Acoustic monitoring of herring related to the establishment of a fixed link across the Sound between Copenhagen and Malmö

Distribution, migration, density, biomass and stock composition of herring in the Sound (ICES Subdiv. 23) during the autumn, winter and spring periods from October 1994 to May 1995. Including comparative results and discussion related to the September 1993 to May 1994 monitoring period.

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by

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1.0 SUMMARY

1.1 Background, objectives, activities, data and methods of analyses

Background: To provide background information for the evaluation of possible impacts of the construction of the Sound Bridge between Denmark and Sweden related to possible changes in distribution and migration patterns of herring in the Sound, the Danish Institute for Fisheries Research has monitored herring occurrence and abundance in the Sound area with special emphasis on the spring spawning western Baltic herring stock during two monitoring periods from September 1993 to April 1994 and from October 1994 to May 1995, respectively.

In the period September 1993 to April/May 1995, 15 hydro acoustic surveys were carried out in the Sound (ICES Subdiv. 23). This report presents results from the monitoring period October 1994 to May 1995 but includes also certain comparative results from the monitoring period September 1993 to April 1994 to summarize the obtained results during both monitoring periods from September 1993 to May 1995. Further, the usefulness of the results related to the construction activities is summarized, and the results are presented in context of advice of future monitoring of herring occurrences and migrations in and through the Sound area, partly related to the activities during establishment of the fixed link across the Sound, and partly related to the environmental protective criteria set up by the Danish Ministry of Environment and Swedish authorities regarding herring migrations in the Sound. The recommended future monitoring of herring in the Sound take into consideration the acoustic sonar monitoring of herring covering a limited cross section (Drogden; depths deeper than 9 m) of the Sound performed by DHI and makes, thus, the two investigation methods complementary to one another.

Related to the construction of the fixed link in the Sound between Denmark and Sweden a number of environmental criteria, among others with respect to herring in the Sound, shall be respected and obeyed. Related to migration routes and distribution of herring the Danish environmental authorities (Miljø- og Energiministeriet og Trafikministeriet Jan. 1995) and Swedish authorities (Vattendomstolen Jul. 1995) have set the following criteria: Situations where sediment fans block for the passage of herring through Drogden and Flinterenden when migrating south to the spawning areas and when migrating north to the feeding areas must not arise. Monitoring and effect evaluation shall be established to ensure that the protective clauses are obeyed.

Objectives: The objectives of the monitoring investigations on herring in the Sound are to obtain detailed information about and describe horizontal and vertical distribution, densities, biomass and stock composition of herring in the Sound with special emphasis on the western Baltic herring stock, and successively describe the spatial and temporal variances in the occurrences of herring based on continuous (repeated) monitoring activities. The latter gives indirect quantitative information (indices) about the migration patterns of herring in the Sound. Further, the purpose is to establish reference data and knowledge concerning the herring in the Sound related to design of later monitoring programmes for evaluation of the environmental impact from the construction of the fixed link between Denmark and Sweden (e.g. evaluation of herring occurrence and migration related to construction activities and to dispersion of suspended sediment fans).

Activities, data and methods of analyses: In the period October 1994 to April/May 1995, 8 hydro acoustic surveys and 8 synchronous fishing surveys with experimental gill nets were carried out in the Sound. Echo integration divided in acoustic transects covering the whole Sound from Helsingør-Helsingborg (north) to Drogden (south) was performed on each acoustic survey once a month during the autumn, winter and spring periods. Identical transects on both Danish and Swedish side, respectively, were covered monthly. The investigations included biological sampling performed on each fishing survey with scientific, multi panel gill nets equipped with a broad spectre of mesh sizes. From the biological sampling species distribution and herring stock composition were analysed with respect to length and age distribution, length weight relationship, and sex ratio. Further, the racial composition of the caught herring was examined based on meristic characters and mean length in order to distinguish between relative occurrence of juvenile herring from the western Baltic spring spawning stock and the North Sea autumn spawning stock (Bank herring) in the Sound. Abundance indices of herring in age and length groups were calculated from the combined acoustic integration values according to stock composition data from the biological sampling using length dependant target strength values from literature estimates. Data from hydrographical CTD-profiles sampled during the 8 acoustic surveys were analysed to evaluate variations in relative density of herring related to hydrographical conditions.

1.2 Results

Results: The performed analyses of hydro acoustic measurements and biological samples show that the far most abundant fish species in the Sound during both monitoring periods was herring with measured biomass up to 130.000 tonnes in the late summer and autumn period. Among herring stocks occurring in the Sound the western Baltic spring spawning herring stock usually referred to as the Rügen herring was by size the far most important stock component throughout the monitoring periods. The results from the present investigations support results from previous qualitative tagging studies (Biester 1979; Otterlind 1984) that the Sound is a major over-wintering area and an important spawning migration route for the western Baltic herring stock.

Investigations of herring occurrences in the Sound have (so far) focussed on the periods from late summer to late spring (Tab. 1). The measured total biomass and abundance of herring in the Sound varied between 130.000 to 5.000 tonnes and 940 mill. to 40 mill. herring in the period September 1993 to May 1995 (Tabs. 2 & 3). The maximum measured herring abundances in the Sound area constitute a significant part of the total yearly catch of western Baltic spring spawning herring in the whole western Baltic, Skagerrak-Kattegat and North Sea area with a long term average on 172.000 tonnes during the period 1974-94 (see App. p. 68-72).

No consequent and very distinctive spatial and temporal patterns in herring occurrences within the Sound area during the two year period can be deduced. In general, the occurrence of herring in the Sound was observed to be higher in 1993/94 than in 1994/95. Highest occurrences were observed in Sept. 93 and lowest in Apr. 94. In both monitoring periods the highest abundances of herring in the Sound were found in the period Sept. to Feb./(Mar.) both in 1993/94 and 1994/95. Within this period, the herring had a tendency to concentrate in the central Sound, especially around the island of Ven (strata G3-G4). However, there seems to have been a more continuos southwards displacement (emigration) of herring in 1994/95 than in 1993/94 where the emigration occurred abruptly over a relatively short period in Feb./Mar. (Fig. 3; Tabs. 2 & 3).

In all months both in 1993/94 and 1994/95 the highest abundances of herring were found in the depth layer from the sea surface to 20 m depth. Within this layer the highest concentrations were, in general, found in the 10-20 m depth layer with few smaller concentrations in the surface layer from 5-10 m depth. The occurrences of herring in depths below 20 m were very limited. (Figs. 4-18 & Fig. 19). Related to the Sound link construction area there were observed spatial limited high concentrations of herring in the sea surface layer (5-10 m depth) in strata G9-G10 in the autumn and early winter period in 1993/94. The same relatively high concentrations in the same strata and depth strata occurred practically during the whole second monitoring period from October 1994 to May 1995. (Figs. 4-18 & Fig. 19; Tab. 4).

Direct observations when performing hydro acoustic surveys and following qualitative, comparative analyses of the hydrographical CTD samples related to herring occurrence patterns shown on printed echograms indicated that when hydrographical stratification exist in the water column, i.e. existence of halo- and/or thermocline(s) in the pelagic water layer, herring tended to concentrate in the layers around these cline(s), i.e. the herring tended to be distributed in dense scattered layers in association with bottom slopes or hydrographical stratified water layers. Herring in the Sound did not occur in large schools but, rather, showed a densely aggregated distribution pattern which appear from the acoustic signal peaks which only very infrequent exceeded values of -53 dB which were set as the fish school threshold value. (Not shown).

No extensive data analyses of herring occurrence related to hydrographical conditions have been performed. More detailed comparative analyses of data from CTD-profiles on 1 m depth interval basis, including influence of the exact location of haloclines, thermoclines and distinct oxygen layers on relative herring abundance, i.e. related to measured acoustic integration values (Sa-values) per 1 m depth stratum, would have demanded more extensive acoustic data resolution and further acoustic raw data handling than performed within the present data analyses and requested through the present monitoring programme. However, the performed data analyses on herring occurrences related to mean hydrographical conditions within 5 m depth layers through the water column in different geographical strata of the Sound show that the southwards displacement of herring out of the Sound in the period October to January towards the spawning grounds during the 1994/95 monitoring period did coincide with decreases in water temperature in all depth layers of the Sound (Fig. 19). Further, increases in mean salinity in all depth layers and relatively lower oxygen saturation in the deeper layers were observed from October-December, and through the whole period salinity increased with depth. Seen in light of these observed hydrographical changes, and in light of the fact that salinity will increase at bottom when relatively high saline inflowing North Sea water enters the Sound (from Kattegat) near bottom, the observed (gradual) hydrographical changes might have initiated the observed southwards displacement of herring which coincide with these changes. (Fig. 19; Nielsen and Stæhr 1996).

During the period from October 94 to May 95 herring with total lengths between 45-60 scm were dominant in all areas of the Sound, and within this length interval the most frequent size categories were the 48-58 scm herring in general. During the whole period, maximum length frequency peaks appeared to be, respectively, at 52-54 scm in the central Sound (superstratum 2) corresponding to age group 4 (except for October 94: age group 5); and 53-56 scm in the southern Sound (superstratum 3) corresponding to age groups 4-6 (also including age group 3 in December); and, finally, 49-54 scm in the northern Sound (superstratum 1) corresponding to age groups 2-3 in October-December and age groups 3-4 in January-May. (Figs. 20 & 21). In accordance with these results it appears from Fig. 22, that the age groups 2 to 7 constituted the main part of herring in all months and all areas in the Sound with dominance of the 3- to 5-group within this age interval. In October-December the 3-group occurred with the highest density of all age groups, and after 1 January this cohort continued to be dominant as 4-group in the months January-May. In general, highest relative densities of the dominant age-groups were found in the central (and northern) Sound during the whole period. (Fig. 22 & Tab. 5). In November, significantly lower densities were observed in the northern Sound (superstratum. 1) compared to the surrounding periods. Sound herring were found to be between 1 to 12 years old.

Mean length per age group for herring seemed not to be different between areas, i.e. between herring in the northern, central and southern Sound in the same seasons (Fig. 21).

Within the whole period from October 94 to May 95 the young immature herring, i.e. the 1- and 2-group, were most abundant in October-December with mean lengths between 44-49 scm in this period, and highest densities of both these age groups were observed in the northern Sound (superstratum 1) except in November where the 2-group was relatively most abundant in the central Sound (superstratum 2) compared to the other areas. (Figs. 21-23 & Tab. 5). Preliminary morphometric data on herring race were sampled during the October 1994 survey in all three superstrata, and the number of vertebrae as a racial index were counted (Tab. 7). Being a rough racial division based on relatively few samples it appears, that a important part of the 1-group could have been autumn spawning North Sea (Bank) herring as the mean count of vertebrae was well above 56, i.e. 56.2188. The mean count of vertebrae for the 2-group herring in the Sound in October 1994 was 56.0513 which indicate that only a minor part of this group was North Sea (Bank) herring. For all older age groups the mean count of vertebrae were below 56 which indicates that far the dominant part of the 3+ - group either were western Baltic (Rügen) spring spawning herring or/and Kattegat spring spawning herring (and/or less important local Sound stock components). Based on present knowledge about distribution patterns and relative abundances of the three latter mentioned herring stock components in the relevant period, i.e. 1993-1995 (see App. p. 68-72 and section 2.2), related to the measured herring abundances in the Sound within the present monitoring programmes, it is likely that the major part of the observed 3+ -group was western Baltic spring spawning herring, at least in periods with occurrence of high abundances of herring in the Sound as this is the dominating stock in the whole Kattegat and western Baltic area today.

It appears from Fig. 23, that the abundances of all maturity groups varied significantly between months and areas, and that both sexes showed parallel monthly and geographical oscillations. Juvenile herring were most abundant in the northern and central Sound from October to December and within this period the most extreme abundances of juvenile herring were found in the northern part of the Sound. Further, during the whole period October 1994 to May 1995 juvenile herring were least abundant in the southern part of the Sound compared to the central and northern parts. This is in accordance with the above reported indices of likely relatively high abundances of juvenile North Sea (Bank) herring in the Sound distributed southwards from the Kattegat-Skagerrak area into the northern and central parts of the Sound. In general, a higher number of female immature herring than male immature herring were observed in the Sound. (Fig. 23).

Mature and spawning herring were abundant in the whole Sound area during the period Oct. 1994 to Jan. 1995 with a decreasing tendency later in that period, and also with a slightly decreasing tendency towards the most southern parts of the Sound (superstratum 3). The amount of mature and spawning herring decreased significantly in February-May. However, in May intermediary abundances of mature and spawning herring were found, especially in the central Sound. The latter might be caused by occurrence of some local spawning around the island of Ven. The observed decrease in mature and spawning herring in the spring period from February and onwards indicates that a spawning migration had begun from the Sound area to the spawning grounds in the western Baltic Sea around Rügen and Griefswalder Bodden. This migration seems to have taken place in early spring, and already starting in late winter (January to February). For both juvenile, mature and spawning herring in the Sound there seems not to have been any significant differences in abundance of the different maturity groups between the two sexes in different months and areas.

Regarding occurrence of post spawned herring in the Sound the picture is somewhat more complicated. In general, only very few post spawned herring were found in the Sound compared to the abundance level of the other maturity groups found within the area. No distinct and consequent temporal, geographical and sexual patterns in distribution or occurrence can be distinguished for post spawned herring in the Sound, except that no post spawned herring have been found in October month. Post spawned herring were present in all other months in small numbers indicating (some) occurrence of both autumn spawning and spring spawning herring stock components in the Sound. Related to the northwards migration of western Baltic herring from the spawning grounds back to the feeding grounds during spring it can be concluded that these herring not seemed to concentrate in large amounts in the Sound for longer periods within the season from October to May. It can not, based on the present monitoring programme and data material, be concluded whether the Sound or the Belt Sea is the most important migration route back to the northern feeding grounds.

1.3 Conclusive remarks

The identified patterns in spatial and temporal occurrence of herring in the Sound are in good agreement with the described distinct migration pattern of the Rügen herring between the main spawning ground in the western Baltic Sea and the feeding areas via two migration routes, i.e. an principal north-westward route extending to the Kattegat/Skagerrak/North Sea area and an eastern one extending to about 16 E in the Baltic Sea, according to Otterlind (1984) and Biester (1979) based on earlier extensive tagging experiments (see also App. p. 68-72 and section 2.2).

By comparison of the found number of three year old and older herring (3+ -group) in the here monitored part of the Sound in Oct. 94, with the found number of 3+ -group herring in the whole ICES subdiv. 23 (App.Fig.A8) obtained through German-Danish herring monitoring investigations (combined acoustic and trawl survey) performed in Oct. 94 in the Kattegat- and Baltic area with R/V Solea, it appears that the present analyses have measured the double biomass of herring (455 mill. 3+ -group) compared to the number of herring found through the Solea-monitoring (217 mill. 3+ -group). (Not shown). However, the important point here is that both monitoring programmes measure significant biomass of herring in the Sound area, and further, that comparison of the number of 3+ -group herring in Subdiv. 23 and Subdiv. 22 (incl. the Belt Sea; App.Fig.A8) monitored by R/V Solea shows that only 44 mill. 3+-group herring, i.e. a fifth of the number found in Subdiv. 23, were found in Subdiv. 22. This indicates that the Sound area might be the more important over-wintering and migration area compared to the Belt Sea and surrounding areas.

