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THE BALTIC SEA – A SEMI-ENCLOSED SEA, AS SEEN BY THE HYDROLOGIST

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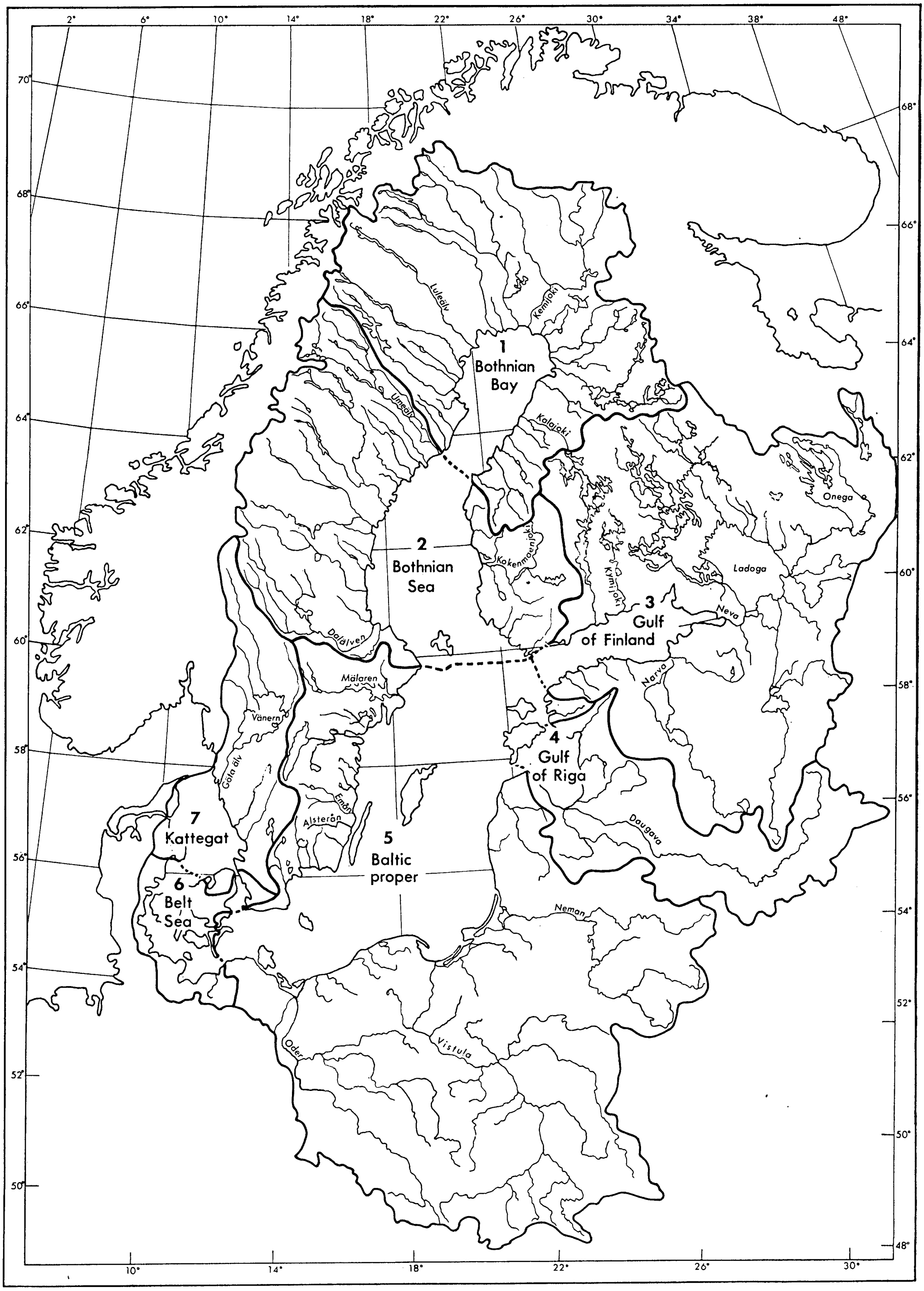
The paper discusses water renewal of the Baltic Sea, a semi-enclosed basin, the general configuration of the water balance, the size and distribution of its individual elements and the interrelations between them. Connections between long-term variations in the water balance and certain ecological features are stressed. To make possible a deepened understanding of the water renewal, international cooperation has been organized between the seven riparian countries.

At the margins of the world ocean there are situated a number of semi-enclosed seas: the Baltic Sea, Adriatic Sea, Mediterranean Sea, Black Sea, Red Sea, Hudson Bay etc. The water renewal of these seas has two main components: fresh water and salt water.

