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Interannual variations of the amount of herring in relation to plankton biomass and activity, temperature and cloud coverage in the Baltic Sea

by

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Herring biomass in the ICES sub-divisions 22, 24-32 depend on eutrophication of the Baltic Sea during the 20th century. Superimposed, there are interannual variations, which coincide with those of mesoplankton biomass and phytoplankton activity (production index), temperature (SST, air [near bottom]) and cloud coverage. The latter fits with the amount and phase of the galactic cosmic ray flux as described by Svensmark and Friis-Christensen (1997) and Svensmark (1998).

keywords: Baltic Sea, 1972 to 1992, variations of herring biomass, plankton biomass, activity, temperature, cloud coverage, galactic cosmic ray flux

Introduction

The Baltic Sea, a semi-enclosed, intra-continental basin at the eastern edge of the North Atlantic Ocean, is situated in a region of prevailing westerly winds (Figure 1). The humid climate and the limited water exchange through narrow and shallow straits provoke a brackish water system with estuarine circulation. Nutrients are trapped in the deep water below the halocline commonly throughout the year. There is no significant vertical transport of nutrient rich deep water by winter convection like outside the permanently stratified basin.

This caused oligothrophic conditions up to the middle of the 20th century, when plankton and fish production were dominantly dependent on the nutrient supply through the Danish straits (Gessner, 1957). Later, the trophic level increased significantly due to stronger nutrient input from the drainage area by municipal and industrial sources and especially by the enhanced use of fertilisers. There is manifold evidence for this development for example by the concentration of soot particles and of exoskeletons of the cladoceran *Bosmina coregoni maritima* in the sediment of the northern Baltic Sea (Salonen et al., 1995), by the correlation between fertilisers used and the concentration of inorganic phosphorus in the sea water (Figure 2, Nausch et al., 1999) or by the extension of the area with laminated sediments, i.e. anaerobic conditions (Jonsson et al., 1990).

The course of the herring biomass in the ICES sub-divisions 22, 24-32 (compiled by Thurow, 1997b) coincides with the changing trophic stage of the Baltic Sea during the last century (Figure 2). Such a link had been assumed already by Hansson and Rudstam (I 990) basing on catch statistics. It supports the statement of Brandt (1894) that farmers actually might enable fishermen to increase their fishing success (in near coastal waters).

The estimation of herring biomass had been performed in different ways (Thurow, 1997a,b). There is a change in 197 1 from classical assessments to the virtual population analysis (VPA), with some overlapping years. The latter method is assumed to be more precise.

Generally, the herring stock is the result of reproduction, somatic growth and various causes of mortality. The synchronisation within the food web is of special importance during critical life spans. The change from lecito- to exotrophic nutrition is such (e.g. Hjort,1914 cited in Kiarboe and Johansen, 1986; Kisrboe et al, 1985; Rosenthal and Hempel, 1970; Schnack, 1972) whether in spring or in autumn, depending on the spawning time of different populations. The feeding conditions during summer determine the following over-wintering success of those herring year classes which were the object of Thurow's (1997a,b) biomass estimation.

Taking the results of the seventies and nineties, a certain decadal variability superimposes the secular biomass trend. Its regularity induced the wish to compare it with patterns of potential influences in order to find a reasonable explanation.

Material and Methods

There are complex data sets available for the relevant period, consisting of the mesozooplankton biomass (0.2 – 20 mm large) as the food source of adult herring, the (near bottom air and sea water) temperature influencing the stratification conditions and the metabolic activities of organisms, the chlorophyll-concentration as a proxy of phytoplankton biomass, the primary productivity, and the production index (phytoplankton biomass specific primary production) as a measure of phytoplankton activity. The patterns of cloud coverage had been included as the source of temperature variations as well as the flux of galactic cosmic rays and the solar activity. The two latter are recently discussed as a potential link between them and the cloud formation, e.g. by Tinsley (1997), Svensmark and Friis-Christensen (1997) and Svensmark (1998). Finally, the North Atlantic Oscillation Index (e.g. Lamb and Pepplen,1987), which is recently often used to describe atmospheric influences on the environment of the ICES area (e.g. Hurrel, 1995; Planque and Taylor,1998), had been considered as well. Details of the data origin and some methodological background are summarised in Table 1.