2.0 INTRODUCTION

2.1 Objectives

The objectives of these monitoring investigations on herring in the Sound are to obtain detailed information about and describe horizontal and vertical distribution, densities, biomass and stock composition of herring in the Sound with special emphasis on the western Baltic herring stock, and successively, describe the spatial and temporal variances in the occurrences of herring based on monthly (repeated) monitoring activities. The latter gives indirect quantitative information (indices) about the migration patterns of herring in the Sound.

Further, the purpose is to establish reference data and knowledge concerning the herring in the Sound related to design of later monitoring programmes for evaluation of the environmental impact from the construction of the fixed link between Denmark and Sweden (e.g. evaluation of herring occurrence and migration related to construction activities and to dispersion of suspended sediment fans).

2.2 The western Baltic herring stock - background

The Sound is a transition area for several migrating fish stocks such as herring, garfish, lumpsucker, mackerel, and to some extent cod. Also some smaller, local resident fish stock components of cod, flatfish, herring and several other species are found here. Results on early tagging experiments (Biester 1979; Otterlind 1984) showed that the Sound is a major over-wintering area and an important migration route for the present important western Baltic (Rügen) herring stock. However, no detailed quantitative investigations of the over-wintering western Baltic herring in the Sound and of the passage of migrating herring in and through the Sound, have previously been carried out. Only qualitative and anecdotal information existed before the present studies. This stock is by size the most important fish stock component occurring in the Sound. The present monitoring programme has measured up to 130.000 tons of herring in the late summer and autumn period in the Sound area (Sept. 1993). The most important feeding grounds of the western Baltic herring are situated in Skagerrak-Kattegat and the North Sea area where the 2 year old and older herring are located during summer. In late summer (July/August), they migrate southwards through Kattegat. During the period (late) August to March, the herring are found in high concentrations in the Sound, and spawning at Rügen and surrounding areas in the western Baltic takes place during April-May. After spawning the herring migrate back to the Kattegat-Skagerrak area (partly ?) through the Sound in late spring. Mature herring will be located in the Sound with high abundance from the late summer period and the first autumn period probably waiting for the right conditions and moment to leave the area heading south towards the spawning grounds during winter and spring. (Biester 1979; Otterlind 1984; Nielsen 1994; present results). The western Baltic herring is an significant fishery resource for the Danish, German, Norwegian and Swedish fishery, partly in the western Baltic area (including the Sound and the Belt Sea), partly in the Kattegat-Skagerrak area and to a less extent in the North Sea (Anon. 1995). For further information see the detailed description of the western Baltic herring stock and exploitation of this stock in Appendix p. 68-72 and Nielsen (1994).

Related to the construction of the fixed Sound link a number of environmental criteria, among others with respect to herring in the Sound, shall be respected and obeyed. Related to migration routes and distribution of herring, the Danish environmental authorities (Miljø- og Energiministeriet og Trafikministeriet, Jan. 1995) and Swedish authorities (Vattendomstolen, Jul. 1995) have set the following criteria: Situations where sediment fans block for the passage of herring through Drogden and Flinterenden when migrating south to the spawning areas and when migrating north to the feeding areas must not arise. Monitoring and effect evaluation shall be established to ensure that the protective clauses are obeyed. The monitoring will be under the responsibility of Danish and Swedish authorities and will be performed as an combination of acoustic monitoring and fishing investigation covering the whole Sound area. The observations from this monitoring shall be related to continuos measurements and modellings of distribution, spreading and concentration of suspended sediment. The herring monitoring programme will not be designed as a feed-back monitoring programme and will as such not function as an control mechanism for the excavation activities.

Several investigations have shown that fish may avoid plumes of suspended sediment. Impacts as sediment fans suspended in the water is feared to function as a barrier for migration, i.e. either to blockade or delay migration. Other likely effects could be significant changes in distribution pattern, migration route and migration rate. In total, this might lead to reduced recruitment to the stock for years where the migration is affected caused by the missing correspondence between the spring plankton bloom, and the time of spawning. If this situation continues for several years it can lead to a collapse of the stock. The known literature does not describe thresholds for avoidance reactions to plumes of suspended sediment of limestone and glacial till for herring during a migration situation. However, laboratory experiments investigating threshold values for avoidance by sensitive pelagic species as herring from other types of suspended sediment have shown threshold values at 9-12 mg/l of sediment with median particle diameter of 6.2 µm (Johnston & Wildish 1981). Earlier behavioural investigations showed that threshold concentrations of suspended sediment for schooling herring were 19±5 mg/l for fine sediment with median particle diameters of 4.5 µm and 35±5 mg/l for coarser sediment (Wildish et al. 1977). A concentration of 6 mg/l (maximum 10 mg/l) suspended sediment of limestone and glacial till has, based on the available literature information, been chosen as the expected threshold for avoidance reactions of herring in the Sound. Demersal fish as cod, flatfish and eel seem to be able to tolerate somewhat higher concentrations of suspended material.

3.0 MATERIALS AND METHODS

In the period October 1994 to April/May 1995, 8 hydro acoustic surveys and 8 synchronous fishing surveys with experimental gill nets were carried out in the Sound (ICES Subdiv. 23). Echo integration divided in acoustic transects covering the whole Sound from Helsingør-Helsingborg (north) to Drogden (south) was performed on each survey once a month during the autumn, winter and spring periods. Identical transects on both Danish and Swedish side, respectively, were covered monthly. The investigations included biological sampling performed on each survey with scientific, multi panel gill nets equipped with a broad spectre of mesh sizes. Data from hydrographical CTD-profiles were sampled during the 8 acoustic surveys. A schematic presentation of survey activities with reference to survey index, survey period and performed investigations / activities during each survey is given in Tab. 1 & App. Tabs. A2-A4. Survey period refers to acoustic integration period during survey and synchronous gill net fishing and hydrographical data sampling.

3.0.1 Study and survey area: The study area covers both Danish and Swedish waters in the Sound from Helsingør in the north to Drogden in the south. The study area has been divided into 13 subareas in order to describe small scale geographical variations within the larger area (Fig. 1 & Tab. 8). Each subarea is approximately 2.5 NM**2 wide in the north-south-going direction. The surveyed area in the Sound divided by strata and superstrata is shown in Figs. 1 & 2. The area sizes of the different strata in nautical square miles (NM**2) are given in Fig. 1. Areas of localities with given bottom depths are given in Tab. 4. Positions for the division of the Sound into strata G1-G13 are shown in Tab. 8.

3.0.2 Hydro acoustic echo integration: Sampling of echo integration data has been performed with a mobile, scientific SIMRAD EY-200 38 kHz single beam echosounder system mounted in R/V HAVFISKEN, DFU, (App. Fig. A5) during all acoustic surveys except for the May 1995 survey where echo integration were performed with a SIMRAD EK 400 38 kHz single beam system on board R/V DANA, DFU. From both research vessels integration was carried out with a towed body (paravane) mounted transducer (swinger) typically towed in a depth of ca. 2 m below sea surface. This operation distance is as near the surface as possible taking physical turbulence from currents and wind into account. The upper 3 m layer from the transducer placement can not be integrated using echo sounder methods in general, i.e. integration has not been performed in the 0-5 m depth layer in the whole study area. The operating frequency on all surveys was 38 kHz and basic settings of high power, 1 ms pulse duration, and 1 kHz receiver bandwidth were used. The schematic diagram in App. Fig. A5 shows the set-up of the used hydro-acoustic echo integration system on board R/V HAVFISKEN. The echosounder systems are calibrated using the standard copper sphere technique (Foote et al. 1986; Degnbol et al. 1990). Technical data, settings and calibration parameters for the used acoustic systems are given in Tab. 10. The echo integration systems were connected to GPS navigation units from which synchronous position data were sampled. Sampling of acoustic integration data was performed during night. The standard acoustic survey transects divided into way points and way point positions are shown in Tab. 9. These transects cover each strata with a constant zig-zag-pattern on both Danish and Swedish side of the Sound. The specific way point sequence during each acoustic integration survey, i.e. the actual integration cruise route for R/V HAVFISKEN on each integration night and monthly survey dependent of wind and current direction, is shown in App.

Tab. A3. Cruise speed was typically 3-6 knots dependent of wind and current. Acoustic integration data were analysed with the Echo-Ann analyser system (Degnbol et al. 1990) and hereby the acoustic data were judged for approximately each 0.4-0.5 nautical mile. The contributions from plankton, air bubbles (including wind induced up welling of surface layers and propeller noise from passing vessels), bottom echoes and (other) noise were removed during the judging procedure. Bottom detection on dense fish schools / aggregations (typically herring) were compensated during judging. When fish echoes were mixed with plankton echoes the contribution from plankton was estimated by comparing the integration values with values obtained on other close sampling positions with similar isolated plankton recordings not containing fish.

For each subarea mean target strength (mean TS) was estimated for each species or category of species and each species length group by using TS - length relations for the most important fish species occurring in the Sound by fish biomass. The target strength is species and size dependent, and TS is mainly determined by factors as target swimbladder size, target swimbladder directivity (tilt angles), target fat content and target behaviour. The following empirical estimated TS algorithms were used (Anon. 1992 (4)):

Herring:	$TS = 20 \log L - 71.2$	(Anon. 1983).
Gadoids:	$TS = 20 \log L - 67.5$	(Anon. 1984).

An overall mean TS for each subarea was then estimated. The TS contributions from each species and species length group were weighted in the proportion of their respective occurrences in the gill net catches during the parallel (in time and space) performed biological sampling based on gill net fishery. The mean area back scattering strength (Sa) for each subarea was estimated. The total number of each fish species and fish species length group in each subarea was then estimated by calculating the values of mean Sa divided by mean TS. The number of each fish species and fish species length group was then assumed to be in proportion with their contribution to total catch in the gill net fishery. Allocation to length and age group for each species was assumed to be in accordance with the length and age distribution for each species in the gill net catches. Allocation of fishing stations was based on a spatial and temporal representative and covering fishery related to the acoustic integration activities.

3.0.3 Biological sampling: Fishing surveys were performed with experimental (scientific) gill nets (App. Fig. A6 & Tab. 11). Each setting comprise 7-9 nets (panels) with mesh sizes 19.5 mm, 21.0 mm, 26.0 mm, 27.0 mm, 28.0 mm, 29.0 mm, 34.0 mm, 46.0 mm, 55.0 mm and 60.0 mm. Usually fishing was performed with standard sets of 8 nets (panels) with mesh size 19.5, 21, 26, 27, 28, 29, 34 and 55 mm, respectively. The used gill nets were approximately 30-40 m long and 5 m high (deep). Technical measures of the used gill nets during surveys are given in Tab. 11 and shown in App. Fig. A6. Dependent of time, weather and water currents the fishing stations were stratified to cover both demersal and pelagic water layers and all geographical strata during each survey on both Danish and Swedish side of the Sound. Both demersal and pelagic gill net settings were carried out related to judgment of highest probability of catching the fish representatively. Fishery was mainly performed during night synchronous with acoustic integration. Fishing were in October 1994 performed from a chartered commercial fishing vessel (F/V POSEIDON, No. K52) and on all following surveys from R/V HAVKATTEN II, DFU, during the period October 1994 to May 1995. Both vessels used the same gear. During the May 1995 acoustic integration survey with R/V DANA no synchronous biological sampling, i.e. fishing, were performed as biological data from the April 1995 survey were used. Details of each fishing station regarding settings in geographical stratum, fishing positions (start/end), fishing depth and depth layer, and fishing time together with the area adaption between biological data (i.e. the fishery data sampling) and acoustic integration data for each survey are given in App. Tab. A3. Further, details of fishing vessel, weather (wind direction and speed), water current speed and cloud cover were recorded. The number of caught fish, i.e. catch raw data, in the gill nets per fish species divided by year, survey and mesh size is shown in App. Tab. A7.

Catch were for each mesh size on all settings during all fishing surveys sorted and determined to fish species. Standard sampling included length measurements (total length) of all caught fish by species per mesh size, and total weight (in grammes) of catch by species per mesh size, and thus, also resulting recording of total catch weight by species pooled for all mesh sizes on each fishing station. Clupeoids (herring and sprat) were length estimated to semi-centimetre (scm) below and all other species to centimetre (cm) below.

On every second fishing survey expanded individual sampling of herring in each superstratum was performed: In each superstratum 5 herring specimens per semi-centimetre group were sampled. These fish samples were analysed in laboratory and data on individual length, weight, fat content (muscle tissue), age (otoliths), sex (gonads) and sexual maturity (gonads) were recorded. Further, limited meristic sampling (vertebrae counts) for race determination has been conducted on herring caught on the October 1994 survey.

From the biological sampling species distribution and herring stock composition were analysed with respect to length and age distribution, length weight relationship, and sex ratio. Further, racial composition of herring was examined based on meristic characters and mean length in order to distinguish between relative occurrence of juvenile herring from the western Baltic spring spawning stock and the North Sea autumn spawning stock (Bank herring) in the Sound. This was performed related to morphometric herring stock identification parametres given in literature. Abundance indices of herring in age and length groups were calculated from the combined acoustic integration values according to stock composition data from biological sampling using length dependant target strength values from literature estimates.

3.0.4 Hydrographical sampling: Sampling of hydrographical data has been performed with an mobile SEACAT SBE 19-03 CTD (Conductivity, Temperature, Density - profiler) on all surveys during the period October 1994 to May 1995 except for the May 1995 survey carried out with R/V DANA (Tab. 1; App. Tab. A4). The hydrographical sampling comprised vertical profiles of: pressure (decibars; giving depth), temperature (°C), conductivity (μS/cm), salinity (‰), oxygen content (% and ml/l), sampling time (seconds) and UTC time and date. The sampled profiles were stratified in attempt to obtain an even distribution representing all geographical strata and depth strata during the different surveys. Further, it was attempted to take profiles in areas with, respectively, high, intermediate, and low abundances of herring. Based on these (rather limited) hydrographical data it has been attempted to give an comparative judgment of herring occurrences, i.e. herring abundances and concentrations, related to hydrographical conditions (mean temperature, mean salinity and mean oxygen concentration) per depth stratum through the water column for each geographical superstratum in the Sound where CTD-profiles has been taken. Details related to each hydrographical profile station regarding station number, date, UTC time, geographical position and depth are given in App. Tab. A4. Calculated means of temperature (°C), mean salinity (‰) and mean oxygen saturation (%) divided into depth layers related to herring abundance are shown in Fig. 19.

More detailed comparative analyses of CTD-profiles on 1 m depth interval basis, including influence of the exact location of haloclines, thermoclines and distinct oxygen layers on relative herring abundance, i.e. related to measured acoustic integration values (Sa-values) per 1 m depth stratum, would have demanded more extensive acoustic data resolution and further acoustic raw data handling than performed within the present data analyses and requested through the present monitoring programme!