HYDROMORPHOLOGY

The Baltic Sea has a meridianal extension of more than 1500 km and a latitudinal one of about 650 km. The area of the drainage basin is only about four times that of the sea (Fig. 1). The Baltic Sea consists of a series of deep basins, separated by sills (Table 1, Fig. 2). Three gulfs (Gulf of Bothnia, Finland and Riga) extend far inland from the central Baltic, also called the Baltic Proper: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Bothnian Bay
2
Bothnian Sea
3
Gulf of Finland
4
Gulf of Riga
5
Baltic proper
6
Belt Sea
7
Kattegat
Luleälv
Kemijoki
Umeälv
Kalajoki
Kokenmaenjoki
Kymijoki
Dalälven
Mälaren
Vänern
Göta älv
Emån
Alsterån
Onega
Ladoga
Neva
Narva
Daugava
Neman
Vistula
Oder
2°
6°
10°
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22°
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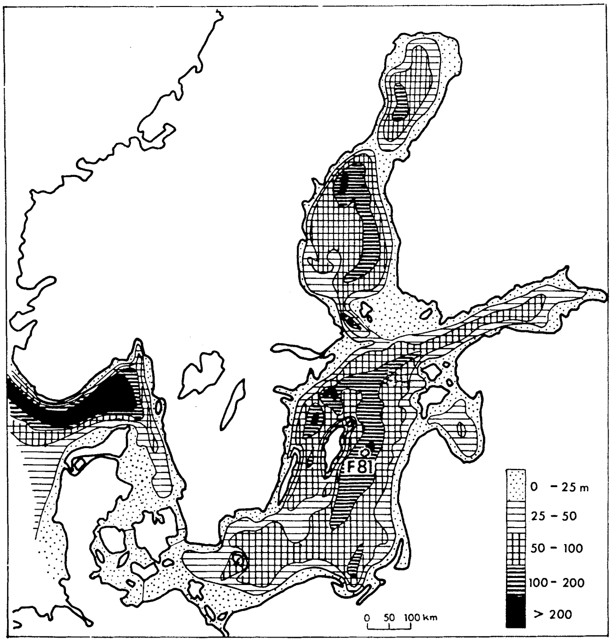

Fig. 2.
Morphometry of the Baltic Sea. F 81 marks position of observation station in Fig. 10.

- the Gulf of Bothnia is the northernmost part of the Baltic, separated from the Baltic Proper by the archipelago of Åland. The Gulf is divided into a shallow northern and a deep southern part separated by the archipelago of the Kvarken Island
- the Gulf of Finland is the easternmost part of the Baltic with a sillfree connection to the Baltic Proper
- the Gulf of Riga is separated from the Baltic Proper by the islands Sarema and Muhu and the shallow waters around them.

The Danish Straits and the Kattegat form the transition zone of the Baltic, interconnecting it across the Skagerak and the North Sea with the Atlantic ocean. Three different strait channels are distinguished:

Fig. 1.
Drainage basin and subregions of the Baltic Sea and its transition area. Representative rivers indicated by names. Dashed lines show boundaries between Baltic Sea subregions. Thick lines show boundaries between the corresponding drainage basins.

Table 1.
Morphometry data on the different parts of the Baltic.

Subbasin	Ehlin No. (1)	Area km² (1)	Max depth m (2) (3)	Volume km³ (1)	Drainage basin km² (4)
Gulf of Bothnia		115879		6378	489870
1. Northern Bothnia (Bothnian Bay)	1	36804	146	1492	269955
2. Southern Bothnia (Bothnian Sea)	2–5	79075	294	4886	219915
3. Gulf of Finland	6	29571	123	1103	420990
4. Gulf of Riga	7	18096	51	408	130960
5. Baltic Proper	8–15	209184	459	13029	607730
6. Danish Straits		20352		290	
. The Sound	16	1243		16	
. Belt Sea	17	19109		274	
7. Kattegat	18–19	22043		507	
Total Baltic					
1–5 excluding estuary area		372730	459	20917	1649550
1–7 including estuary		415125	459	21714	

(1) Ehlin, U., Mattisson, I. & Zachrisson, G. (1974)
(2) Kullenberg, B. (1967)
(3) Fonselius, S. (1969a)
(4) Mikulski, Z. (1970)

- The Sound between the Scandinavian Peninsula and the island of Zealand, which constitutes the main navigational route between the Baltic and the North Sea
- the Great Belt between the islands of Zealand and Fyn
- the Little Belt between the island of Fyn and the Jutland Peninsula.

WATER BALANCE - WATER EXCHANGE

The oceanographers working with the Baltic mostly focus on internal water exchange processes, such as the mixing between layers and between subregions, or between coastal waters and the open water mass. They are further interested in the water exchange with the North Sea, the path followed by individual salt water inflows, the salinity distribution in the Baltic and the development of the oxygen conditions in its deep water. Hydrologists, on the other hand, have a tendency to regard the semi-enclosed sea more as a whole and seen in near relation to the land area drained. They are occupied with the storage in the basin and the external water exchange, and take less notice of the salinity of the different water balance elements (whether salt water or fresh water).

A semi-enclosed basin is in some important aspects characterized by its fresh water balance: the basin is negative when it would have to be refilled with water from the outside in order to compensate for the water loss. In a positive basin the water surplus resulting from a positive fresh water balance leaves the basin as outflow. If these both types of flow were hindered by a wall at the outlet, the water level in the basin would decrease in the former case and increase in the latter.

The result of the water exchange conditions can be seen in the salinity distribution within the basin. Normally, positive basins have low salinity or are even brackish, whereas negative basins are strongly saline.

The Baltic Sea is characterized by a positive fresh water balance, and its water is brackish. The basin is in hydraulic contact with the North Sea over the shallow thresholds in the Danish Straits, which only allow a restricted water exchange. A longitudinal salinity profile is shown in Fig. 3. Basically the water mass of the Baltic consists of an upper layer with continuous through-flow of fresh water from the rivers discharging into the Baltic and a lower layer of higher salinity, where the water is renewed in an oscillatory manner through irregular salt water intrusions.

