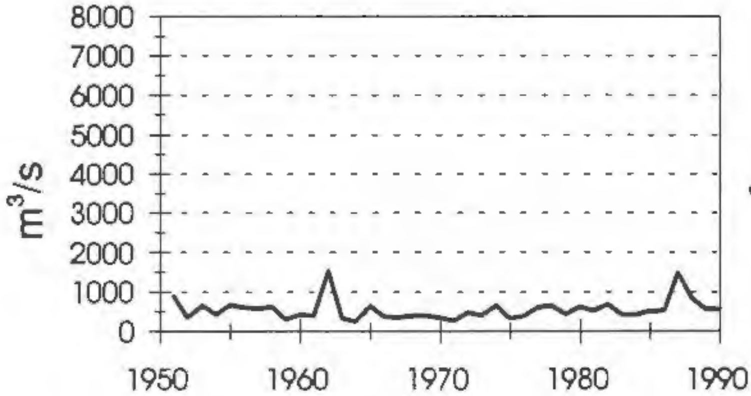
Gulf of Riga



December - February



March - May



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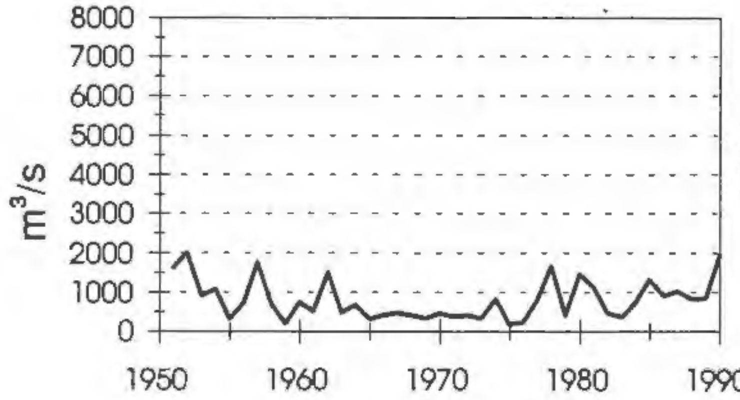
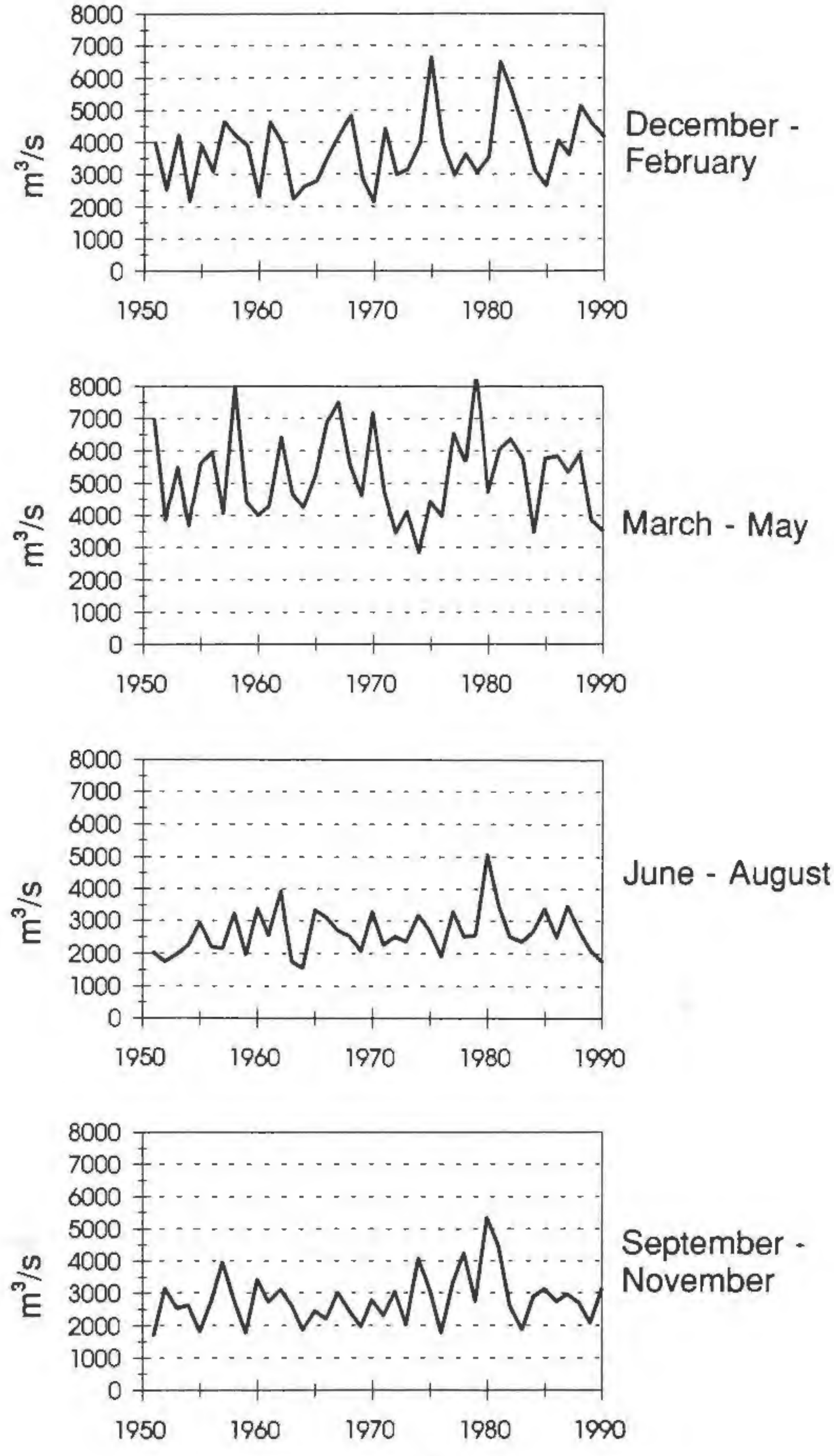
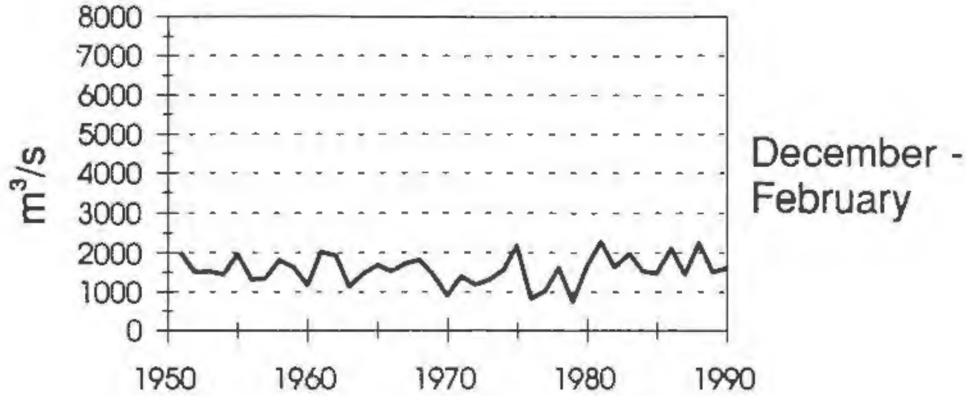