4.0 RESULTS

4.1 Type of results given

Results and type of information given based on the present monitoring programme and performed investigations related to herring in the Sound with special emphasis on the western Baltic herring stock:

Results on early tagging experiments (Biester, 1979; Otterlind 1984) showed that the Sound is a major over-wintering area and an important migration route for the presently important western Baltic (Rügen) spring spawning herring stock. However, no detailed quantitative investigations of the over-wintering herring from this stock and the passage of migrating Rügen herring in and through the Sound have previously been carried out. Only qualitative and anecdotal information exist. Thus, before the present monitoring investigations of herring in the Sound area during the period September 1993 to May 1995 were implemented no systematic investigations and detailed and quantitative data and information have existed related to the following:

a) Overall and relative spatial and temporal distribution (horizontal as vertical) of herring in the Sound in different geographical areas and months over the year. I.e. the question about where and when these considerable amounts of herring in the Sound actually are located in the area and where and when they concentrate is answered.

b) Quantitative indices of migration patterns and residence areas in the Sound related to previous (qualitative) mappings and investigations of the overall migration pattern of the Rügen herring between the spawning grounds in the western Baltic around Rügen and Griefswalder Bodden in the spring time and the summer feeding grounds in the Kattegat, Skagerrak and North Sea area. This is based on continuous and repeated monitoring.

c) Estimates of absolute and relative density and biomass of herring in the whole Sound area (horizontal as vertical) in different areas and periods.

d) Information about stock composition of the herring occurring in the Sound in different areas over the year.

e) Information about herring abundance in all areas of the Sound - in both Danish and Swedish waters - in different seasons related to depth stratification and hydrographical conditions in different depth layers in the Sound.

4.2 Actual results given

The performed analyses of hydro acoustic measurements and biological samples show that the far most abundant fish species in the Sound during both monitoring periods was herring with measured biomass up to 130.000 tonnes in the late summer and autumn period. Among herring stocks occurring in the Sound the western Baltic spring spawning herring stock was by size the far most important stock component throughout the monitoring periods.

Investigations of herring occurrences in the Sound have (so far) focussed on the periods from late summer to late spring (Tab. 1). Biomass in tonnes per NM**2 and abundance in number in millions per NM**2 of herring in the Sound divided by stratum for different months / surveys during the overall survey period from September 1993 to May 1995 are shown in Tabs. 2 & 3. The measured total biomass and abundance of herring in the Sound varied between 130.000 to 5.000 tonnes and 940 mill. to 40 mill. herring in the period September 1993 to May 1995 (Tabs. 2 & 3). The maximum measured herring abundances in the Sound area constitute a significant part of the total yearly catch of western Baltic spring spawning herring in the whole western Baltic, Skagerrak-Kattegat and North Sea area with a long term average on 172.000 tonnes during the period 1974-94 (see App. p. 68-72).

No consequent and very distinctive spatial and temporal patterns in herring occurrences within the Sound area during the two year period can be deduced. In general, the occurrence of herring in the Sound was observed to be higher in 1993/94 than in 1994/95. Highest occurrences were observed in Sept. 1993 and lowest in Apr. 1994. In Sep.-Oct. 1993 and in Oct. 1994 around 100.000 tonnes of herring or more were found in the whole Sound area. In Nov.-Jan. in both 1993/94 and 1994/95 there was around 40-70.000 tonnes, however, while the biomass in Jan. 1995 was intermediary (approx. 40.000 tonnes) between the level in Nov.-Dec. (60-70.000 tonnes) and a stable level in Feb.-May both years around 5-20.000 tonnes the biomass in Feb. 1994 differed from this pattern as a biomass of around 85.000 tonnes was observed here. (Tab. 2; Fig. 3). In all months from Sep. 1993 to Feb. 1994 there were more than 500 mill. herring in the Sound. This abundance level was only reached in Oct. 1994 in the period Oct. 1994 to May 1995 (Tab. 3). Differences in condition of the herring (length-weight-relationship) were found (Tab. 6) which explains ~~the~~ slightly different temporal distribution in abundance of herring in numbers compared to ~~the~~ biomass distribution. Thus, in both monitoring periods the highest abundances of herring in the Sound were found in the period Sept. to Feb./(Mar.) both in 1993/94 and 1994/95. Within this period, the herring had a tendency to concentrate in the central Sound, especially around the island of Ven (strata G3-G4). However, there seems to have been a more continuos southwards displacement (emigration) of herring in 1994/95 than in 1993/94 where the emigration occurred abruptly over a relatively short period in Feb./Mar. (Fig. 3; Tabs. 2 & 3).

The contour-plots in Figs. 4-18 present the total number of herring measured in each pelagic depth strata, i.e. visualize the total measured number of herring in each pelagic water layer down through the vertical water column divided by geographical strata. In Tab. 4 herring density in each bottom depth strata is presented, i.e. density of herring per depth locality with given bottom depth is given. In all months both in 1993/94 and 1994/95 the highest abundances of herring were found in the depth layer from the sea surface to 20 m depth. Within this layer the highest concentrations were, in general, found in the 10-20 m depth layer with few smaller concentrations in the surface layer from 3-10 m depth. The occurrences of herring in depths below 20 m were very limited. (Figs. 4-18 & Fig. 19). Related to the Sound link construction area there were observed spatial limited high concentrations of herring in the sea surface layer (3-10 m depth) in G9-G10 in the autumn and early winter period in 1993/94. The same relatively high concentrations in the same strata and depth strata occurred practically during the whole second monitoring period from October 1994 to May 1995. (Figs. 4-18 & Fig. 19; Tab. 4).

In general, the waters in the Sound is hydrographically stratified with a low saline upper water layer separated from a high saline bottom layer. However, besides this general and roughly described vertical hydrographical pattern the currents and hydrographical conditions in the Sound is rather complex and variable (shifting) with respect to depth, time and space, e.g. current direction and speed influenced by variation related to inflow of oceanic water from Skagerrak-Kattegat or/and outflow based on freshwater run-off from Baltic rivers, vertical and horizontal stratification, turbulence/up-welling, etc. This complicates the elucidation of characteristic herring distribution and abundance patterns related to distinct hydrographical conditions based on the rather limited hydrographical data material sampled within the present monitoring programme.

Direct observations when performing hydro acoustic surveys and following qualitative, comparative analyses of the hydrographical CTD samples related to herring occurrence patterns shown the printed echograms indicated that when hydrographical stratification exist in the water column, i.e. existence of halo- and/or thermocline(s) in the pelagic water layer, herring tended to concentrate in the layers around these cline(s), i.e. the herring tended to be distributed in dense scattered layers in association with bottom slopes or hydrographical stratified water layers. Herring in the Sound did not occur in large schools but, rather, showed a densely aggregated distribution pattern which appear from the acoustic signal peaks which only very infrequent exceeded values of -53 dB which were set as the fish school threshold value. (Not shown).

No extensive data analyses of herring occurrence related to hydrographical conditions have been performed. More detailed comparative analyses of data from CTD-profiles on 1 m depth interval basis, including influence of the exact location of haloclines, thermoclines and distinct oxygen layers on relative herring abundance, i.e. related to measured acoustic integration values (Sa-values) per 1 m depth stratum, would have demanded more extensive acoustic data resolution and further acoustic raw data handling than performed within the present data analyses and requested through the present monitoring programme. However, the performed data analyses on herring occurrences related to mean hydrographical conditions within 5 m depth layers through the water column in different geographical strata of the Sound show that the southwards displacement of herring out of the Sound in the period October to January towards the spawning grounds during the 1994/95 monitoring period did coincide with decreases in water temperature in all depth layers of the Sound (Fig. 19). Further, increases in mean salinity in all depth layers and relatively lower oxygen saturation in the deeper layers were observed from October to December. The mean salinity dropped to a slightly lower level in Jan.-Feb. and dropped (slightly) again in March-April compared to the Oct.-Dec.-period. Generally, the salinity increased with depth as expected. Seen in light of these observed hydrographical changes, and in light of the fact that salinity will increase at bottom when relatively high saline inflowing North Sea water enters the Sound (from Kattegat) near bottom, the observed (gradual) hydrographical changes might have initiated the observed southwards displacement of herring which coincide with these changes. (Fig. 19; Nielsen and Stæhr 1996).

The measured numbers of herring per length group (length frequencies) and observed mean lengths per age group divided by geographical area (superstratum), year and month during the period October 1994 to May 1995 are shown in Fig. 20 and Fig. 21, respectively. Densities of herring in number per NM**2 in different age groups divided by geographical area (superstratum), year and month during the period October 1994 to May 1995 are shown on Fig. 22 and in Tab. 5. During the whole period, herring with total length between 45-60 scm were dominant in all areas of the Sound, and within this length interval the most frequent size categories were the 48-58 scm herring in general. During the period from October 94 to May 95, maximum length frequency peaks appeared to be, respectively, at 52-54 scm in the central Sound (superstratum 2) corresponding to age group 4 (except for October 1994: age group 5); and 53-56 scm in the southern Sound (superstratum 3) corresponding to age group 4-6 (also including age group 3 in December); and, finally, 49-54 scm in the northern Sound (superstratum 1) corresponding to age group 2-3 in October-December and age group 3-4 in January-May. (Figs. 20 & 21). In accordance with these results it appears from Fig. 22 that the age groups from 2 to 7 constituted the main part of herring in all months and all areas in the Sound with dominance of the 3- to 5-group within this age interval. In October-December the 3-group occurred with the highest density of all age groups, and after 1 January this cohort continued to be dominant as 4-group in the months January-May. In general, highest relative densities of the dominant age-groups were found in the central (and northern) Sound during the whole period. In November significantly lower densities were observed in the northern Sound (superstratum. 1) compared to the surrounding periods. The oldest herring found in October-December in the whole Sound area was the 9-group, while the 10-11-12-groups were totally absent here. The three latter mentioned (old) age groups occurred in limited amounts in all areas of the Sound in the period January-May. In the northern Sound (Superstratum 1) the 9-group was absent in November-December.

Mean length per age group for herring seemed not to be different between areas, i.e. between herring in the northern, central and southern Sound in the same seasons (Fig. 21).

Within the whole period from October 94 to May 95 the young immature herring, i.e. the 1- and 2-group, were most abundant in Oct.-Dec. with mean lengths between 44-49 scm in this period. Highest densities of both these age groups were observed in the northern Sound (superstr. 1) except in Nov. where the 2-group was relatively most abundant in the central Sound (superstr. 2) compared to the other areas. (Figs. 21 & 22; Tab. 5). Preliminary morphometric data on herring race were sampled during the October 1994 survey in all three superstrata, and the number of vertebrae as a racial index were counted (Tab. 7). Being a rough racial division based on relatively few samples it appears, that a important part of the 1-group could have been autumn spawning North Sea (Bank) herring as the mean count of vertebrae was well above 56, i.e. 56.22. This should be seen in context with juvenile North Sea herring of the 1-group and the 2-group are known to occur in the Sound and that North Sea herring typically have a mean count of vertebrae well above 56.0. The mean count of vertebrae for the 2-group herring in the Sound in October 1994 was 56.0513 which indicate that only a minor part of this group was North Sea (Bank) herring. For all older age groups the mean count of vertebrae were below 56 which indicates that far the dominant part of these herring either were western Baltic (Rügen) spring spawning herring or/and Kattegat spring spawning herring (and/or less important local Sound stock components). The three latter mentioned stock components can not be separated based on the limited racial investigations performed here. This would demand a monitoring program of much more extensive dimensions than the actual performed. Based on present knowledge about distribution patterns and relative abundances of the three latter mentioned herring stock components in the relevant period, i.e. 1993-95 (see App. p. 68-72 & section 2.2), related to the measured herring abundances in the Sound within the present monitoring programmes, it is likely that the major part of the observed 3+ -group was western Baltic spring spawning herring, at least in periods with occurrence of high abundances of herring in the Sound as this is the dominating stock in the whole Kattegat and western Baltic area today. This conclusion is based on the relatively high estimated amounts of herring in the Sound during the survey period(s). However, no definite conclusions about stock identity can be made based on the present limited racial data material in number and time.

Number of herring per NM**2 divided by sex and maturity group in the northern (superstratum 1), central (superstratum 2) and southern (superstratum 3) Sound during the period October 1994 to May 1995 is shown in Fig. 23. Maturity index matA is juvenile (immature) herring, matB mature and spawning herring, and matC is post spawned herring. It appears from Fig. 23, that the abundances of all maturity groups varied significantly between months and areas, and that both sexes showed parallel monthly and geographical oscillations. Juvenile herring were most abundant in the northern and central Sound during the period October-December, and within this period the most extreme abundances of juvenile herring were found in the northern part of the Sound. Further, during the whole period October 1994 to May 1995 juvenile herring were least abundant in the southern part of the Sound compared to the central and northern parts. This is in accordance with the above reported indices of likely relatively high abundances of juvenile North Sea (Bank) herring (1-group) in the Sound distributed southwards from the Kattegat-Skagerrak area into the northern and central parts of the Sound. In general, a higher number of female immature herring than male immature herring were observed in the Sound. (Fig. 23).

Mature and spawning herring were abundant in the whole Sound area during the period Oct. 1994 to January 1995 with a decreasing tendency later in that period, and also with a slightly decreasing tendency towards the most southern parts of the Sound (superstratum 3). The amount of mature and spawning herring decreased significantly in February-May. However, in May intermediary abundances of mature and spawning herring were found, especially in the central Sound. The latter might be caused by occurrence of some local spawning around the island of Ven. Parallel with the observed abundance pattern of juvenile herring, the mature and spawning herring were found in relatively low numbers in the northern Sound and relatively high numbers in the central and southern Sound in November compared to the months of October and December. This pattern show existence of temporal variations in local migration and concentration of over-wintering juvenile and mature and spawning herring within the Sound area during the autumn and winter period. The observed decrease in mature and spawning herring in the spring period from February and onwards indicates that a spawning migration had begun from the Sound area to the spawning grounds in the western Baltic Sea around Rügen and Griefswalder Bodden. This migration seems to have taken place in early spring, and already starting in late winter (January to February). For both juvenile, mature and spawning herring in the Sound there seems not to have been any significant differences in abundance of the different maturity groups between the two sexes in different months and areas.

Regarding occurrence of post spawned herring in the Sound the picture is somewhat more complicated. In general, only very few post spawned herring were found in the Sound compared to the abundance levels of the other maturity groups found within the area. No distinct and consequent temporal, geographical and sexual patterns in distribution or occurrence can be distinguished for post spawned herring in the Sound, except that no post spawned herring have been found in October month. Post spawned herring were present in all other months in small numbers indicating (some) occurrence of both autumn spawning and spring spawning herring stock components in the Sound. Related to the northward migration of western Baltic herring from the spawning grounds back to the feeding grounds during spring it can be concluded that these herring not seemed to concentrate in large amounts in the Sound for longer periods within the season from October to May. It can not, based on the present monitoring programme and data material, be concluded whether the Sound or the Belt Sea is the most important migration route back to the northern feeding grounds.