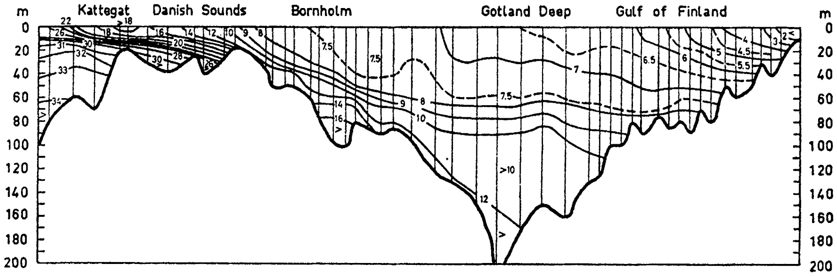

Fig. 3.

Depth profile of the Baltic from Kattegat to Gulf of Finland showing salinity stratification (from ICES/SCOR 1973).

The great vertical stability of the halocline separating the surface water from the deep water very markedly prevents vertical exchange, particularly in the open sea. Stagnant conditions therefore develop in some of the basins of the Baltic Proper. All oxygen may be exhausted and H_2S formed in the bottom water (Fonselius 1969b). The only effective renewal of the deep water occurs through the irregular inflow of oxygenrich water with relatively high salinity from the Kattegat. These inflows can completely renew the stagnant bottom water of the deep basins if it has a higher density than the old bottom water.

Basically, the dynamics can roughly be described by the simple exchange model in Fig. 4. The external forcing functions governing the water exchange are

- fresh water supply
- outside sea level and salinity
- meteorological forcings

The renewal of the water mass is described by the water balance, a concept quite extensively used by hydrologists. The concept implies the quantitative relations and the different interconnections between all the elements responsible for the renewal of the water by different exterior processes: precipitation, evaporation, input by land runoff, salt water inflow through the straits connecting the semi-enclosed basin with the bordering sea, water storage and water outflow. These water renewal processes are evidently of primary importance to the issue of the advancing pollution of the Baltic Sea and its ability to recover from semi-conservative pollutants. However, long-term variations and trends in these water exchange elements also have to be taken into account when analysing trends in the pollution or in the natural biological and chemical conditions.

The water balance is composed of processes of vertical and horizontal water

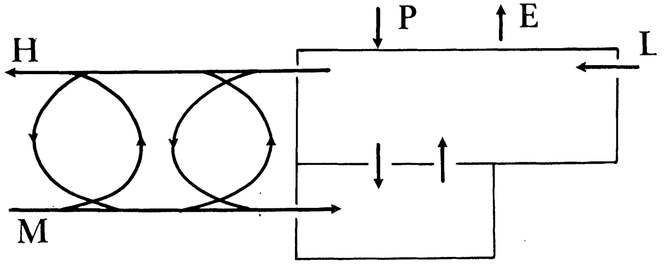

Fig. 4.
Basic dynamics of water renewal of the Baltic.

exchange. On a short-term basis, a change in water storage has also to be taken into account. The vertical and the horizontal parts of the water exchange play different roles in different semi-enclosed basins. In some basins, the vertical exchange may dominate, in others the horizontal may. Any of these exchanges may be either positive or negative.

VERTICAL WATER BALANCE

In the Baltic, the input term of the vertical balance, the average *precipitation*, averages according to existing estimates about 500 mm/yr. The differences are however large as can be seen from Table 2 (400–550 mm/yr). The precipitation is, in general, higher in the southern and eastern parts of the system and lower in the northern parts and the open water areas. The precipitation is lower during winter and spring and higher during summer and autumn.

The determination of this element is evidently difficult due to the fact that it has to be based mainly on data from shore stations, since stations on islands and research vessels are rare. The extrapolation over the water surface makes necessary some acquaintance with the precipitation processes over the sea, which result in a relatively heterogeneous regional distribution. Another difficulty arises from the different national practices with respect to the correction of measured precipitation values for different errors, mainly the aerodynamic deficit which will probably be rather large at such wind-exposed locations as are frequent in the coastal zone. In order to arrive at precipitation values of a reasonable accuracy, there is a need for measurements at sea over a limited period of time, primarily by making use of islands, ferry boats and research vessels, but also by use of radar determinations.

The water loss in the vertical balance is the *evaporation*. This is a poorly known element, there being large variances in the magnitude as calculated by different authors (Table 2). This loss amounts to 460–570 mm/yr according to reasonable estimates. The regional variation is influenced by the water temperature and climatic conditions. The evaporation therefore seems to be highest over the open sea in the Baltic Proper and lowest in the inner part of the Gulf of Bothnia.

The seasonal variation is to a large extent influenced by the relation between air and water temperature, leading to a minimum in spring and a maximum in autumn and early winter. The ice cover evidently represses the annual evaporation during winter, especially in the northern Gulf.

There are major difficulties in arriving at good estimates of this balance element: absolute measurements are practically impossible, so the hydrologist

Table 2.
Historical development of estimates on main water balance elements.