Results

A decadal temperature variability of about 2 to 4 K is obvious in the upper ten meters of the Baltic Sea. It coincides with displacement volume variations of the mesozooplankton above the thennocline. About 80% of the mesozooplankton is concentrated in this layer, detected during the seasonal biomass peak in August (Postel, 1995). The zooplankton concentration varies more than a factor of two within the time interval of about 10 years (Figure 3). Both significant patterns are pronounced best during summer.

(Warm summers do not always correlate with mild winters).

The herring biomass estimates show similar patterns. Higher zooplankton volumes and temperatures (i.e. stronger stratification) go with larger herring biomass concentrations. Its variations amount approximately one Million tons within the entire area.

Sea water temperature and the zooplankton volume are combined with potential sources of their decadal fluctuations in Figure 4. The similarities between the seasonal / interannual patterns ofvarious are striking, especially during the eighties, despite their differences in sampling characteristics.
Maxima of the sun spot numbers (Figure 4a) are followed by minima of the cosmic ray flux (and vice versa) about two years later (4b). The other parameters behave synchronously to the variations of the cosmic ray influx. Cloudy periods in the western Baltic Sea area (4c) and lower temperatures in the air and in the upper 10 m of the water column (4d,e) coincide with the high intensity of the cosmic rays, as observed on the global scale by Svensmark and Friis-Christensen (1997).
Further, the patterns of clouds and temperature correlate with those of the production index of phytoplankton in the upper 20 m (4f). The index is primary productivity normalised to chlorophyll and mainly a function of the light conditions. "Blue sky" (4c) guaranties intensive radiation and corresponds with higher temperatures (4d,e), which increases the stratification of the water column and keeps the phytoplankton in favourable light conditions above the thermocline. Such an agreement is missing for the concentration of phytoplankton-chlorophyll and for primary productivity per m^3 (Figure 5). A correspondence is evident again in the patterns of the epipelagic zooplankton biomass (Figure 4g).
High numbers of the North Atlantic Oscillation Index (NAOI) indicate strong zonal atmospheric circulation, commonly an increased moisture transport and mild winters over north-western Europe (Hurrel,1995). The patterns (Figure 4h) look different from those of the other parameters (lc-g) for the first moment. An expected coherence between the NAOI and the air temperature is slightly apparent during January and February only. During summer periods, a high NAOI is even accompanied by a low amount of cloud coverage (4c) in the western Baltic Sea in spite of westerly (maritime) weather. This supports lower cloud formation in the "weather kitchen of Europe" during summer periods of a low cosmic ray influx (4b).

The part of the data sets used for comparisons covers 20 years only. Significance in a statistical sense is generally assumed, if the observation length includes the period in question at least three times. However, this lack of objectivity might be substituted by the manifold matching patterns of different parameters. The distance between the peaks in summer is on average approximately 9 years, indicated by the three lines in Figure 4.

Discussion and Conclusions

The annual averages of herring biomass reached a level of 4 to 5 million tons in the Baltic Sea during the second half of the last century. It was an increase up to ten times in comparison to the first half. The dependence on eutrophication is without any doubt.

At this situation, fluctuations of about 20% of the total stock show similarities with decadal patterns of mesozooplankton . The pronounced correspondence during summer implies the dependence of herring stock rather on the food conditions during this season than on the survival conditions of Larvae whether in spring or in autumn,

The plankton activity, i.e. the food quality plays probably a major role within the food web. This might be concluded from the congruence between the mesozooplankton patterns and the production index of phytoplankton, which is missing in comparison to the proxies of phytoplankton biomass (chlorophyll concentration, primary production per volume of water).
The production index (PI) of phytoplankton relay on favourable conditions of photosynthetic active radiation. In this respect the inverse correlation of the PI and the cloud cover is not surprising.