5.0 FUTURE MONITORING

Proposed future monitoring activities related to herring in the Sound area:

1) Based on the observed spatial and temporal variations in distribution and abundance of herring in the Sound it is evident that the herring concentrate in the northern and central part of the Sound during the late summer, autumn and early winter period and probably perform a (more or less) continuous migration southwards to the spawning grounds as the total herring biomass decline in the Sound during that period, and because there seems to be a tendency to southwards relative displacement of herring in the later part of this period. The migration from the spawning grounds to the feeding area(s) is not well documented, however, sexual maturity indices seems to indicate that there is some (continuous ?) migration in the spring from March to May of post spawned herring from the southern spawning grounds northwards through the Sound. Future monitoring should ensure that the large concentrations of herring which have been observed in previous years (1993-1995) in the Sound have arrived to the Sound area during late summer and autumn from the feeding grounds in the north, and that they leave the Sound (as mature) to the spawning grounds during late autumn, winter and early spring. Further, monitoring should examine whether post spawned herring migrating northwards during the late spring period are found in the Sound in that period. To implement this, a macro scale monitoring - in form of hydro acoustic integration and synchronous biological sampling - of herring in the whole Sound seems necessary, at least once during the autumn / early winter period (e.g. from first in Oct. to late Nov.) to ensure that maturing and mature herring has arrived to and are found with significant abundance in the Sound area at that time, and once again in the early spring period (e.g. March/April) to ensure that the mature and maturing herring are migrating southwards from the Sound, i.e. are lieving the area, and that post-spawned herring migrating northwards has begun to show up in the Sound area.

2) Avoidance reactions to plumes of suspended sediment of limestone and glacial till for herring during a migration situation is not properly investigated, and an amount of 6 mg/l (maximum 10 mg/l) suspended material is, based on available literature information, chosen as the expected threshold for avoidance reactions of herring. Future detailed investigations on micro scale, in form of acoustic monitoring of herring distribution related to actual dispersion of sediment fans from construction activities, should be implemented to examine the effect on herring distribution of the actual occurring sediment fans in the construction area during establishment of the fixed link.

3) To ensure that the continuous herring migration through the Drogden and Flinterenden area actually does occur during the construction period it seems reasonable that a acoustic sonar monitoring of herring occurrences in that area is performed as a supplement to the above suggested monitoring on macro scale. This would, besides the information about the continuos herring migration in that isolated area, give information about whether the main herring migration takes place through Flinterenden or through Drogden in the construction area.

6.0 TABLES

Table 1. Schematic presentation of survey activities during the period September 1993 to May 1995.

Month	September	October	November	December	January	February	March	April	May
Surveys 1993/1994	S-09-93	S-10-93	S-11-12-93	See Nov.	S-01-94	S-02-94	S-03-94	S-04-94	
Period(s)	17-22/9	25-30/10	29/11-4/12		10-15/1	14-19/2	14-19/3	11-16/4	
Acoustic integration	x	x	x		x	x	x	x	
Biological sampling	x	x	x		x		(x)	x	
Individ. analysis of herr.							x		
Hydrographical sampling									
Surveys 1994/1995		S-10-94	S-11-94	S-12-94	S-01-95	S-02-95	S-(02)-03-95	S-(03)-04-95	S-05-95
Period(s)		17-20/10	21-27/11	12-16/12	9-16/1	6-10/2	27/2-4/3	27/3-2/4	25/5
		24-26/10							30-31/5
Acoustic integration		x	x	x	x	x	x	x	x
Biological sampling		x	x	x	x	x	x	x	
Individ. analysis of herr.		x		x		x		x	
Hydrographical sampling		x	x	x	x	x	x	x	

Table 2. Biomass of herring in tonnes per square nautical mile divided by stratum and survey (month) during the period September 1993 to May 1995. Grand total is the total amount of herring in tonnes in the whole Sound area.

BIOMASS IN TONNES PER NM**2															
SURVEY	**S-09-93**	**S-10-93**	**S-11-12-93**	**S-01-94**	**S-02-94**	**S-03-94**	**S-04-94**	**S-10-94**	**S-11-94**	**S-12-94**	**S-01-95**	**S-02-95**	**S-03-95**	**S-04-95**	**S-05-95**
STRATA															
G01	557,74	324,20	-	-	-	-	16,34	312,89	49,73	480,85	142,86	25,80	219,43	32,00	31,49
G02	737,93	453,03	506,01	530,49	149,59	93,59	40,60	487,41	78,85	281,55	169,13	95,15	104,57	37,45	55,32
G03	651,81	551,39	490,77	847,32	1.174,19	142,17	77,28	632,76	64,06	490,83	235,55	107,03	157,63	70,25	45,03
G04	726,00	448,47	256,90	451,08	1.339,29	101,90	40,74	591,81	244,56	371,29	174,97	32,50	229,97	50,33	45,14
G05	407,88	453,94	179,74	313,91	503,28	81,60	20,89	410,60	315,75	127,91	255,39	32,62	82,20	41,26	78,24
G06	568,71	412,26	176,89	281,67	487,33	91,95	26,03	424,05	381,70	204,50	219,35	26,68	34,85	83,82	61,31
G07	541,65	265,61	266,47	218,02	96,93	114,54	12,38	292,39	286,52	195,40	136,77	30,80	60,86	143,87	55,81
G08	398,25	398,70	62,93	211,75	-	-	8,14	390,79	437,33	233,76	124,80	33,97	30,33	27,86	41,74
G09	433,94	420,30	415,38	131,55	130,30	-	4,05	578,28	226,47	211,04	242,11	69,16	29,23	31,21	52,85
G10	414,59	188,62	297,97	71,85	55,85	-	4,52	151,39	403,55	172,25	8,13	16,51	31,87	20,79	88,01
G11	194,86	319,68	257,64	113,86	4,34	-	3,31	57,68	72,88	100,86	7,27	3,81	49,59	8,53	-
G12	157,34	34,68	35,09	3,99	1,74	-	1,38	1,34	4,43	2,93	6,99	0,76	4,03	4,55	0,19
G13	-	-	-	-	-	-	-	1,62	2,87	3,02	-	-	-	-	1,79
MEAN	482,56	355,91	267,80	288,68	394,28	104,29	21,31	333,31	197,59	221,25	143,61	39,57	86,21	45,99	42,84
MIN	157,34	34,68	35,09	3,99	1,74	81,60	1,38	1,34	2,87	2,93	6,99	0,76	4,03	4,55	-
MAX	737,93	551,39	506,01	847,32	1.339,29	142,17	77,28	632,76	437,33	490,83	255,39	107,03	229,97	143,87	88,01
GRAND TOTAL	130.241,01	96.741,95	69.504,27	71.711,28	84.533,13	15.291,28	5.342,55	99.723,53	67.146,45	60.499,38	40.369,97	10.738,89	19.673,69	14.651,56	13.589,99

Table 3. Number of herring in millions per square nautical mile divided by stratum and survey (month) during the period September 1993 to May 1995. Grand total is the total number of herring in millions in the whole Sound area.

ABUNDANCE: NUMBER INN MILL. PER NM**2															
SURVEY	S-09-93	S-10-93	S-11-12-93	S-01-94	S-02-94	S-03-94	S-04-94	S-10-94	S-11-94	S-12-94	S-01-95	S-02-95	S-03-95	S-04-95	S-05-95
STRATA															
G01	3,96	2,96	-	-	-	-	0,12	2,07	0,38	2,77	0,71	0,22	1,92	0,29	0,29
G02	5,24	3,95	4,31	4,08	1,15	0,83	0,31	2,9	0,6	1,62	0,84	0,67	0,79	0,3	0,44
G03	5,13	4,32	4,18	6,52	9,04	1,02	0,64	3,54	0,55	2,99	1,08	0,62	1	0,47	0,3
G04	5,89	3,39	2,19	3,45	10,23	0,77	0,31	2,87	1,81	2,06	0,91	0,21	1,57	0,36	0,32
G05	3,03	3,61	1,39	2,39	3,83	0,65	0,13	2,11	2,05	0,69	1,46	0,25	0,45	0,33	0,63
G06	4,08	2,97	1,37	1,91	3,31	0,63	0,17	2,32	2,43	1,14	1,36	0,17	0,21	0,57	0,42
G07	3,56	1,92	1,89	1,6	0,71	0,76	0,08	1,6	1,54	1,17	0,77	0,19	0,39	0,86	0,33
G08	2,62	2,79	0,41	1,43	-	-	0,07	1,82	2,33	1,26	0,63	0,2	0,19	0,18	0,27
G09	2,92	2,84	2,74	0,82	0,81	-	0,03	2,66	1,11	1,05	1,18	0,36	0,16	0,19	0,32
G10	3,22	1,27	1,96	0,44	0,34	-	0,03	0,71	1,83	0,82	0,04	0,1	0,21	0,14	0,61
G11	1,52	2,16	1,63	0,69	0,03	-	0,02	0,29	0,32	0,48	0,03	0,02	0,32	0,06	0
G12	1,11	0,23	0,22	0,02	0,01	-	0,01	0,01	0,03	0,01	0,03	0,01	0,03	0,03	0,01
G13	-	-	-	-	-	-	-	0,01	0,02	0,01	-	-	-	-	0,01
MEAN	3,52	2,70	2,03	2,12	2,95	0,78	0,16	1,76	1,15	1,24	0,75	0,25	0,60	0,32	0,30
MIN	1,11	0,23	0,22	0,02	0,01	0,63	0,01	0,01	0,02	0,01	0,03	0,01	0,03	0,03	-
MAX	5,89	4,32	4,31	6,52	10,23	1,02	0,64	3,54	2,43	2,99	1,46	0,67	1,92	0,86	0,63
GRAND TOTAL	939,84	718,83	516,67	523,04	626,90	111,38	39,64	517,20	383,13	336,31	214,41	66,60	130,89	96,68	93,55

Table 4. Herring density per bottom depth locality, i.e. per locality with given bottom depth, in the Sound divided by geographical superstratum during the period from October 1994 to May 1995.

HERRING DENSITY BY DEPTH LOCALITY: NUMBER IN MILL. PER NM**2 DIVIDED BY BOTTOM DEPTH STRATUM										
			SURVEYS							
SUPERSTRATUM	DEPTHSTRATUM	AREA, NM**2	S-10-94	S-11-94	S-12-94	S-01-95	S-02-95	S-03-95	S-04-95	S-05-95
	5 - 10 M	5,4	7,69	1,96	5,43	3,69	3,07	1,66	1,90	2,19
SUP.STR. 1	10 - 20 M	21,3	3,16	0,60	2,77	0,92	0,37	1,49	0,29	0,17
	> 20 M	13,2	2,11	0,07	1,60	0,16	0,07	0,61	0,03	0,03
	5 - 10 M	18	5,75	4,72	2,81	2,69	0,66	1,04	1,68	2,36
SUP.STR. 2	10 - 20 M	60,5	1,83	1,91	1,27	1,12	0,16	0,64	0,55	0,04
	> 20 M	12,6	1,21	0,66	0,32	0,25	0,05	0,23	0,03	0,01
	5 - 10 M	39,1	2,28	2,65	1,67	0,90	0,38	0,46	0,34	0,82
SUP.STR. 3	10 - 20 M	45,9	1,37	1,00	0,66	0,42	0,09	0,08	0,05	0,00
	> 20 M	0,6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table 5. Number of herring per nautical mile (N/NM**2) divided by age for the Sound area as a whole during the period October 1994 to May 1995. Total area of the Sound is 279 NM**2.

Year	Month	Survey													
			Age	1	2	3	4	5	6	7	8	9	10	11	12
1994	10	S-10-94		64051	136084	460927	374955	206331	265615	197608	97946	28582	0	0	0
1994	11	S-11-94		98316	174021	346961	260877	199632	119471	79836	54437	19696	0	0	0
1994	12	S-12-94		61366	219462	396387	211646	199416	53396	36305	14760	5173	0	0	0
1995	1	S-01-95		9609	49783	159081	176819	168766	75448	54649	45302	17345	1587	959	300
1995	2	S-02-95		0	29062	33672	69510	48795	21740	14352	13648	4243	566	63	144
1995	3	S-03-95		0	61254	94633	112257	88454	45399	27145	22424	9048	2838	1872	387
1995	4	S-04-95		0	29595	53167	83926	78075	46819	23129	17179	6962	2081	907	262
1995	5	S-05-95		0	65752	106414	165768	138094	82938	42730	32217	12807	3307	1496	432

Table 6. Regression equations and statistics for length-weight relationships divided by survey and superstratum based on data from samplings of individual herring during the performed surveys in the period October 1994 to May 1995.

1994	11	S-11-94	1	weight=(exp((-9,4922)+(3,6917*(log(length))))/1000)	0,1954	0,0497	1	210	0,9633	211	0,0001	5515,8
1994	11	S-11-94	2	weight=(exp((-8,7571)+(3,5023*(log(length))))/1000)	0,2004	0,0507	1	187	0,9623	188	0,0001	4779
1994	11	S-11-94	3	weight=(exp((-8,9746)+(3,5590*(log(length))))/1000)	0,3419	0,0856	1	160	0,9153	161	0,0001	1728,9
1994	12	S-12-94	1	weight=(exp((-10,0376)+(3,8198*(log(length))))/1000)	0,2779	0,0707	1	98	0,9675	99	0,0001	2916,8
1994	12	S-12-94	2	weight=(exp((-8,6833)+(3,4792*(log(length))))/1000)	0,3538	0,0885	1	90	0,9449	91	0,0001	1544,7
1994	12	S-12-94	3	weight=(exp((-8,4479)+(3,4237*(log(length))))/1000)	0,601	0,1508	1	77	0,8701	78	0,0001	515,6
1995	1	S-01-95	1	weight=(exp((-9,7570)+(3,7498*(log(length))))/1000)	0,2082	0,0533	1	191	0,9628	192	0,0001	4949,8
1995	1	S-01-95	2	weight=(exp((-8,7642)+(3,4948*(log(length))))/1000)	0,1739	0,044	1	225	0,9655	226	0,0001	6297,2
1995	1	S-01-95	3	weight=(exp((-9,5246)+(3,6918*(log(length))))/1000)	0,3362	0,0848	1	167	0,9191	168	0,0001	1896
1995	2	S-02-95	1	weight=(exp((-9,5626)+(3,7013*(log(length))))/1000)	0,3229	0,0831	1	91	0,9561	92	0,0001	1982
1995	2	S-02-95	2	weight=(exp((-8,6065)+(3,4513*(log(length))))/1000)	0,2092	0,0534	1	133	0,9691	134	0,0001	4173,8
1995	2	S-02-95	3	weight=(exp((-10,0558)+(3,8245*(log(length))))/1000)	0,3947	0,0999	1	88	0,9433	89	0,0001	1463,4
1995	3	S-03-95	1	weight=(exp((-7,8762)+(3,2551*(log(length))))/1000)	0,3172	0,0808	1	167	0,9066	168	0,0001	1621,3
1995	3	S-03-95	2	weight=(exp((-8,0698)+(3,3082*(log(length))))/1000)	0,2096	0,0532	1	202	0,9504	203	0,0001	3866,5
1995	3	S-03-95	3	weight=(exp((-8,4420)+(3,4058*(log(length))))/1000)	0,3812	0,0962	1	144	0,897	145	0,0001	1254,5
1995	4	S-04-95	1	weight=(exp((-7,1336)+(3,0541*(log(length))))/1000)	0,5452	0,1373	1	74	0,8699	75	0,0001	495
1995	4	S-04-95	2	weight=(exp((-6,4038)+(2,8785*(log(length))))/1000)	0,5573	0,1399	1	67	0,8634	68	0,0001	423,5
1995	4	S-04-95	3	weight=(exp((-6,3202)+(2,8584*(log(length))))/1000)	0,5317	0,1333	1	54	0,895	55	0,0001	460,1
1995	5	S-05-95	1	weight=(exp((-7,1336)+(3,0541*(log(length))))/1000)	0,5452	0,1373	1	74	0,8699	75	0,0001	495
1995	5	S-05-95	2	weight=(exp((-6,4038)+(2,8785*(log(length))))/1000)	0,5573	0,1399	1	67	0,8634	68	0,0001	423,5
1995	5	S-05-95	3	weight=(exp((-6,3202)+(2,8584*(log(length))))/1000)	0,5317	0,1333	1	54	0,895	55	0,0001	460,1

Table 7. Mean count of vertebrae from samplings of individual herring during survey S-10-94 in October 1994 used for race determination.