Author (Date of publication)		1 Bothnian Bay	2 Bothnian Sea	3 Gulf of Finland	4 Gulf of Riga	5 Baltic proper	6 Belt Sea	7 Kattegat	8 Baltic Sea	Comments
PRECIPITATION										
1. Krümmel	mm								550	
(1904)	km^3								(237)	
2. Spethmann	mm								400	
(1912)	km^3								163	
3. Witting	mm	533	554	595	560	570			565	
(1918)	km^3	19,7	44,4	17,6	9,4	115			206	
4. Sokolovski	mm								550	
(1933)	km^3								211	
5. Simojoki	mm	449	(473)	576	569	544			524	
(1949)	km^3	16,6	38,7	17,0	9,5	110			192	
6. Brogmus	mm	405	(425)	560	580	473	515		(474)	
(1952)	km^3	15,0	(35,3)	16,8	9,3	95,5	10,8		(183)	
7. Wyrtki	mm									
(1954)	km^3								(178)	
EVAPORATION										
1. Krümmel	mm								(183)	
(1904)	km^3								(80)	
2. Spethmann	mm								(197)	
(1912)	km^3								80	
3. Witting	mm	294	(421)	510	504	566			498	
(1918)	km^3	11,0	33,2	15,0	8,6	114			182	
4. Sokolovski	mm								500	
(1933)	km^3								193	
5. Simojoki	mm	297	(425)	408	410	522			(460)	
(1949)	km^3	11,0	32,8	12,0	6,8	105			(168)	

(1951)	km³								
7. Brogmus	mm	331	(404)	398	361	(553)	505	(474)	
(1952)	km³	12,3	32,2	12,0	5,8	110	10,6	(183)	
8. Wyrtki	mm							172	
(1954)	km³								
9. Strokina	mm	292		(604)	(604)	(725)		(573)	other regional division
(1956)	km³								
10. Hankimo	mm		495						(1961/62)
(1964)	km³								
11. Palmén & Söderman (1966)	mm					528			(1961/62)
	km³								
INFLOW OF RIVER WATER									
1. Krümmel	mm							(773)	
(1904)	km³							333	
2. Spethmann	mm							(1150)	
(1912)	km³							467	
3. Witting	mm							(1278)	
(1918)	km³	115	95	114	37	106		467	
4. Rundo	mm								
(1930)	km³	110	92	101	22	(84)	5,4	476	
5. Sokolovski	mm							1172	
(1933)	km³							440	
6. Schulz	mm								
(1938)	km³							483	
7. Brogmus	mm	2700	(1330)	4200	2470	570	340	(1240)	
(1952)	km³	100	92,8	126	39,5	114	7,1	(479)	
8. Wyrtki	mm								
(1954)	km³							505	
9. Mikulski	mm	2700	1270	3910	1950	460		1140	
(1968, 1970)	km³	99,9	82,8	115	32,6	110		441	1951–1960
10. Mikulski	mm	(2730)	(1260)	3720	1600	470		1120	
(1972a)	km³	(101)	(83,8)	110	26,7	112		433	1961–1970

has to rely on indirect methods or direct but relative methods. The methods available are primarily the following three:

- the aerological method (Palmén & Söderman 1966), which, however presupposes accurate data on the precipitation and is furthermore dependent on reliable assumptions of the wind field between the aerological stations
- the bulk aerodynamic method, which is based upon data on the vertical gradient of temperature and humidity and on wind data. The equation also contains an exchange coefficient, the determination of which depends on calibration measurements. This method has been applied by Brogmus (1952)
- the energy balance, applied by Strokina (1956), gives the evaporation as a function of the difference between two large terms, which necessarily leads to difficulties with the accuracy.

The difference between precipation and evaporation is expressed by the ver-

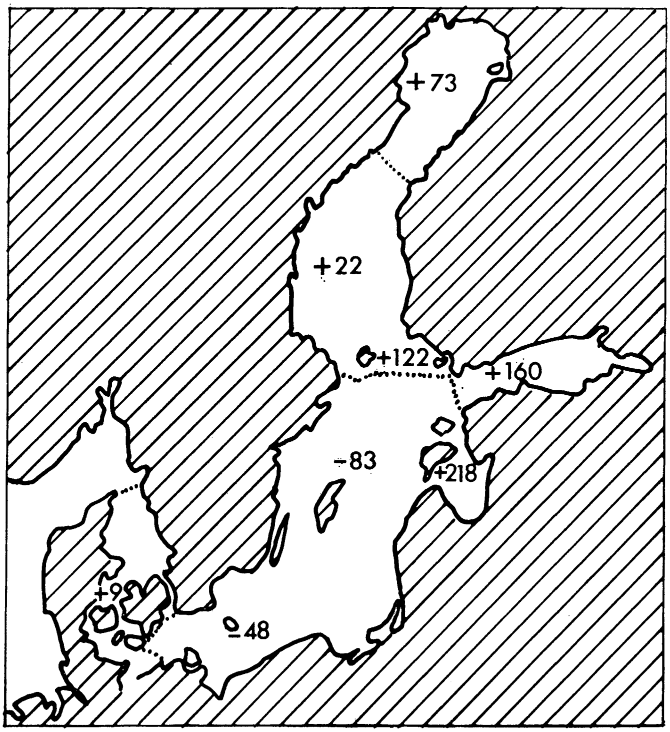

Fig. 5.
Vertical water balance of the different subregions (mm/year) according to estimations by Brogmus (1952).

tical balance, the regional distribution of which is roughly shown in Fig. 5. According to present data, the vertical balance is about zero when averaged over the whole semi-enclosed basin. It is, however, positive over the northern and eastern sub-regions (up to 200 mm/yr) and negative over the Baltic Proper (down to –100 mm/yr). This is the combined result of relatively low precipitation over open sea areas and higher evaporation in the south due to warmer water and often ice-free winters. The balance is principally positive during the summer half of the year and negative during the winter half, oscillating between extremes of the order of ± 10 to 15 mm/mo.