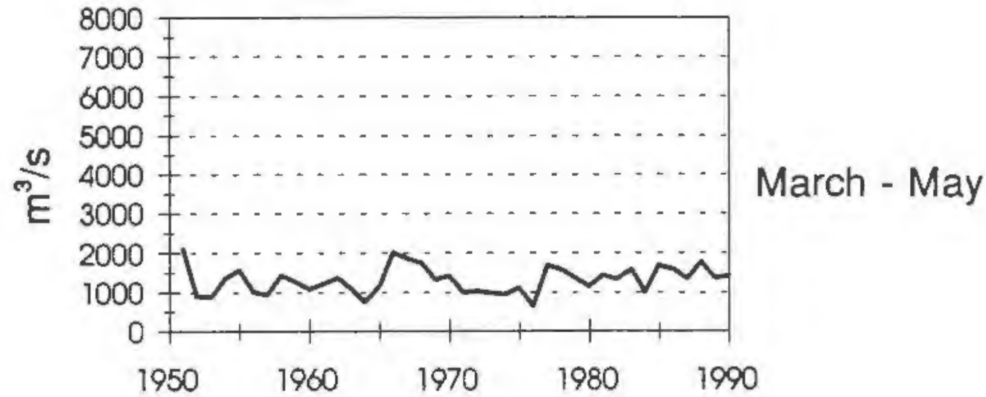
September - November

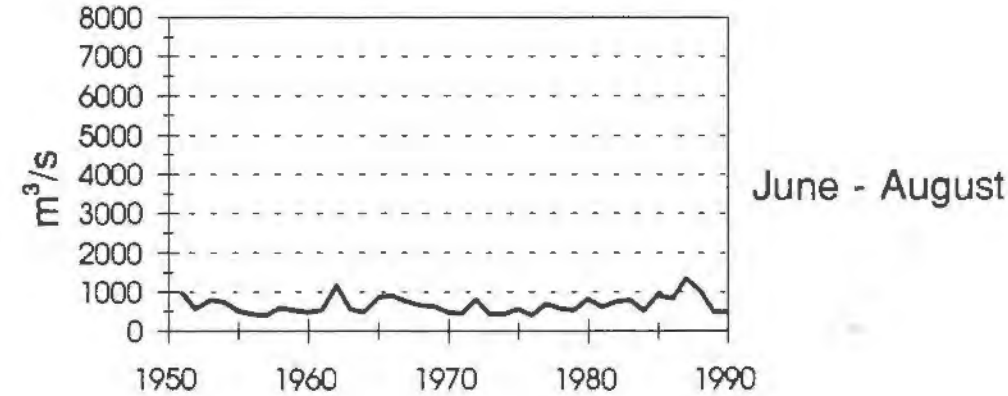
Baltic Proper

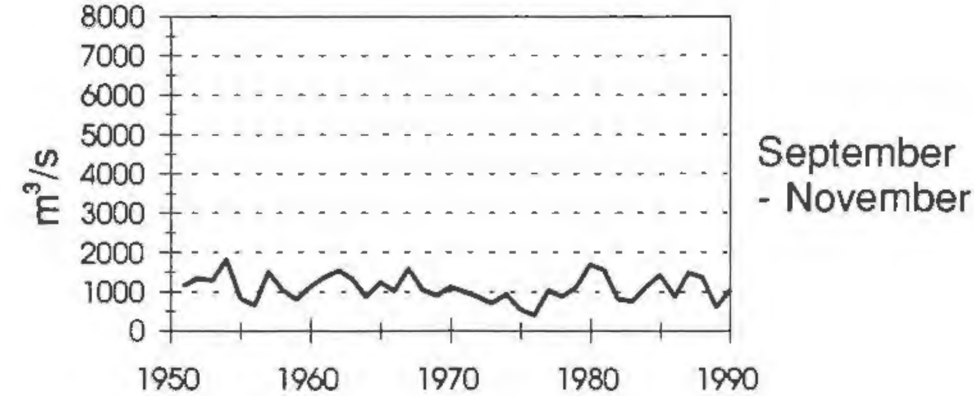


Danish Sounds and Kattegat









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