Year	Month	Survey	Age	Number	Mean count of vertebrae	Std. Dev.	Std. Err.
1994	10	S-10-94	1	32	56,2188	0,7064	0,1249
1994	10	S-10-94	2	39	56,0513	0,793	0,127
1994	10	S-10-94	3	68	55,9412	0,8443	0,1024
1994	10	S-10-94	4	44	55,8864	0,9934	0,1498
1994	10	S-10-94	5	27	55,5926	0,9711	0,1869
1994	10	S-10-94	6	33	55,8485	0,7124	0,124
1994	10	S-10-94	7	25	55,72	0,7916	0,1583
1994	10	S-10-94	8	12	55,6667	0,6513	0,188
1994	10	S-10-94	9	5	55,8	0,8367	0,3742
1994	10	S-10-94	All ages	285	55,9018	0,8418	0,0499

Table 8. **Positions for the division of the Sound into geographical strata G1-G13.**

G1:	56.00.00 - 56.02.50
G2:	55.57.50 - 56.00.00
G3:	55.55.00 - 55.57.50
G4:	55.52.50 - 55.55.00
G5:	55.50.00 - 55.52.50
G6:	55.47.50 - 55.50.00
G7:	55.45.00 - 55.47.50
G8:	55.42.50 - 55.45.00
G9:	55.40.00 - 55.42.50
G10:	55.37.50 - 55.40.00
G11:	55.35.00 - 55.37.50
G12:	55.32.50 - 55.35.00
G13:	55.30.00 - 55.32.50

Table 9. Acoustic survey transect.

WAY POINT	POSITION		
1	55.32.60	12.43.75	Drogden
2	55.32.90	12.52.60	
3	55.34.75	12.47.15	
4	55.36.65	12.56.30	
5	55.37.64	12.52.37	
6	55.38.80	12.51.75	
7	55.39.80	13.01.65	
8	55.41.70	13.00.80	
9	55.42.40	12.49.45	
10	55.42.70	12.47.20	
11	55.43.15	12.56.30	
12	55.45.40	12.51.00	Pinhättan
13	55.48.70	12.54.30	
14	55.46.50	12.42.70	
15	55.49.85	12.47.45	
16	55.49.85	12.40.00	
17	55.50.80	12.46.00	
18	55.51.80	12.40.00	
19	55.52.15	12.45.55	
20	55.53.85	12.43.60	
21	55.55.25	12.47.25	
22	55.55.25	12.42.80	
23	55.56.80	12.45.20	
24	55.56.85	12.40.00	
25	55.58.75	12.44.60	
26	56.00.00	12.42.02	
27	56.01.50	12.41.13	
28	56.01.45	12.38.90	
29	56.00.80	12.39.25	
30	56.00.00	12.40.00	
31	55.59.45	12.34.70	
32	55.58.55	12.41.00	
33	55.57.40	12.33.50	
34	55.55.90	12.40.00	
35	55.55.20	12.34.50	
36	55.54.65	12.39.50	
37	55.52.30	12.34.30	
38	55.53.95	12.41.00	
39	55.50.70	12.35.25	
40	55.53.25	12.41.45	
41	55.49.40	12.36.20	
42	55.50.95	12.41.75	
43	55.48.40	12.37.40	
44	55.49.10	12.44.65	
45	55.45.90	12.38.70	
46	55.45.90	12.47.25	
47	55.43.10	12.41.60	

Table 10. **Technical data and calibrated (basic) settings for the used acoustic integration systems during base-line surveys.**

	R/V HAVFISKEN	**R/V DANA**
Echosounder	SIMRAD EY 200, 38 kHz	SIMRAD EK 4OO, 38 kHz
Transducer	SIMRAD ceramic 38-29/25	SIMRAD
SL + VR	109.9	132.5
10 log psi	-12.9	-20.2
Sound velocity	1472 m/s	1470 m/s
Pulse length	0.0010 s	0.0010 s
TVGc	64.6	64.6
Vpp/unit (20 log R)	0,0010000	0.0010060
A/D zero point adjust:		
Phase 1	17	12
Phase 2	15	12

Table 11. **Technical measurements of gill nets used during base-line surveys.**

Mesh size mm	Height (m)	Length (m)
19.5	5.7	30
21.0	5.7	30
26.0	5.0	39
27.0	5.0	39
28.0	5.4	40
29.0	5.0	40
34.0	5.1	34
46.0	4.7	40
55.0	4.9	40
60.0	4.8	40

7.0 FIGURES

Strata	Area NM**2
G1	8
G2	17
G3	20
G4	18
G5	24
G6	27
G7	40
G8	28
G9	29
G10	25
G11	19
G12	16
G13	8

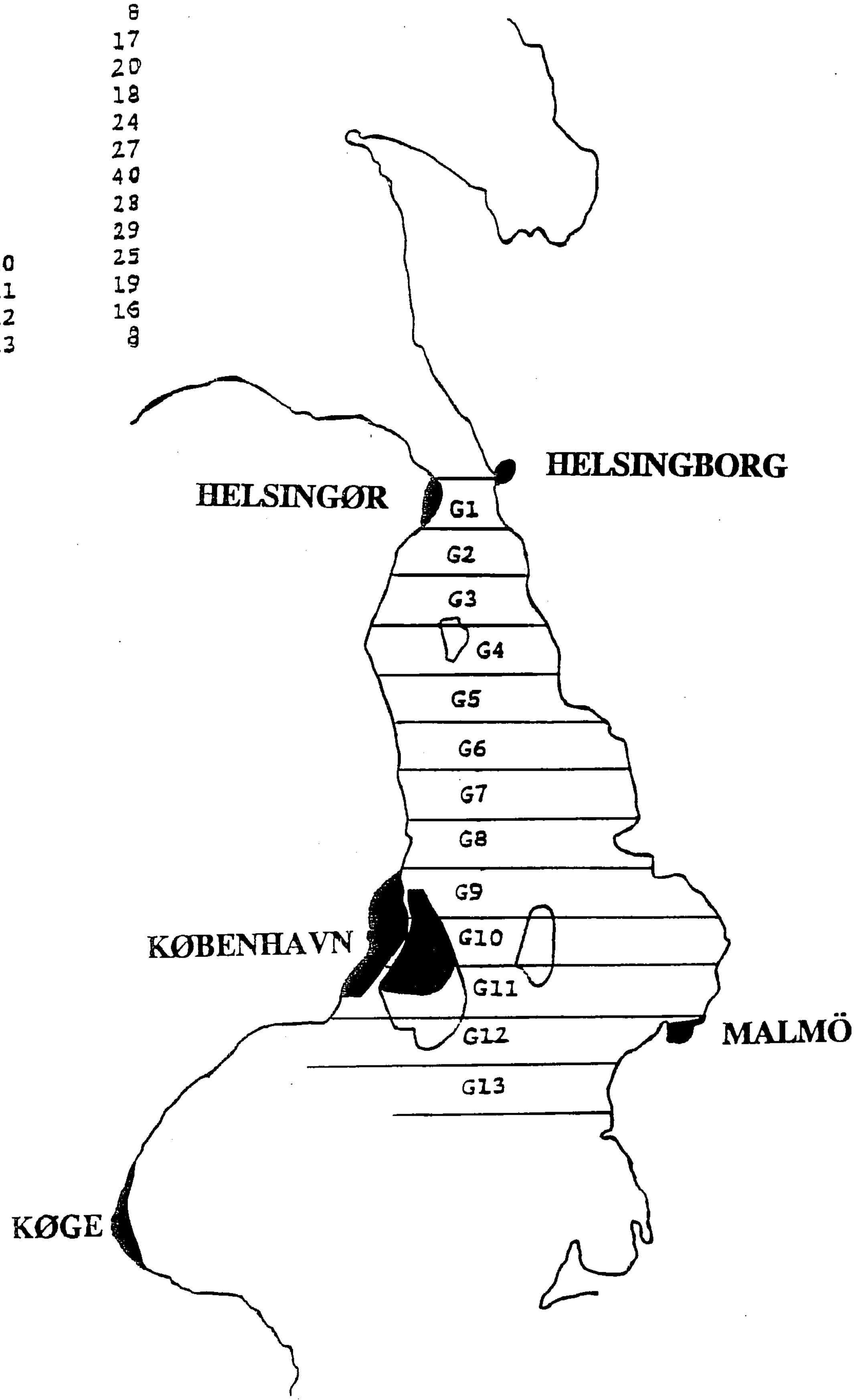


Figure 1. Survey area divided by stratum in the Sound. Area size in nautical square miles (NM**2) is given for each strata.

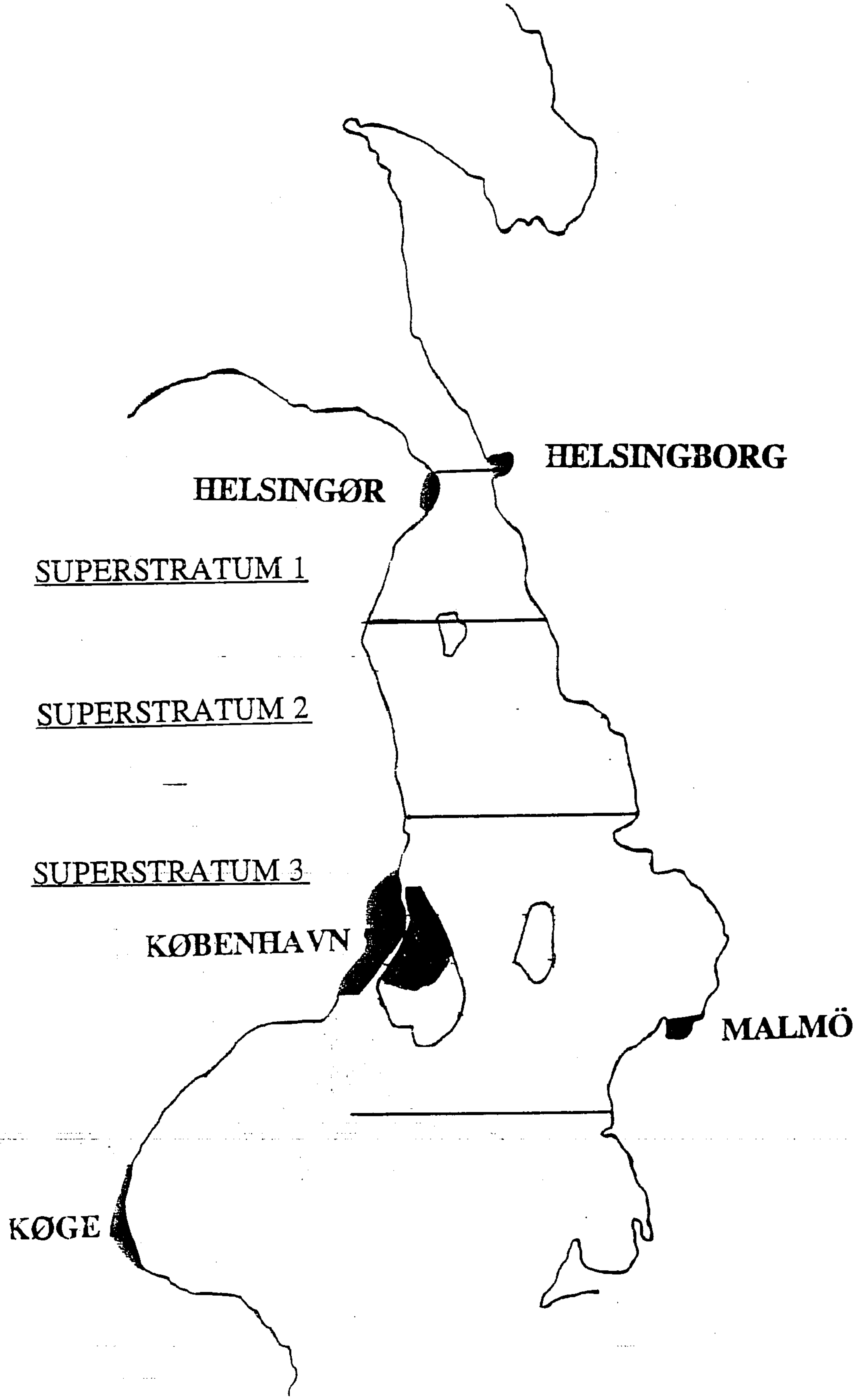
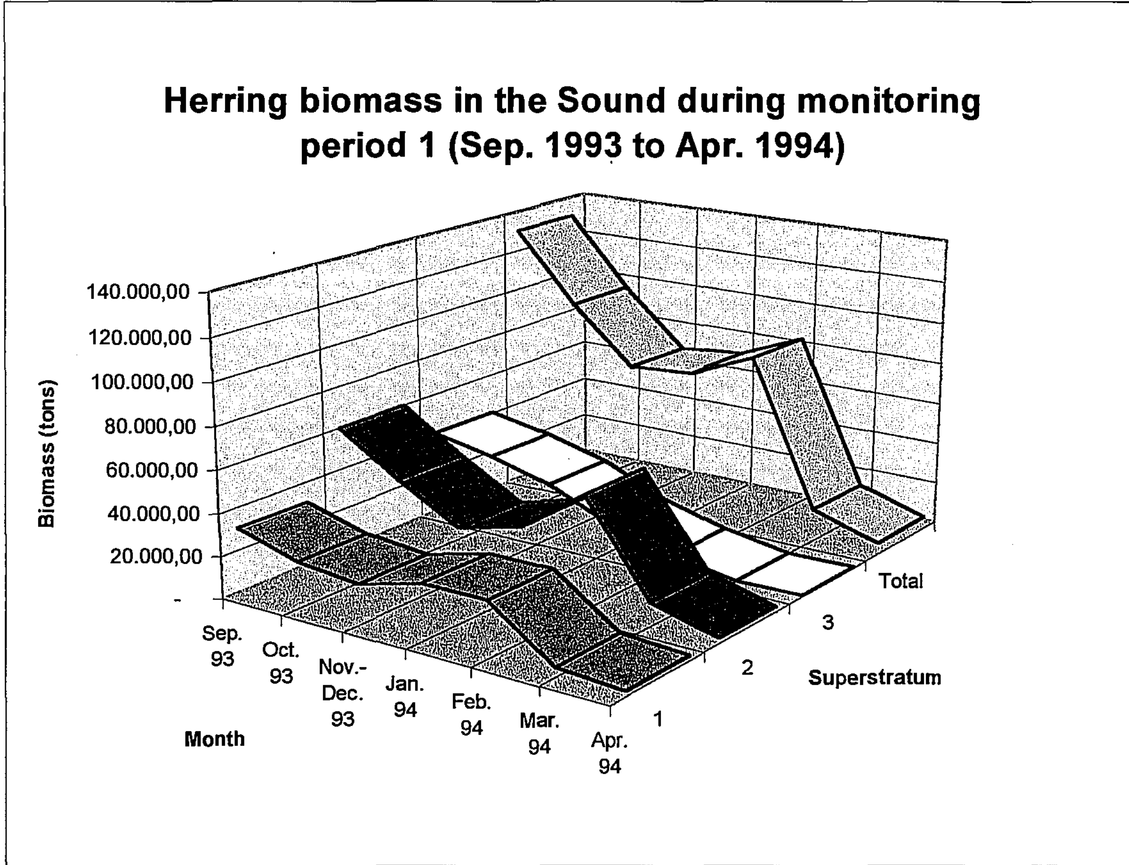