HORIZONTAL WATER BALANCE

The *river runoff* to the Baltic amounts to about 1100 mm/yr when averaged over the whole sea area (see Table 2). The drainage network is such that the Gulf of Bothnia receives water from a great number of rather short rivers, whereas the Gulfs of Finland and Riga and the Baltic Proper are all fed by one or two large rivers together with a large number of small coastal rivers. The horizontal fresh water input is largest in the Gulf of Finland (about 4000 mm/yr), large in the Gulfs of Bothnia and Riga (about 1700 mm/yr) but only about 500 mm/yr in the Baltic Proper.

The annual course of the inflow from different parts of the drainage basin Fig. 6) is characterized by a pronounced delay of the snow melt maxima while moving east and northwards. The annual minima of inflow appear in summer in the central part of the Baltic and in autumn and winter in the northern part.

The runoff is probably the most accurately determined element of the water balance: it can be based on direct measurements in all hydrometrically controlled rivers and for the remaining part of the drainage area it can be calculated from hydrological regionalization. According to present experience, it might indeed be determined quite accurately even from selected, regionally representative rivers.

The direct input of *subsurface runoff* is quite small due to prevailing geological conditions, and amounts, according to Zektzer (1973), to less than 1 % of the total river input. It is probably 50 % smaller on the northern and western side, where the soil layer is to a large extent quite thin. This inflow evidently has to be estimated by indirect methods. In some regions such groundwater inflow might play a larger role and form local areas of inflow.

The term in the horizontal balance which is typical for semi-enclosed seas is the inflow from the adjacent sea. In the case of the Baltic, this inflow is

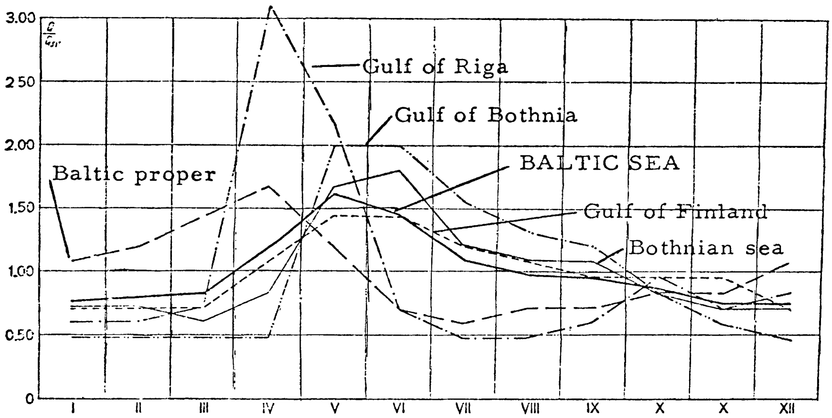

Fig. 6.

Regime of river inflow from different drainage subbasins (From Mikulski 1970). Vertical axis shows mean monthly runoff as a quotient of mean annual runoff.

constituted by *inflowing salt water from the North Sea.* It is to be observed that the main part of the inflowing water stays in the transit zone in the Belts and only a few inflows penetrate into the Baltic Proper (Fig. 4). Soskin (1963) has estimated the inflow from the Kattegat to the Danish Straits to be about 1200 km^3/yr (period 1898–1944). There seems to be an average seasonal variation with higher inflow in winter and lower in summer. There are clear interannual variations of at least ± 25 % around the average.

The salt water inflow has hitherto only been determined indirectly. The existing determinations are therefore still relatively inaccurate, and direct field measurements have only just started. Soskin's calculation is based on stream velocity data from light ships in the northern part of the Danish Straits (Lappegrund and Halskov Rev), using correlations with the inflow as calculated for 30 selected periods, for which this inflow could be calculated from water balance data. During the last decades, oceanographers have directed great interest to these inflows by following the changes in the distribution of salinity and oxygen content (Fig. 7).

Soskin sees the salt water inflow as principally composed of two parts: a continuous deep water stream, generated by the horizontal salinity gradient and an episodic, much more intensive inflow in connection with persistent westerly winds. The importance of the former type has not yet been made clear. The latter form usually occurs during autumn and winter. However, the interval between inflows of this kind can be several years (cf. Fig. 7). In fact, individual inflows may be larger than the annual land runoff to the Baltic. The inflow conditions can, otherwise expressed, be described as influenced mainly by two factors:

- the meteorological situation, represented by the air pressure distribution and wind field, has primarily a short-term influence
- the hydrological situation, constituted by water level and freshwater balance, has a long-term influence.

Thus, strong westerly winds enlarge the inflow, whereas a diminution takes place when the west wind is low (Soskin 1963). The water level difference between the Baltic and the North Sea also influences the process.

The output part of the horizontal balance is the *outflow through the Danish Straits*. On a long-term basis, this term constitutes the result of the integrated vertical and horizontal water balances. According to the Soskin (1963) study this term amounts to about 1600 km³/yr (long-term average). The average seasonal variation corresponds to stronger outflow in winter and weaker in

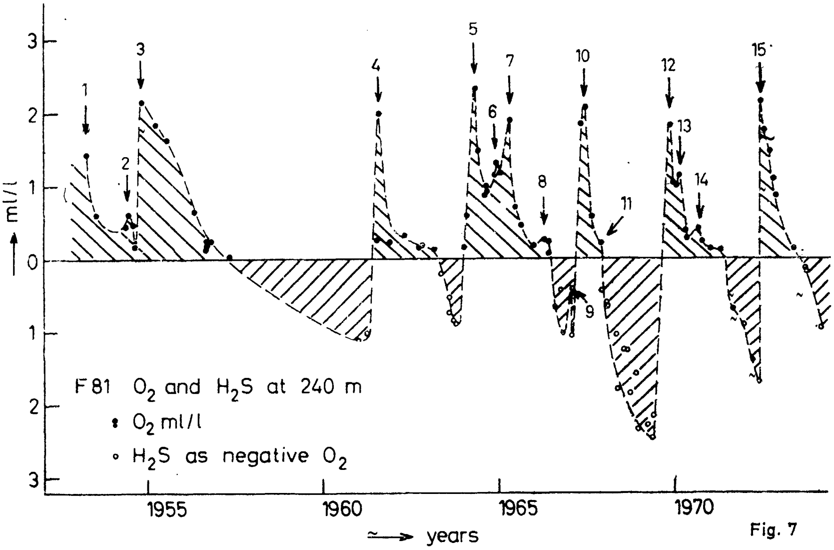

Fig. 7.