The potential influence on the global formation of cloud cover is discussed as the missing link in explaining the solar-climate relationship by Tinsley and Heelis (1993), Tinsley (1994, 1997) as well as by Svensmark and Friis-Christensen (1997). High solar activity reduces the influx of the galactic cosmic rays on the earth. This reduction results from the effect of the solar wind on the magnetosphere. The maxima of the sun spot numbers follow the minima of the cosmic ray flux (and vice versa) about two years later — because, not the sun spots directly modulate the influx of cosmogenic particles and protons, but the strength of the solar wind, which is a result of the chromospheric eruptions following the solar activity peak by the mentioned delay (Landscheidt,1997). The coherence of solar cycle length, galactic cosmic ray flux, cloud formation and consequently the global temperature was demonstrated for the decadal variability by Svensmark (1998). It has been not only successfully shown for the 11 years' ("Schwabe") cycle of solar activity, but also for the secular ("Gleissberg") cycle. The latter was demonstrated by Lassen and Friis-Christensen (1995) comparing the northern land air temperature and. the length of solar cycles over a period of hundred years.
Since charged particles pass the earth atmosphere easier near the magnetic pole than at the equator (Svensmark and Friis-Christensen, 1997), the northern latitudes and the regions in the path of the weather patterns originated here might be primarily affected. This would explain the coherence between data of global and of local origin.

The coherence between positive NAOI during summer (westerly winds) and longer periods of lesser cloud coverage in the Baltic Sea region support such link which might be exist between solar activity, galactic cosmic ray flux, cloud formation and effects in the path of the weather patterns.

Consequently, cycles in solar activity might influence ecological properties complex and reasonable.

The superposition of different influences generates interactions which modulate the solar periodicity in both time and strength (Fock, pers. comm.). Even the solar cycles are varying (Lassen and Friis-Christensen, 1995). Therefore, no exact 11 year periodicity may be found in all properties. However, the corresponding patterns in Figure 4 are striking in the decadal scale. The value of such regularities is the certain degree of predictability (Landscheidt, 1999).

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Figure 1: The western Baltic Sea at the eastern edge of the North Atlantic Ocean, the position of the 'Magnetic Pole and the prevailing path of weather patterns (arrow).

Figure 2: Long-term changes of inorganic phosphorus fertiliser (kt/a) and phosphorus winter concentrations (µmol/l) in the upper 10 m of the water column in the Bomhohn Sea (south-western Baltic Sea) , according to Nausch et al., 1999 in comparison with herring biomass (kt / ICES sub-divisions 22, 24-32) compiled by Thurow (1997a,b); 1903 to 1980 classical estimation, 1971 – 1992 virtual population analysis (VPA).

Figure 3: Variations of sea water temperature, mesozooplankton displacement volume per m^3 and annual averages of herring biomass at decadal scale (details see Table 1).

Figure 4: The seasonal and interannual course of the sun spot numbers (a); the residuals of the linear de-trended cosmic ray flux (b); the cloud cover, white: more than 5/8 are covered (c); the air temperature (d); the water temperature (e); the production index of phytoplankton (f); the zooplankton biomass (g); and the North Atlantic Oscillation Index (h). Dots indicate the sampling intervals, others than every month. Table 1 includes the specific information about the data sets.

Figure 5: The seasonal and interannual course of the chlorophyll concentration and daily primary productivity, monthly averages for the western Baltic Sea.