Figure 2. The survey area divided by superstratum. Superstratum 1: Northern Sound area comprising the strata G1-G3. Superstratum 2: Central Sound area comprising the strata G4-G7. Superstratum 3: Southern Sound area comprising the strata G8-G13.



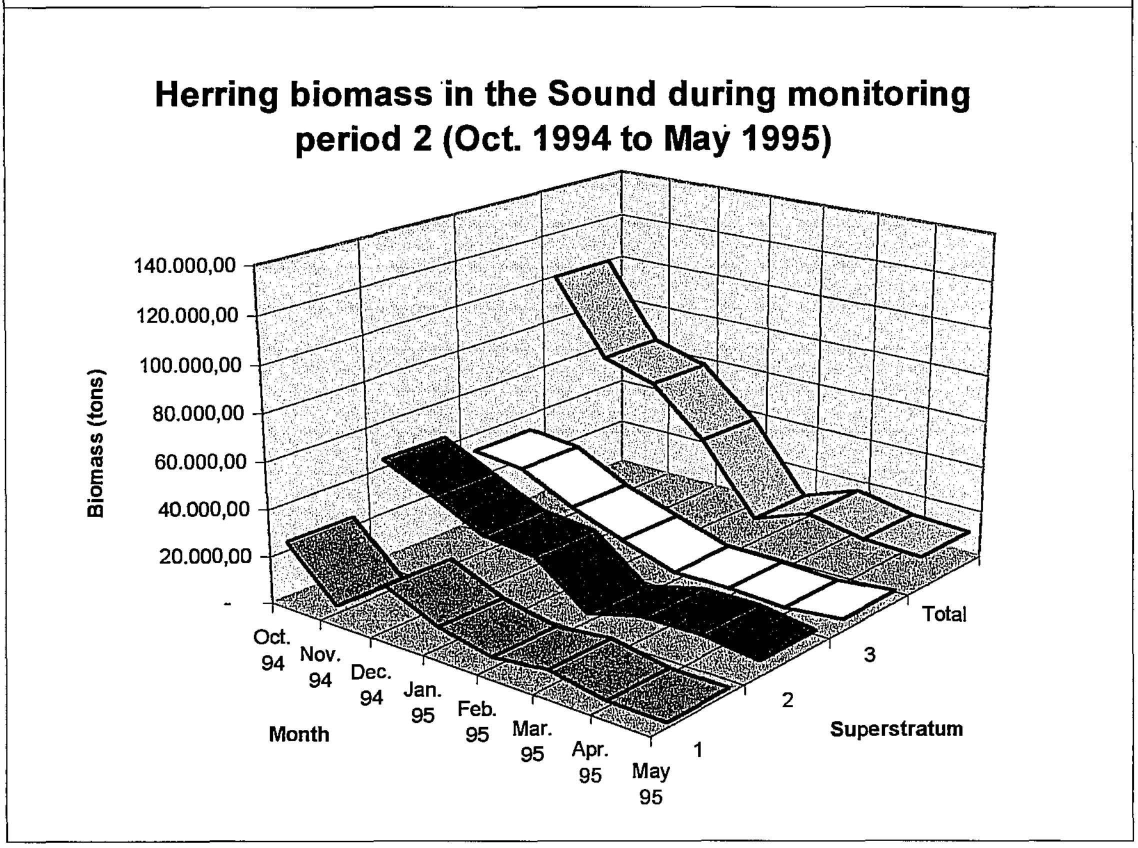


Figure 3. Herring biomasses divided by month and geographical superstratum during the two monitoring periods from September 1993 to May 1995.

Number of herring in September 1993

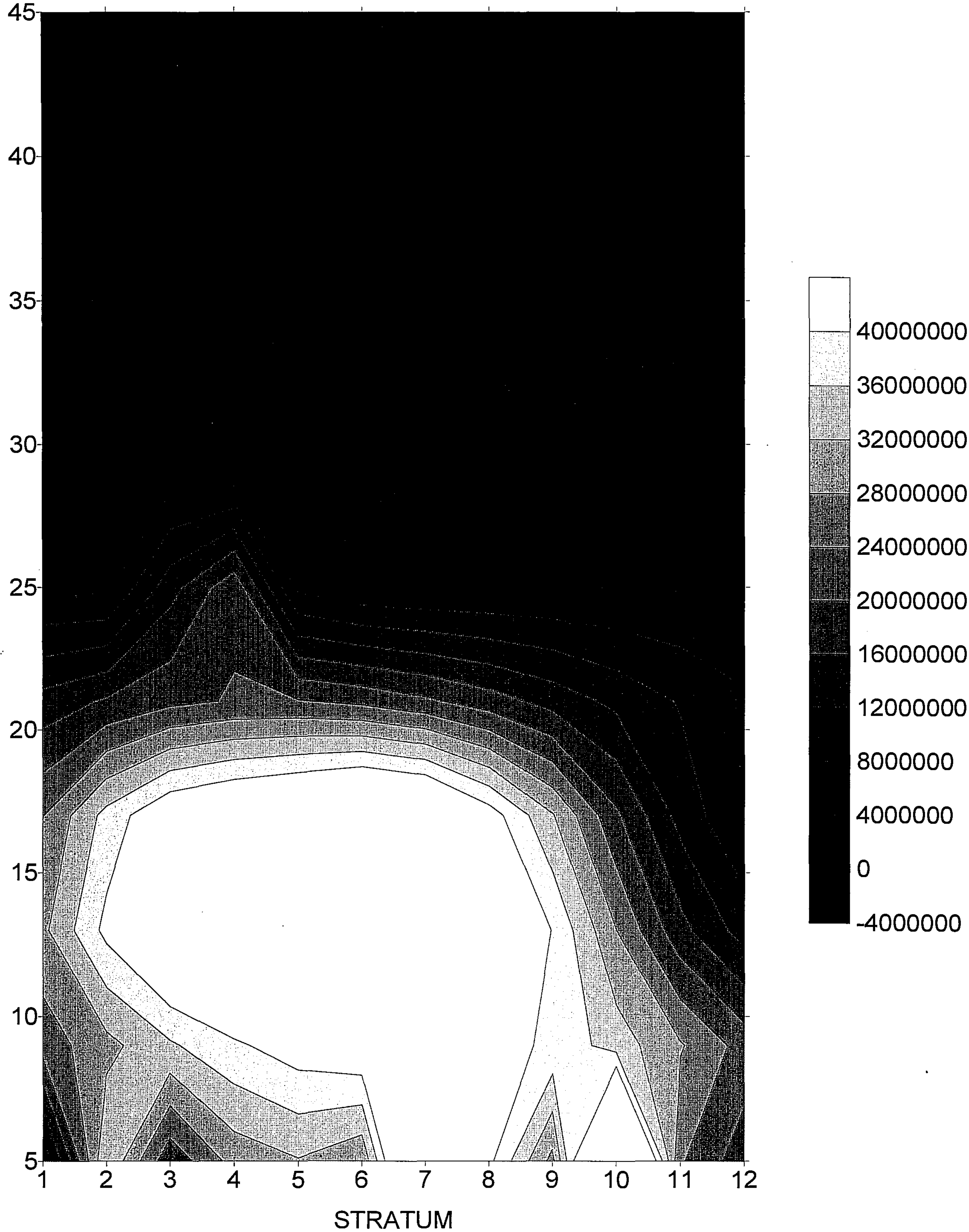


Figure 4. Number of herring divided by geographical strata and depth strata in the Sound in September 1993. Based on the S-09-93 survey.

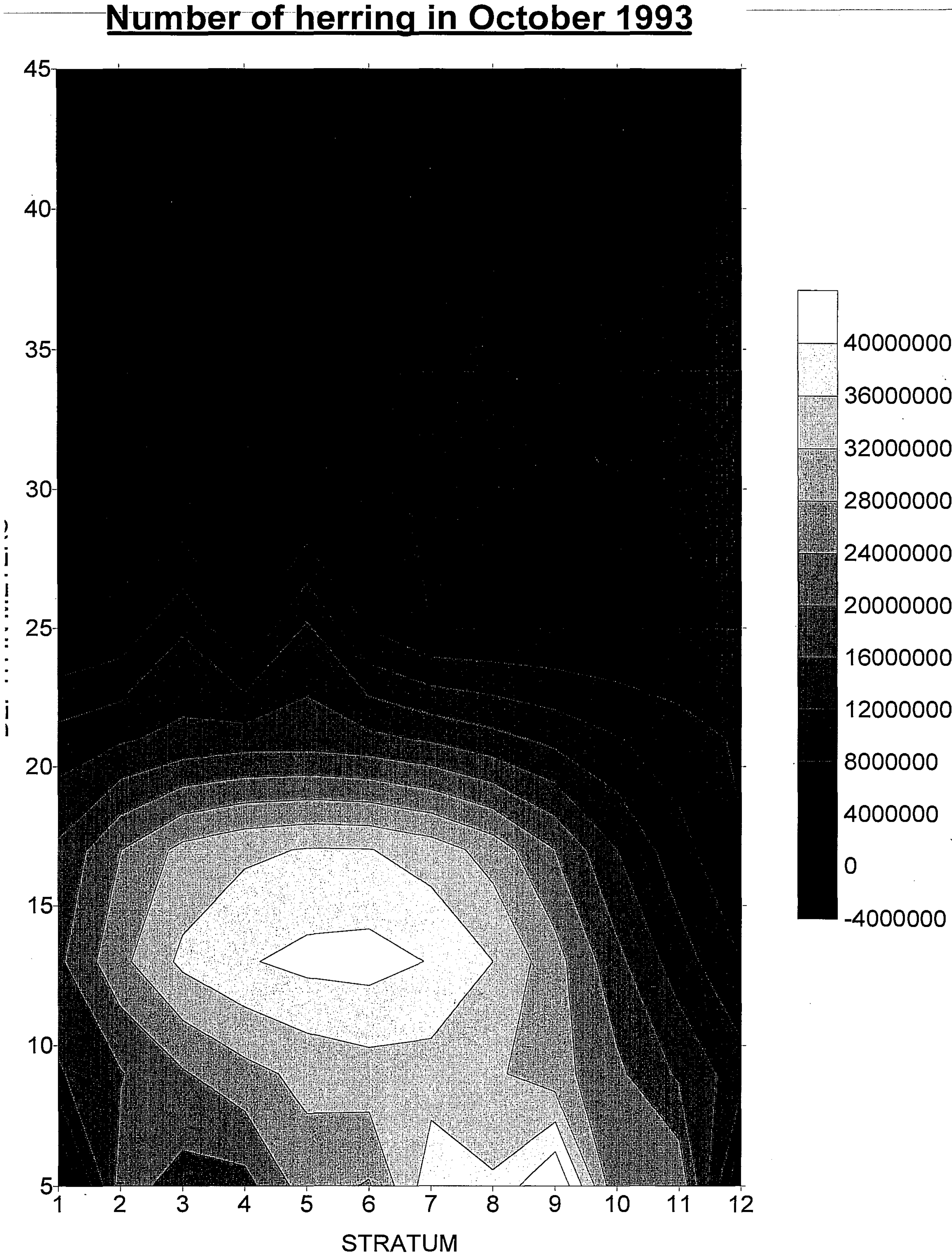


Figure 5. **Number of herring divided by geographical strata and depth strata in the Sound in October 1993. Based on the S-10-93 survey.**