Oxygen and hydrogen sulphide 1953–74 at 240 m depth at station F 81 in the Gotland. Deep (from Engström & Fonselius 1974).

Oxygen expressed in ml/l, hydrogen sulphide as "negative oxygen". Arrows indicate inflows of salt water from North Sea.

summer. Also for this element the interannual variation is considerable, the yearly averages fluctuating at least 30 % above or below the mean.

The outflow has been determined by indirect calculations in the same way as the inflow, but direct measurements have recently started.

In a positive semi-enclosed basin the outflow exceeds the inflow. This is evidently the case in the Baltic, and the net outflow is about 500 km^3/yr, corresponding to the fresh-water balance. In the case of a negative basin such as the Mediterranean the situation is the opposite. As the vertical balance in the Baltic is about zero, the horizontal balance is likewise about zero (as a long-term average) and the net outflow corresponds to the land runoff.

WATER STORAGE

The *total* water storage in the Baltic (by mean water stage) amounts to about 21 000 km^3. However, only part of this storage is *active* and takes part in the water balance: the active storage capacity of the Baltic between highest and lowest monthly extremes thus amounts to about 500 km^3. This is about the same size as the annual river inflow. When considering the water balance on a monthly basis, the *storage changes* can attain positive or negative values. Due to the large atmospheric influence, the interannual course of these storage changes is quite irregular. In fact, the monthly changes normally exceed the annual storage changes. The storage change during a month can thus rise to 150 or 200 km^3 (Wyrtki 1954).

The form of the water level is influenced by three main factors: hydrological, anemobaric (air pressure gradients) and dynamic (wind field effects) (Bergsten 1955). The hydrologist concerned with the water balance operates only with areal averages of the water level, in which such disturbances are to a large degree smoothed out. The water storage and its changes can thus be calculated from water level observations at representative stations and the sea area at the relevant water level. The water density is considered to be of minor importance for the accuracy attainable.

The irregular course of the monthly water storage changes emerge from the fact that the storage is constituted by the water balance. Fig. 8 shows the balance for successive months during the period 1926–30. The highly irregular course of the salt water inflows constitutes the main reason for the large variations in water storage. The irregularities of the outflow evidently also contribute to these variations. The heavy dependence on the atmospheric circulation of both these terms is thus transferred to the short-term changes in the water storage.