Table 1: Origin of data, specifications and remarks

parameter	origin	specification	remarks
water temperature	Institute of Baltic Sea Research, Warnemunde, Germany	vertical (0 to 10 m) averaged data of 19 stations in the Western Baltic Sea , [“Cl	
zooplankton	Institute of Baltic Sea Research, Warnemunde, Germany	displacement volume [ml*m-3], O-maw.25 m, averages of ! to 4 stations in the Western Baltic Sea	organisms larger than 0,2 mm, in August ca.60% Copepods, ca.40% Cladocerans
herring biomass	Balic Sea (ICES sub-divisions 22,24-32), according to Thurow (1997), Table 42	yearly averages of estimates and results of virtual population analysis (VPA), [1000 Tonnes = kt]	
sun spot number	SIDC (Sunspot Index Data Center (http://www.oma.be/KSB-ORB/SIDC/index.html)	monthly averages	
cosmic ray flux	Mt.Washington Neutron Monitor. N44,W71; Altidude 1909 m (Solar Geophysical Data. Coffey,H.E.(ed.)1998)	pressure corrected, monthly mean counts/hour/64 cut-off rigity=1,38GV; indirect measure of cosmic primary radiation	Fig.2 includes residuals of the original data, which were linear de-trended between 1972 and 1992
cloud cover	German Meteorological Agency. observatory Wamemunde (54°11´N,12°5´E), situated near the coast	range: 0 to 8 (8 =100% coverage) monthly averages of 8 obser-vations per day	
primary production index	Institute of Baltic Sea Research, Warnemünde, Germany	[mgC*mg chlorophyll-a-1 *h-1], averages of 0-20m, 1 to 18 stations per month, mostly 2-3; in the Western Baltic Sea	76-78: Geiger-Müller counter, from 80: Scintillation counter,
air temperature	German Meteorological Agency, observatory Warnemunde (54°1 1´N,12°5´E), situated near the coast	monthly averages of 4 to 8 observations per day, [°C]	
North Atlantic Oscillation (NAO) index	International Research Institute for Climate Prediction (IRI) at Lamont-Doherty Earth Observatory of Columbia University, Palisades,USA (http://ingrid/ldeo.columbia.edu/)	pressure difference between the Azores High and the Icelandic Low, divided by their distance	for interpretation c.f. Lamb and Pepplen, 198'

Figure 1:

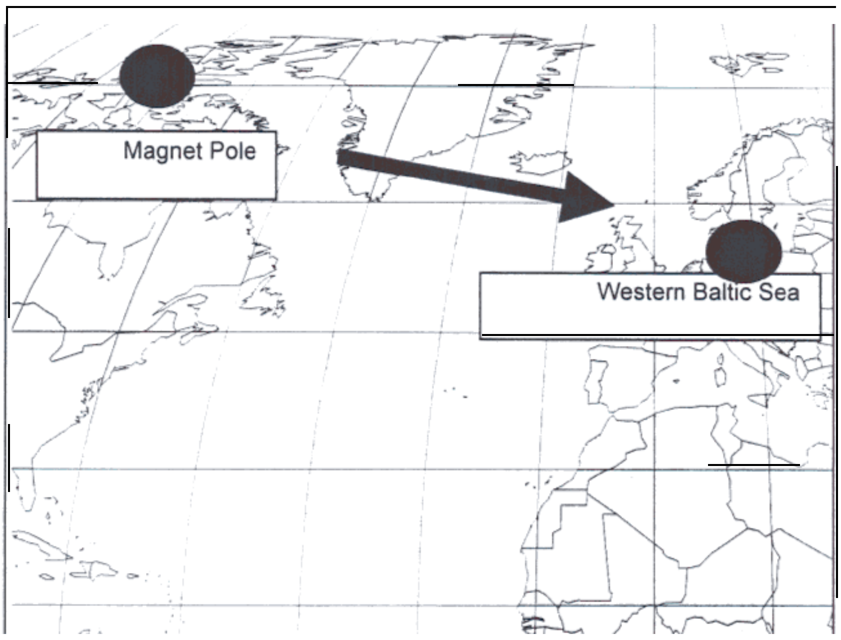
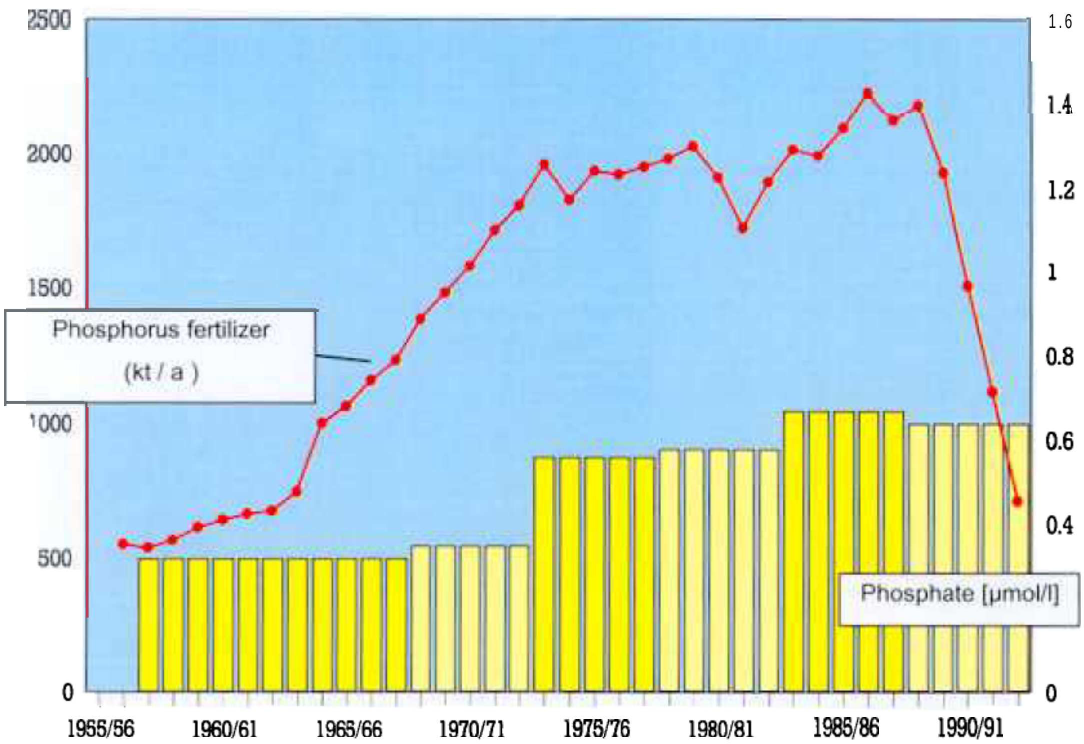
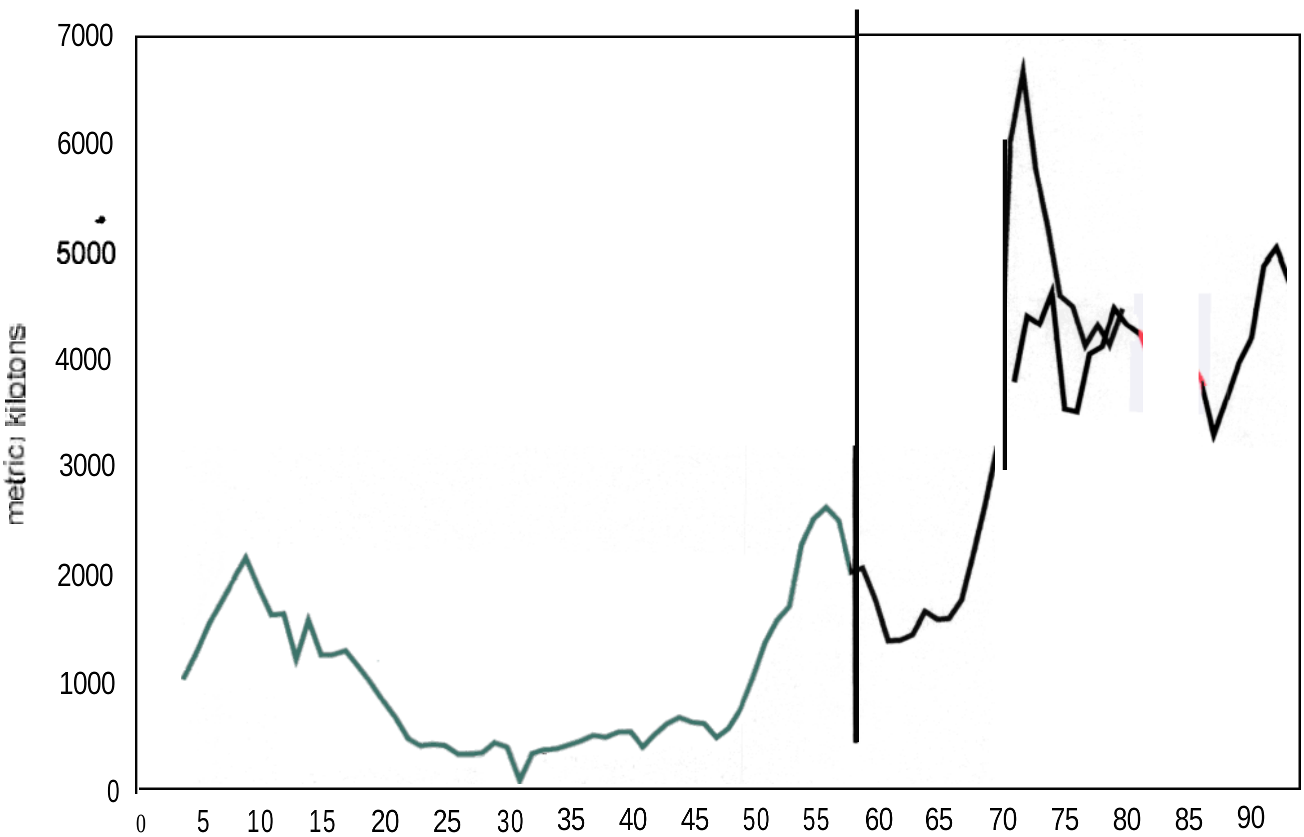