Number of herring in November-December 1993

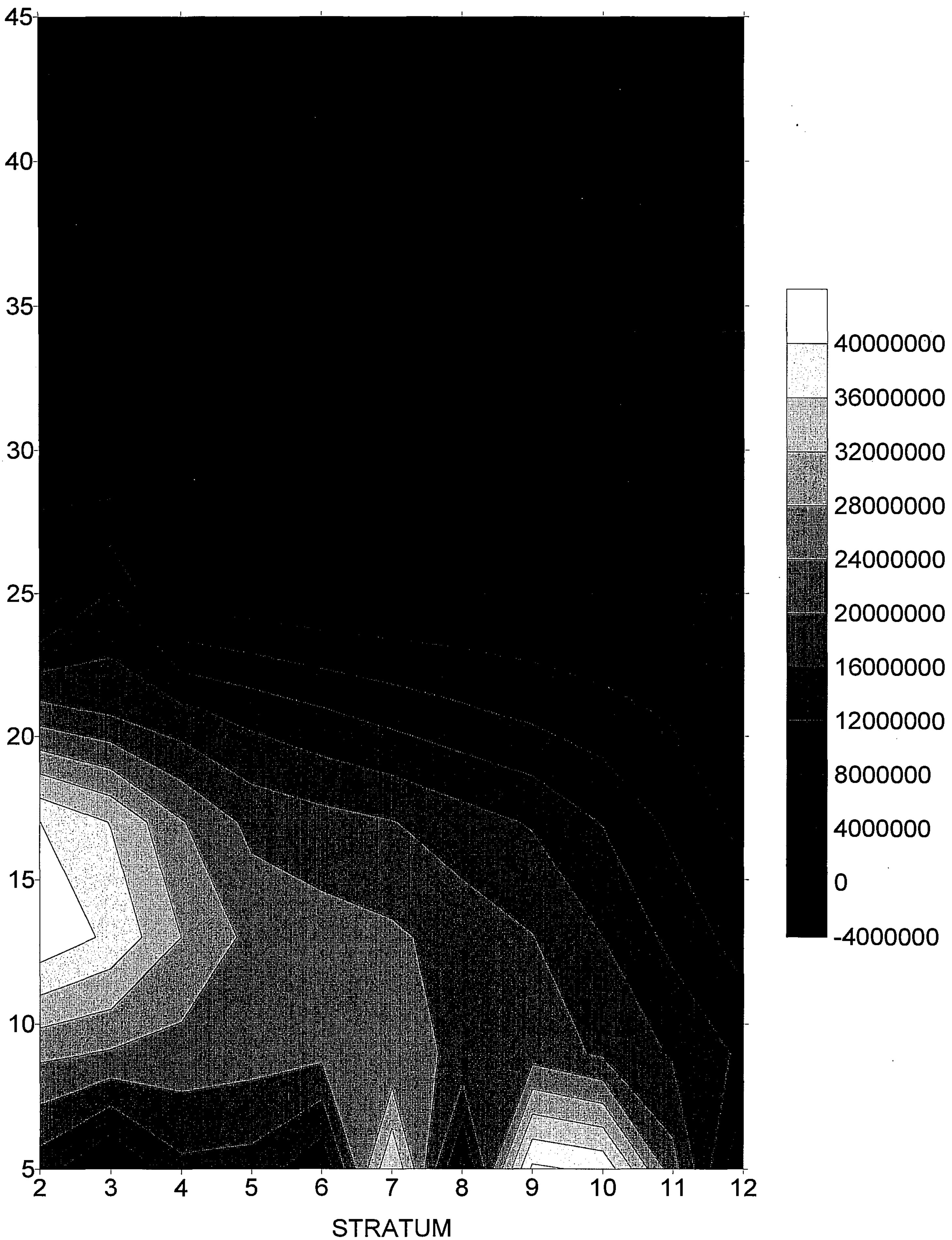


Figure 6. **Number of herring divided by geographical strata and depth strata in the Sound in November-December 1993. Based on the S-11-12-93 survey.**

Number of herring in January 1994

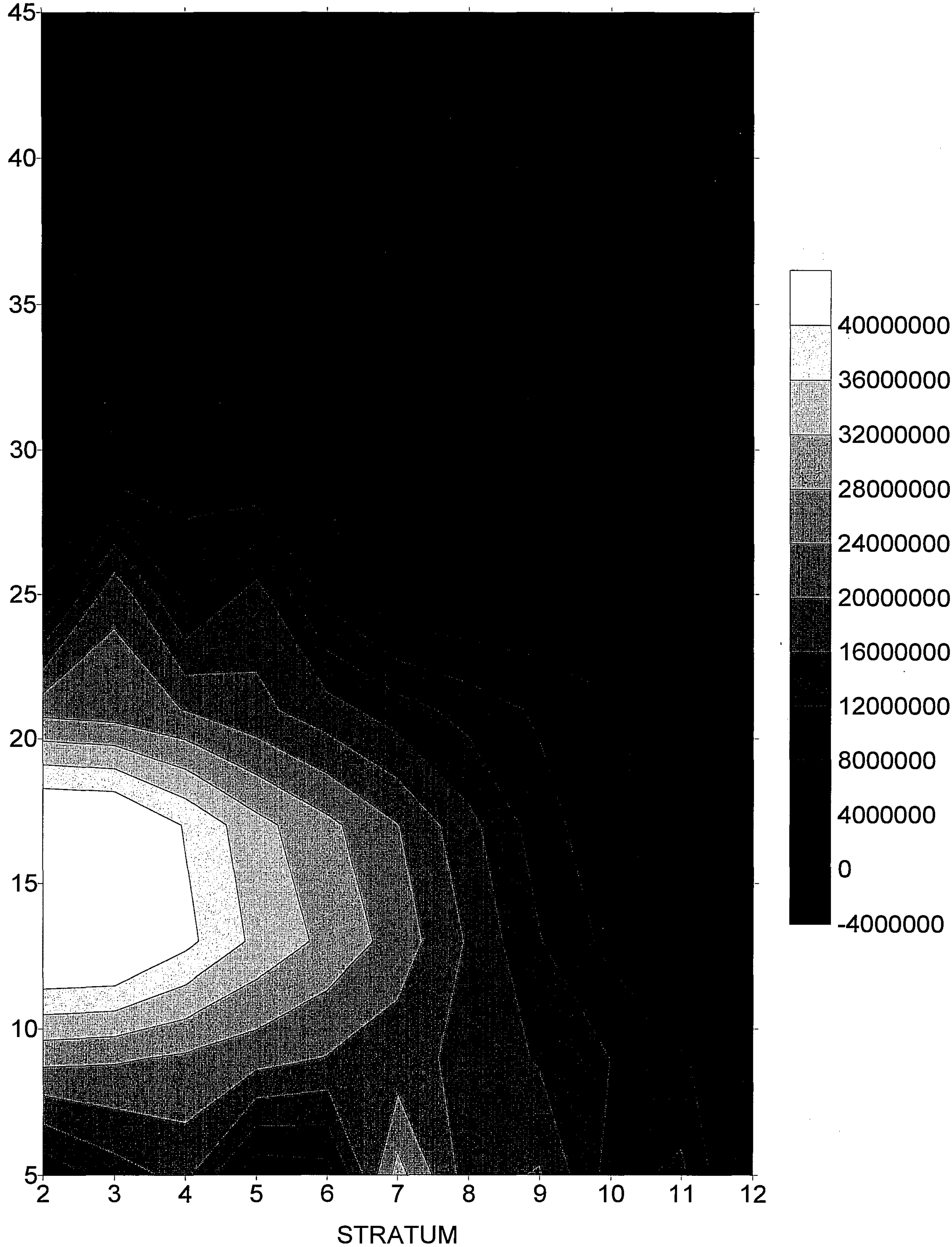


Figure 7. **Number of herring divided by geographical strata and depth strata in the Sound in January 1994. Based on the S-01-94 survey.**

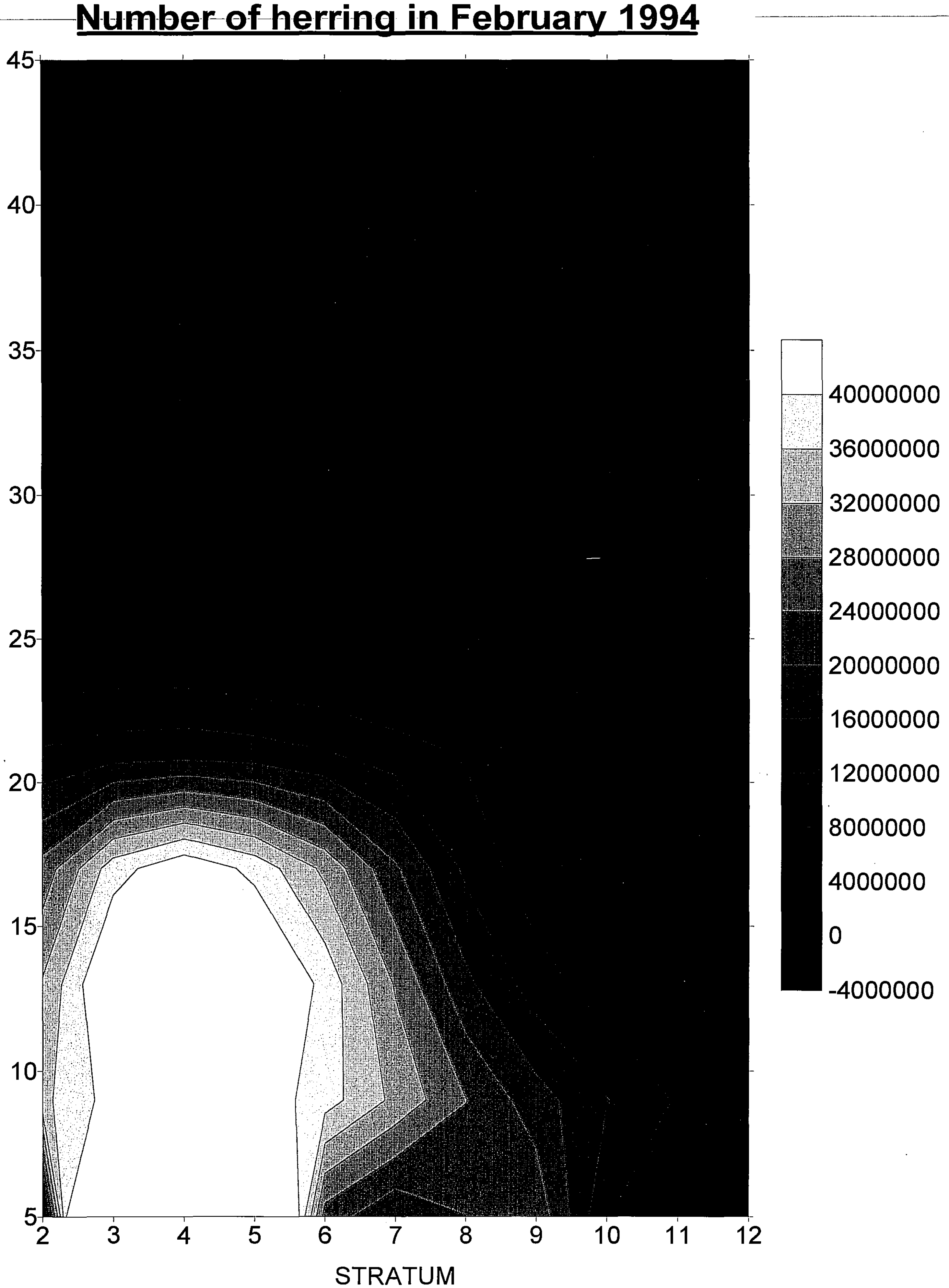


Figure 8. **Number of herring divided by geographical strata and depth strata in the Sound in February 1994. Based on the S-02-94 survey.**

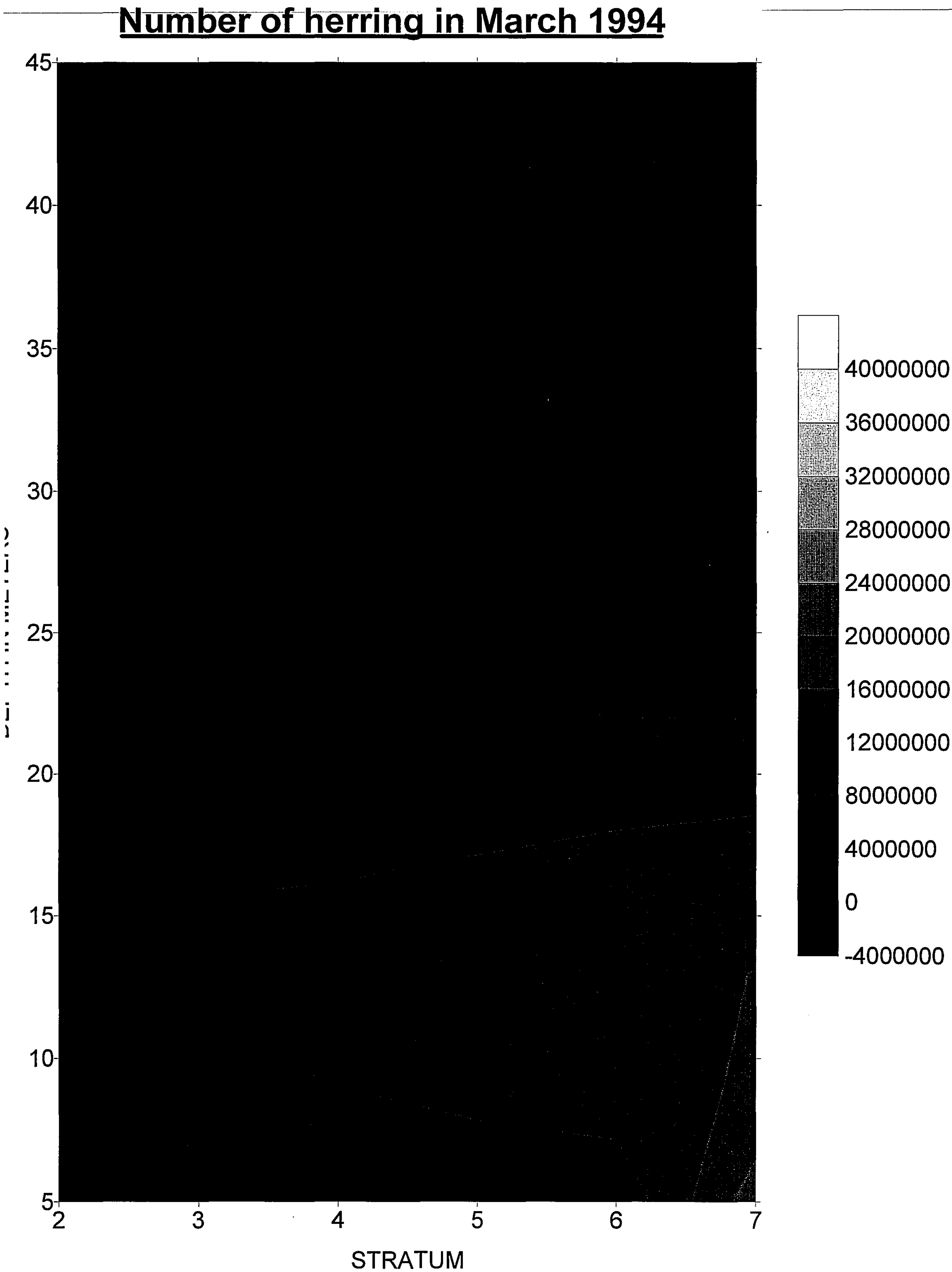


Figure 9. **Number of herring divided by geographical strata and depth strata in the Sound in March 1994. Based on the S-03-94 survey.**