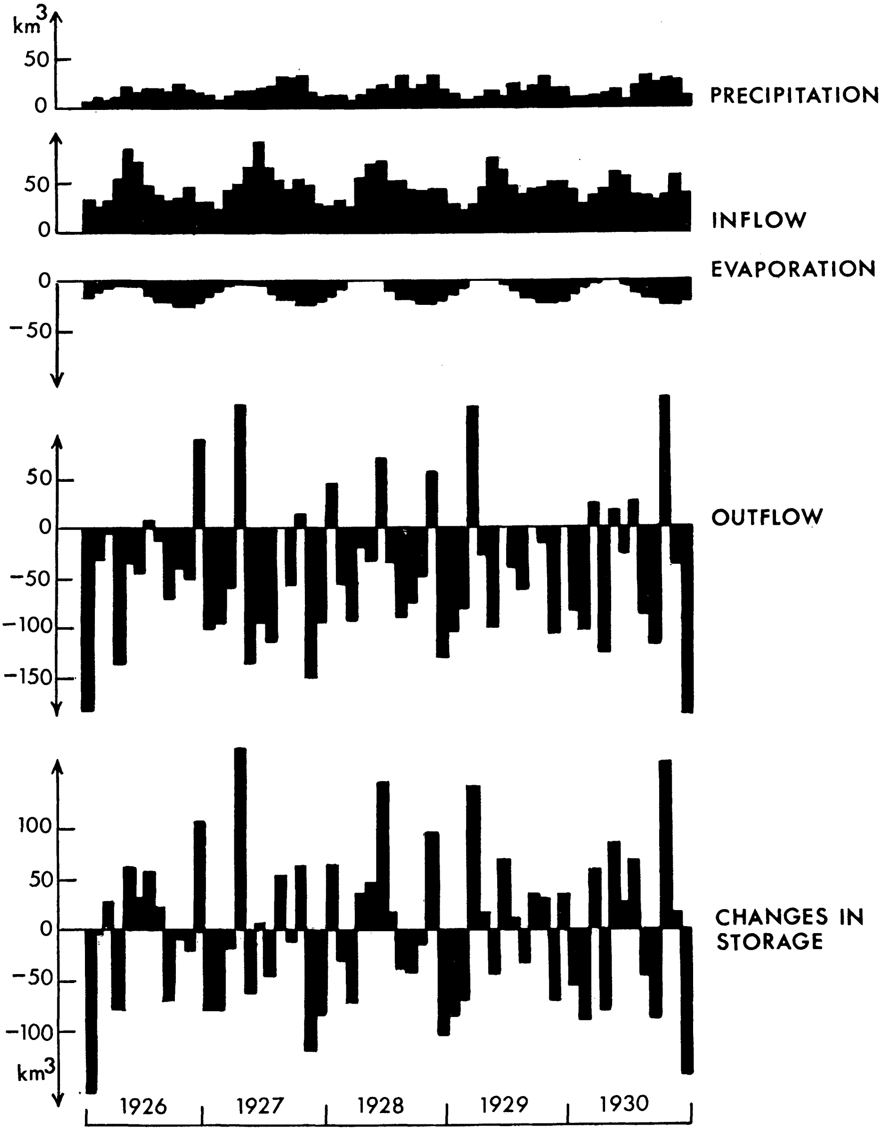

Fig. 8.

Elements of water balance of the Baltic for different months from January 1926 to December 1930.

Water flows and storage changes given in km^3/month. Water outflow through the Danish straits has been combined with salt water inflow from North Sea and is presented as net water exchange. (Based on values from Wyrtki 1954).

Table 3.

Water balance of the Baltic Sea according to different authors.

Annual flows given in mm, km^3 and volume %.

Element of water balance	Krümmel (1904) F = 431 000 km^2			Spethmann (1912) F = 406 720 km^2			Witting (1918) F = 386 000 km^2			Sokolovski (1933) F = 375 000 km^2			Brogmus (1952) F = 386 000 km^2			Brogmus (1952) F = 365 000 km^2		
	mm	km^3	%	mm	km^3	%	mm	km^3	%	mm	km^3	%	mm	km^3	%	mm	km^3	%
Precipitation (P)	550	(237)	42	400	163	26	565	206	31	550	211	32	474	183	13	471	172	15
Inflow of river water (L)	(773)	333	58	(1150*)	467*	74	(1278)	467	69	1172	440	68	1240	479	34	1290	472	42,5
Inflow from the North Sea (M)	–	–	–	–	–	–	–	–	–	–	–	–	1910	737	53	1290	472	42,5
Evaporation (E)	(183)	(80)	14	(197)	80	13	498	182	27	500	193	30	474	183	13	471	172	15
Outflow to the North Sea (H)	(1140)	490	86	(1353)	550	87	1345	491	73	1222	459	70	3150	1216	87	2580	944	85
Inflow of fresh water (P+L-E = H - M)	–	–	–	–	–	–	–	–	–	–	–	–	1240	479	34	1290	472	42,5
Balance total (P+L+M = E+H)	(1223)	(570)	100	1550	630	100	(1843)	673	100	1722	652	100	3624	1399	100	3051	1116	100

* contains 6 mm (2.3 km^3) of underground inflow.

WATER BALANCE SYNTHESIS

The water balance of the Baltic has interested scientists since the beginning of the present century (Table 3). The first water balance schemes (Krümmel 1904, Spethmann 1912, Witting 1918, Sokolowski 1933) are all concerned with only the fresh water balance (precipitation, evaporation, land runoff and outflow). Brogmus (1952) was the first to consider the total water balance (including salt water).

The difference between these two approaches is visualized in Fig. 9. According to the older and more restricted approach, the total water turnover (the sum of all inputs and outputs) is about 650 km^3/yr or about 1700 mm when averaged over the surface of the Baltic. When salt water input is also taken into account, the turnover rises to about 1400 km^3/yr, which is equivalent to about 3600 mm/yr.

In comparing water exchange characteristics of lakes, a hydrological classification, based on the relative contribution of the vertical and horizontal terms to the total input and output, can be used (Szesztay 1974). In the fresh water balance of the Baltic, the importance of the vertical terms to the total balance is quite large (about 30 %). When the salt water contributions are also considered, the influence of the vertical terms is reduced to about 10 %. In order for a lake to be classified as having a through-flow character, the vertical contribution has, however, to be less than 2–3 % (Mikulski 1972b).

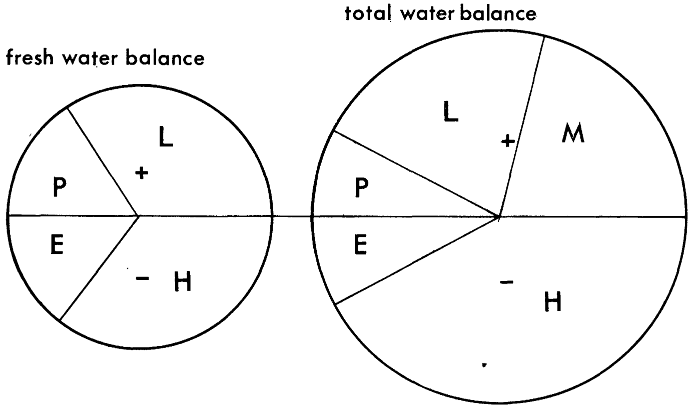

Fig. 9.
Difference between the two water balance approaches. Circle area proportional to total water turnover. Inputs above horizontal line, outputs below the line.