Figure 2:



herring biomass; Baltic Sea (ICES sub-divisions 22, 24-32); 20th century



green: classical estimation; red; VPA

Thurow, 1997

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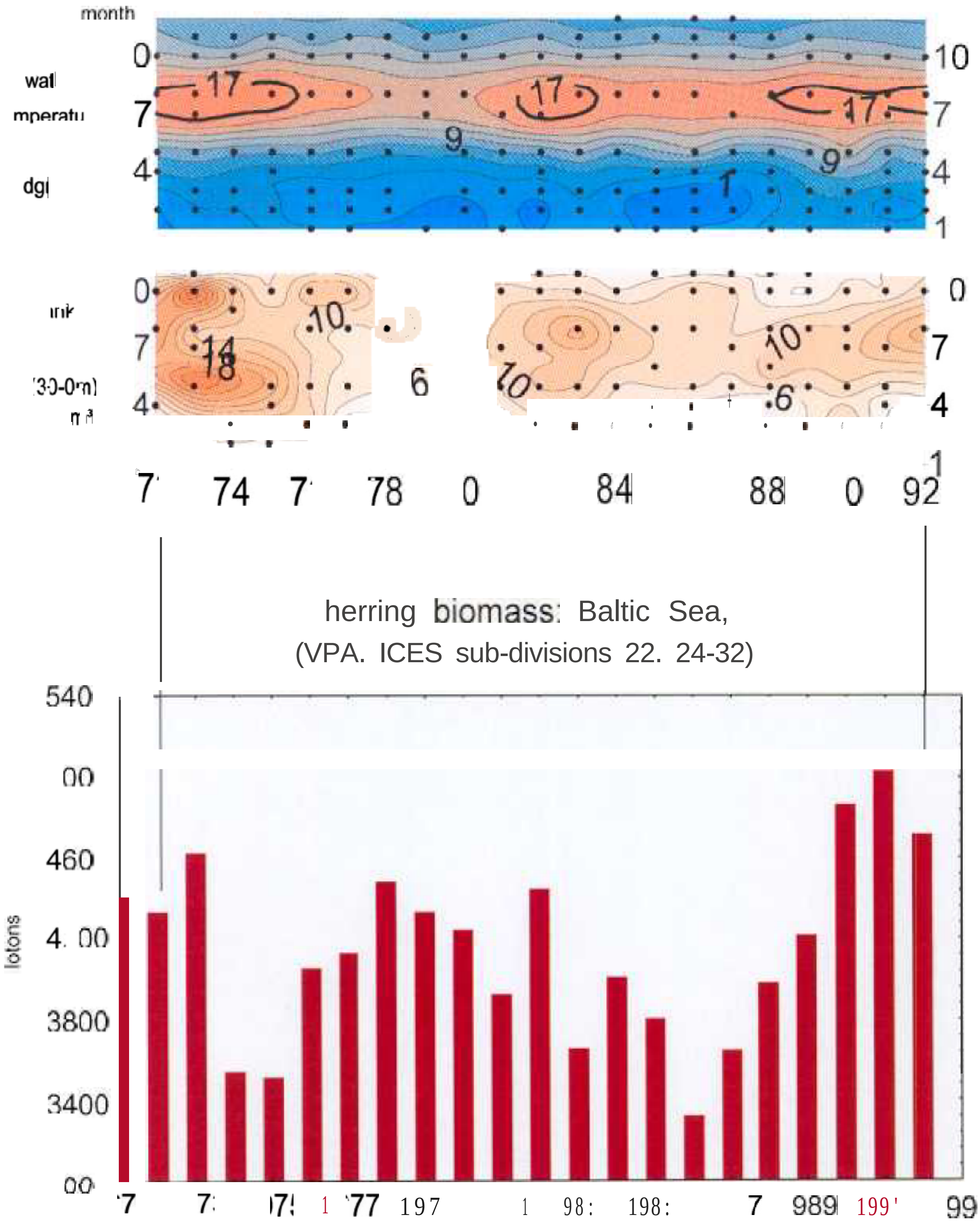