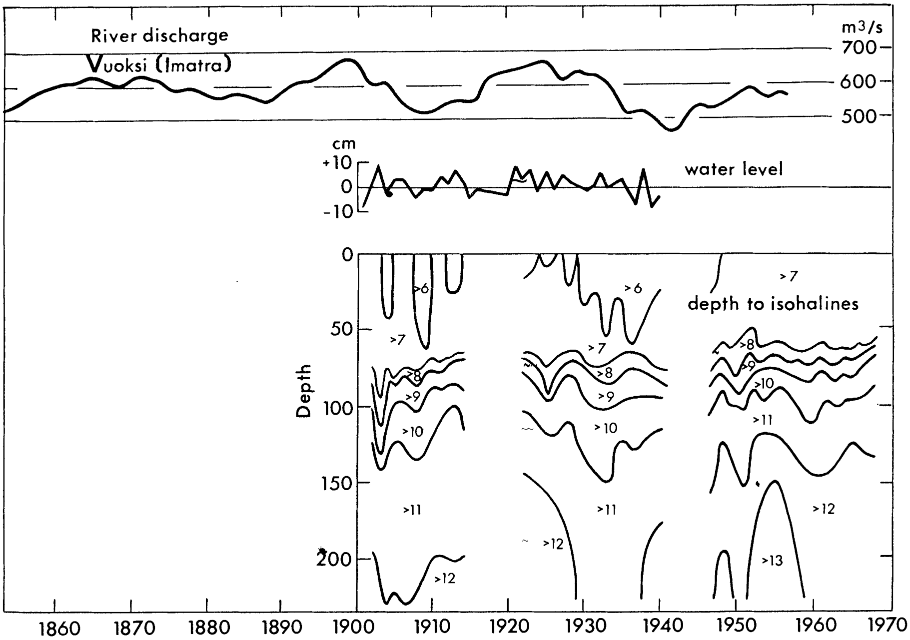

Fig. 10.

Long-term variations of river inflow, water storage and salinity stratification. River inflow illustrated by discharge of river Vouksi. 10 year running mean values according to Fonselius (1969 a).

Water storage illustrated by annual mean of water stage according to Lazarenko (1961). Salinity illustrated by annual means at Gotland' Deep. Station F 81 in Fig. 2. From Fonselius (1969 a).

Therefore, when looked upon from a strictly hydrological aspect, the Baltic basin is of a more stagnant character than a through-flow character, even when the salt water inflow is taken into account.

LONG-TERM VARIATIONS

Long term data series of reasonable reliability exist only for a few of the balance elements, which, however, clearly show that there exist large interannual variations. From Fig. 10 it can be seen that the land runoff is subject to relatively regular variations and trends (Fonselius 1969a), indicating that persistence characterizes the runoff system. The water storage, on the other hand, seems to vary less regularly (Lazarenko 1961). It is evident that long-term variations in the atmospheric circulation have a large influence on several of the water balance elements. However, the time lags which affect the Baltic may differ between elements. For instance, variations in the atmospheric circulation manifest themselves in an immediate way in the precipitation over the sea surface, the evaporation from the sea, the precipitation over the drainage basin and possibly in the inflow from the North Sea. The corresponding influence on the land runoff is, however, subject to a time lag, corresponding to the transit time distribution of the precipitation/runoff system for the different river basins.

Existing data on individual elements are to a large degree incompatible. The long-term averages often represent different periods and in some cases the periods are not even specified. The elements have not been determined independently of each other, and the accuracy is often low. In order to study the long-term variations systematically, homogeneous data series are evidently necessary, and the elements have all to be determined independently of each other.

Table 4.
Element coordinators within project.

Balance element	Element coordinators
Water balance	
precipitation	Sweden/FRG
evaporation	BRD
runoff: rivers	Poland
groundwater	Poland
water storage	USSR
inflow and outflow through the Danish Straits	Denmark
Material input and output	
dissolved substances: river input	Finland
dissolved substances: coastal input (waste water)	ICES
suspended substances: river input	Sweden/Poland
atmospheric fallout	IMI
exchange through the Danish Straits	Denmark
Bathymetric chart, areas, volumes	Sweden
Bibliography	Poland

In order to make possible more accurate determinations of all the individual elements and to produce the data needed, international cooperation has been organized between the seven countries bordering the Baltic Sea (Denmark, Federal Republic of Germany, Finland, German Democratic Republic, Poland, Soviet Union and Sweden). Monthly data are now being collected for the period 1951–75, the responsibility for individual elements being distributed among the participating countries according to Table 4. Methodological research work, involving field measurements is being done during a joint Methodological Pilot Study, July 1975 – Dec 1976. The project takes place within the International Hydrological Decade Programme.

The data series gathered will make possible a closer analysis of long-term fluctuations, leading to a better understanding of different interrelations of elements. It is evident that such long-term fluctuations as are to be seen for some of the elements must have direct consequences on the salt balance, and that fluctuations in the latter influence the salinity conditions in the Baltic. Thus, changes might be caused in the stratification. In fact, a clear trend has been reported for the present century in the level of the halocline, which has risen from about 80 m in the beginning of the century to about 60 m in the sixties (Fonselius 1969a), (see Fig. 10). At the same time, the stratification has been sharpened.

The long-term variations just discussed may be partly *natural* and partly *caused by man's activities*. Examples of man-caused changes in the water and material balances are regime changes in the land runoff due to changes in land use and flow regulations for water power and other purposes, introduction of polluted water, oxygen depletion of the North Sea deep water etc.

Once relevant long-term trends and periodicities have been determined and the physical processes causing them understood, a prediction of future deterministic changes in the individual water balance elements and of changes in the interrelations between elements and in the total water turnover is possible. Possible regularities revealed in the water balance during past time would evidently be of great value as a basis for explaining observed ecological phenomena.

Furthermore, should prediction of future water balance development be found possible, this would facilitate ecological forecasting within the Baltic ecosystem.

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