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herring biomass: Baltic Sea,
(VPA. ICES sub-divisions 22. 24-32)
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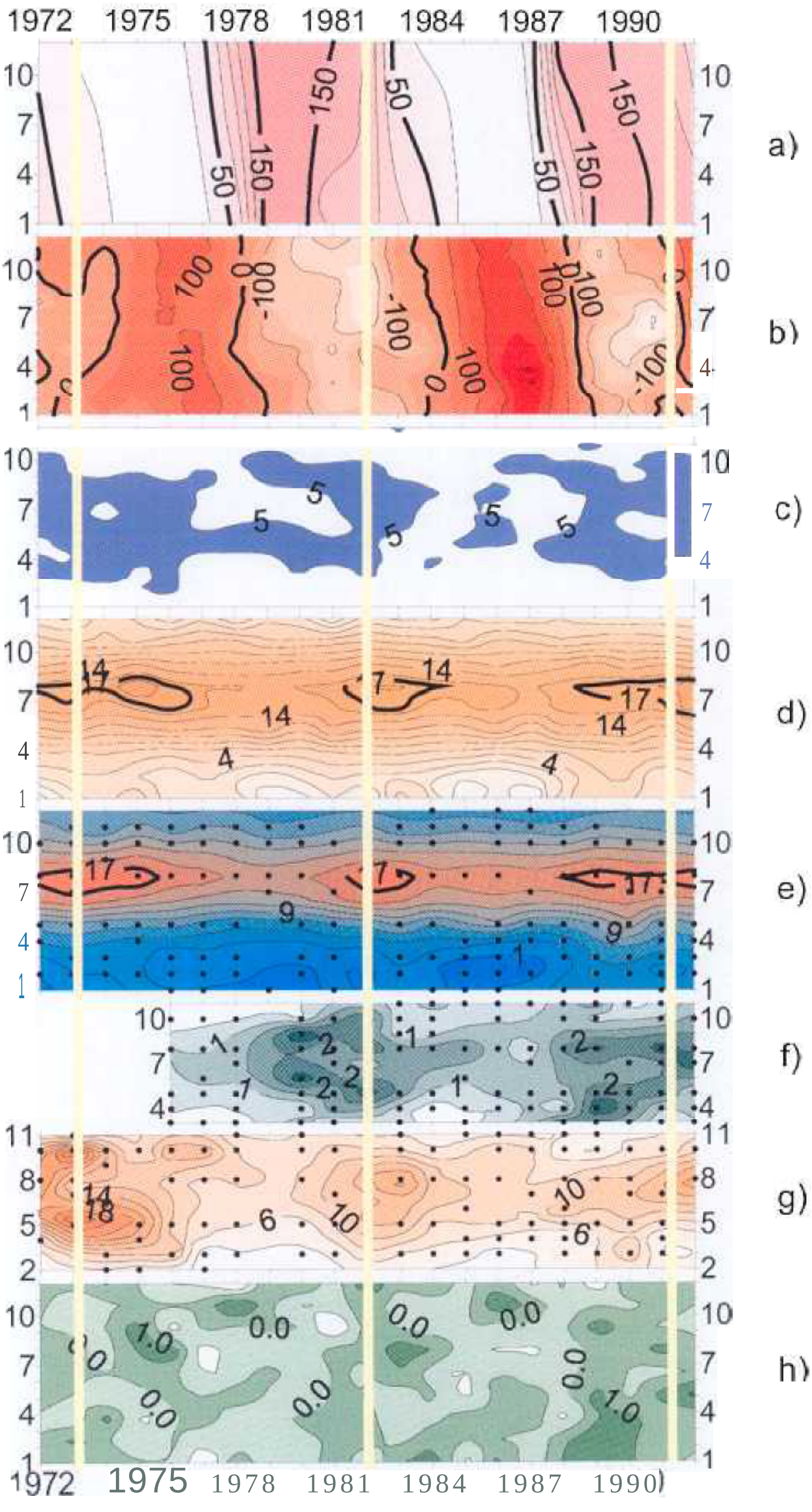
Figure 4



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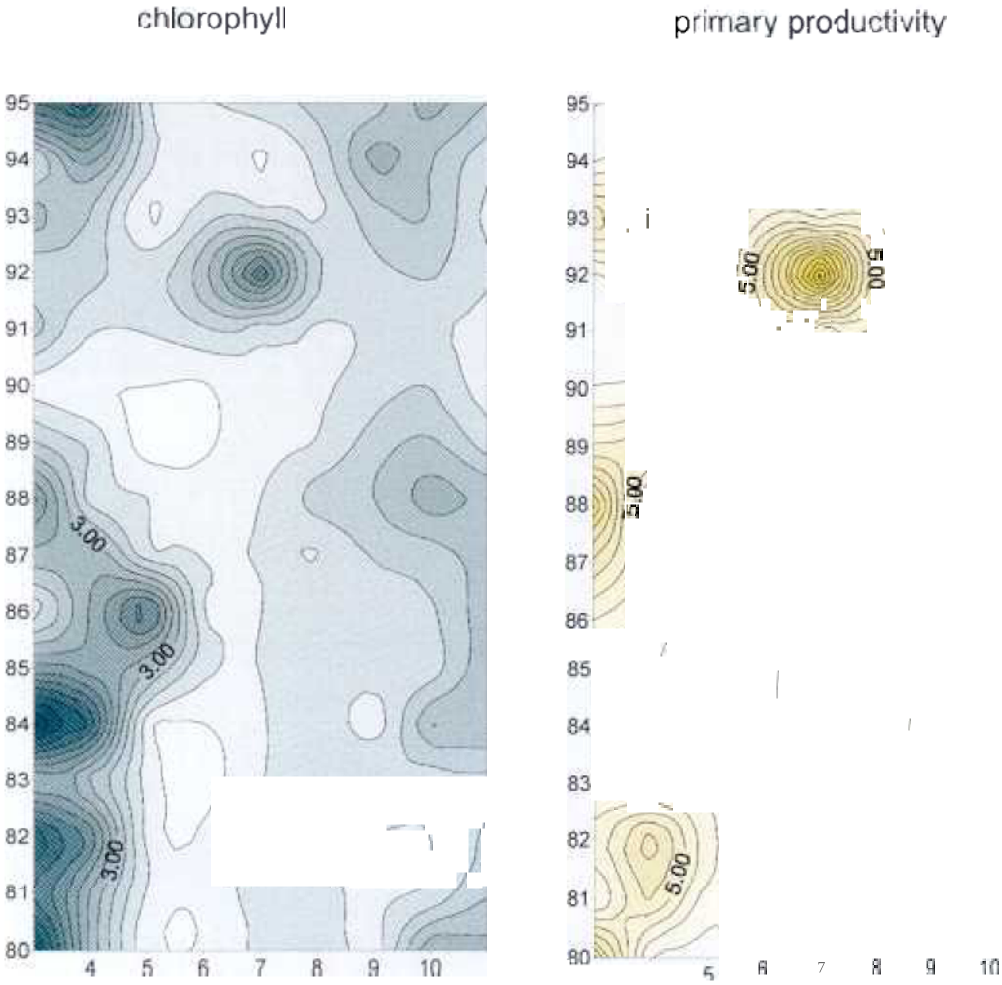
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