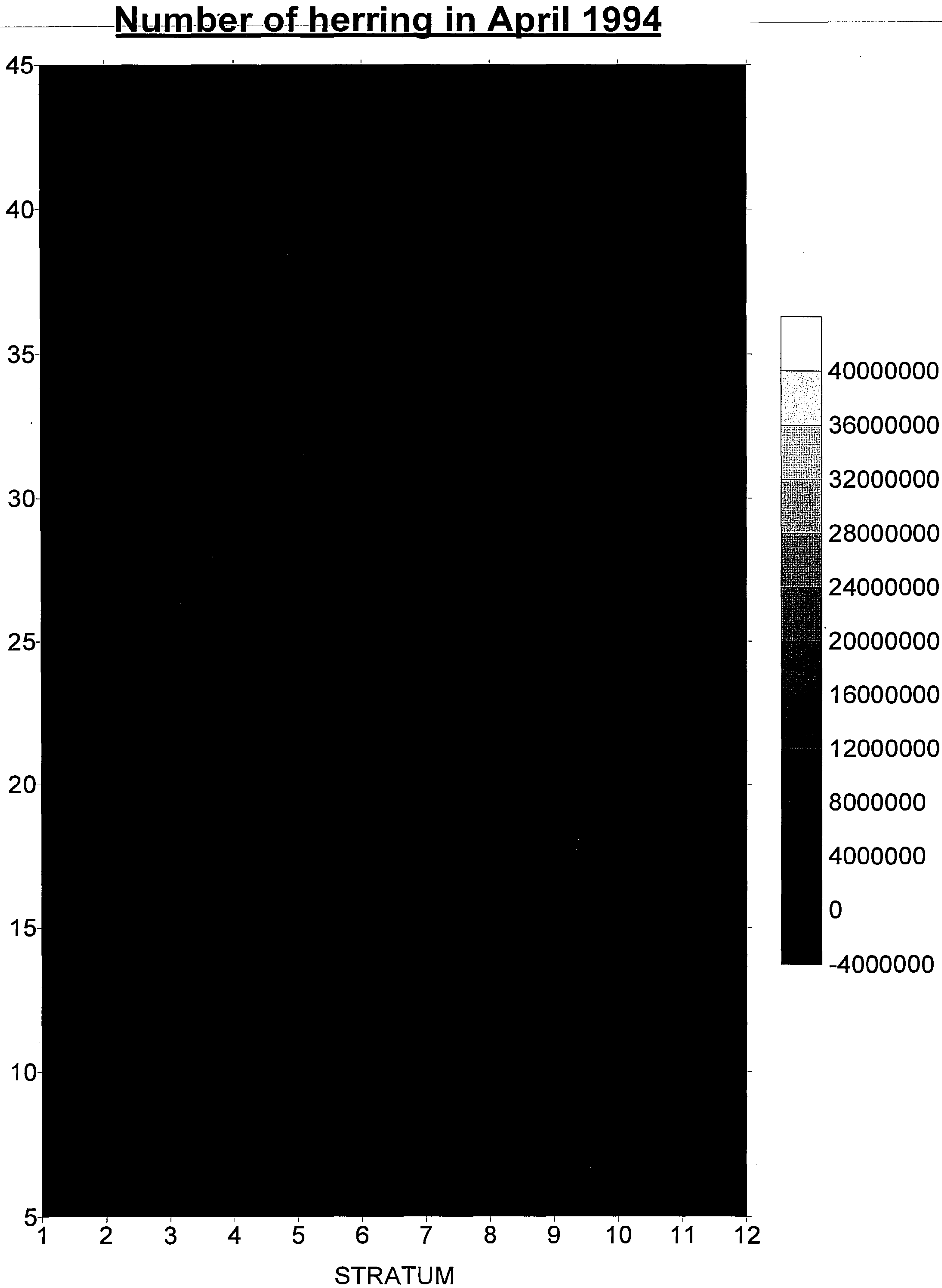


Figure 10. Number of herring divided by geographical strata and depth strata in the Sound in April 1994. Based on the S-04-94 survey.

Number of herring in October 1994

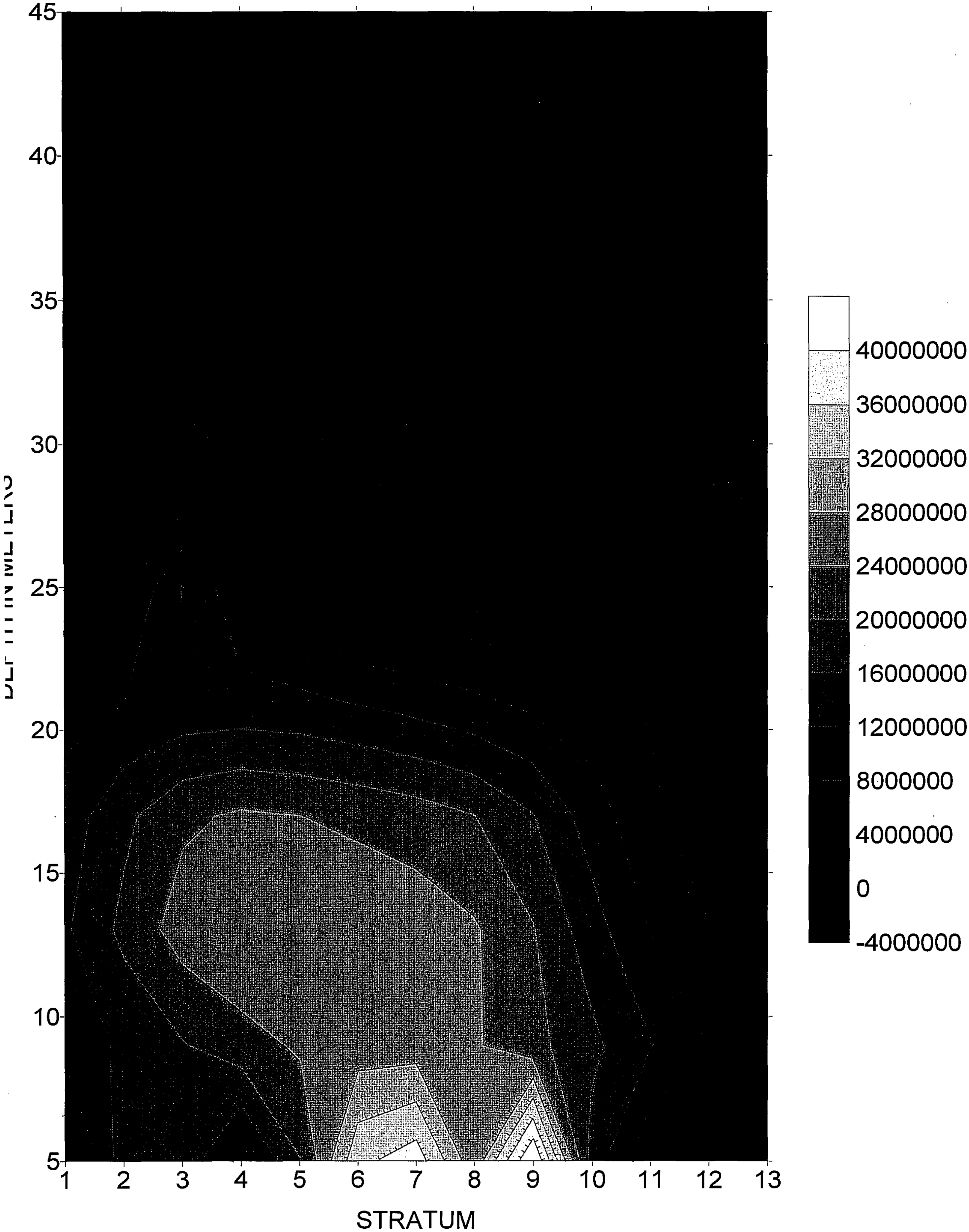


Figure 11. Number of herring divided by geographical strata and depth strata in the Sound in October 1994. Based on the S-10-94 survey.

Number of herring in November 1994

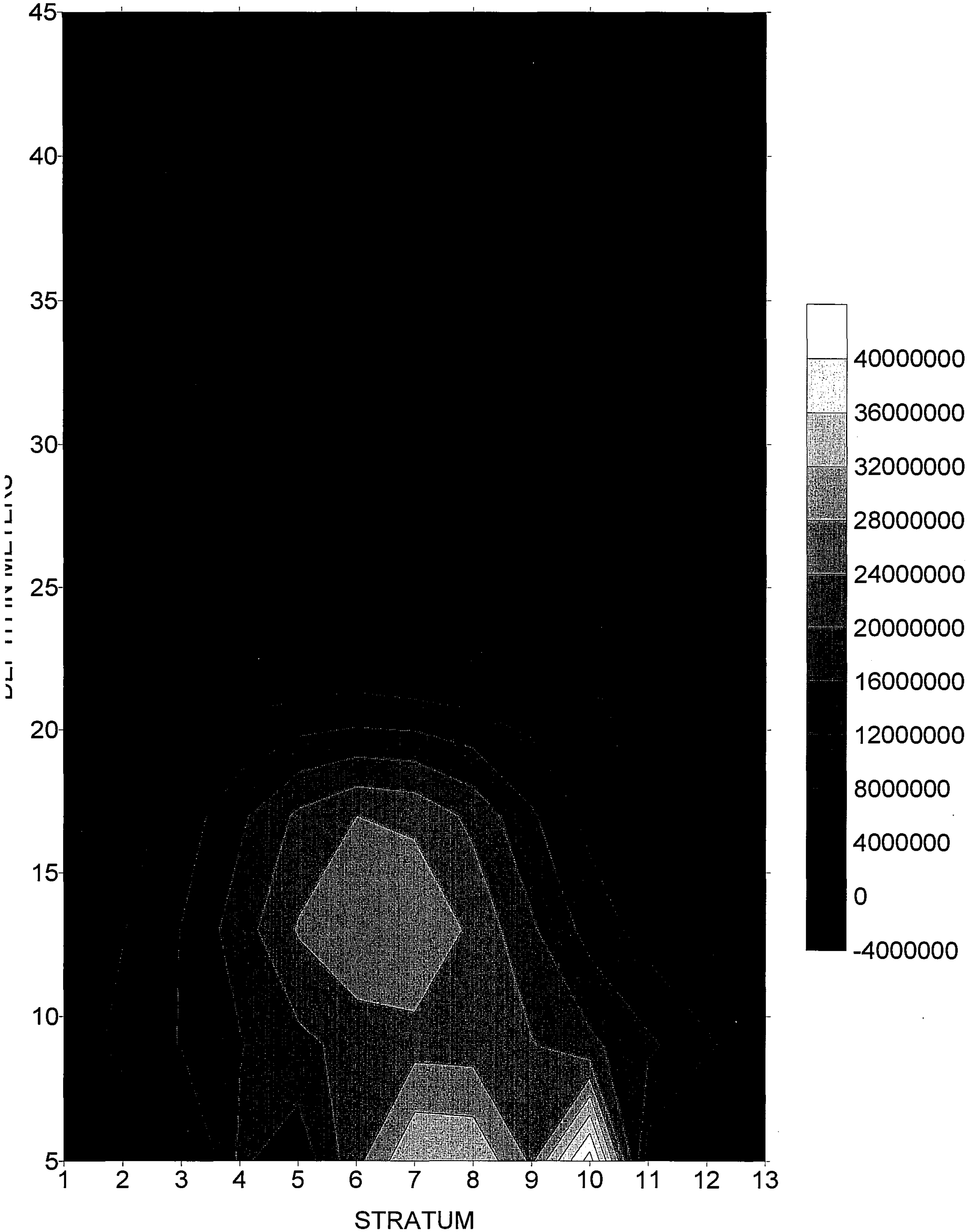


Figure 12. **Number of herring divided by geographical strata and depth strata in the Sound in November 1994. Based on the S-11-94 survey.**

Number of herring in December 1994

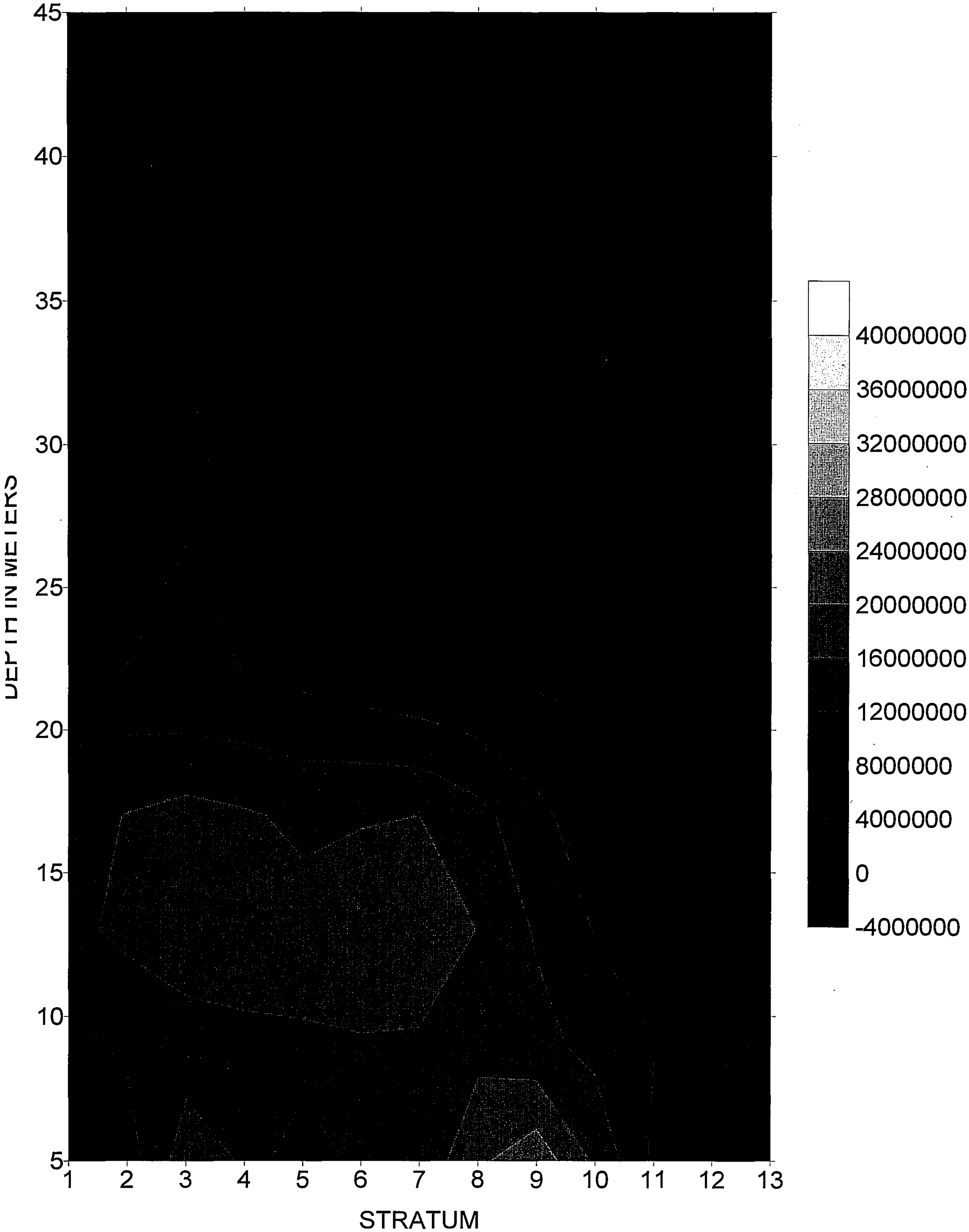


Figure 13. Number of herring divided by geographical strata and depth strata in the Sound in December 1994. Based on the S-12-94 survey.

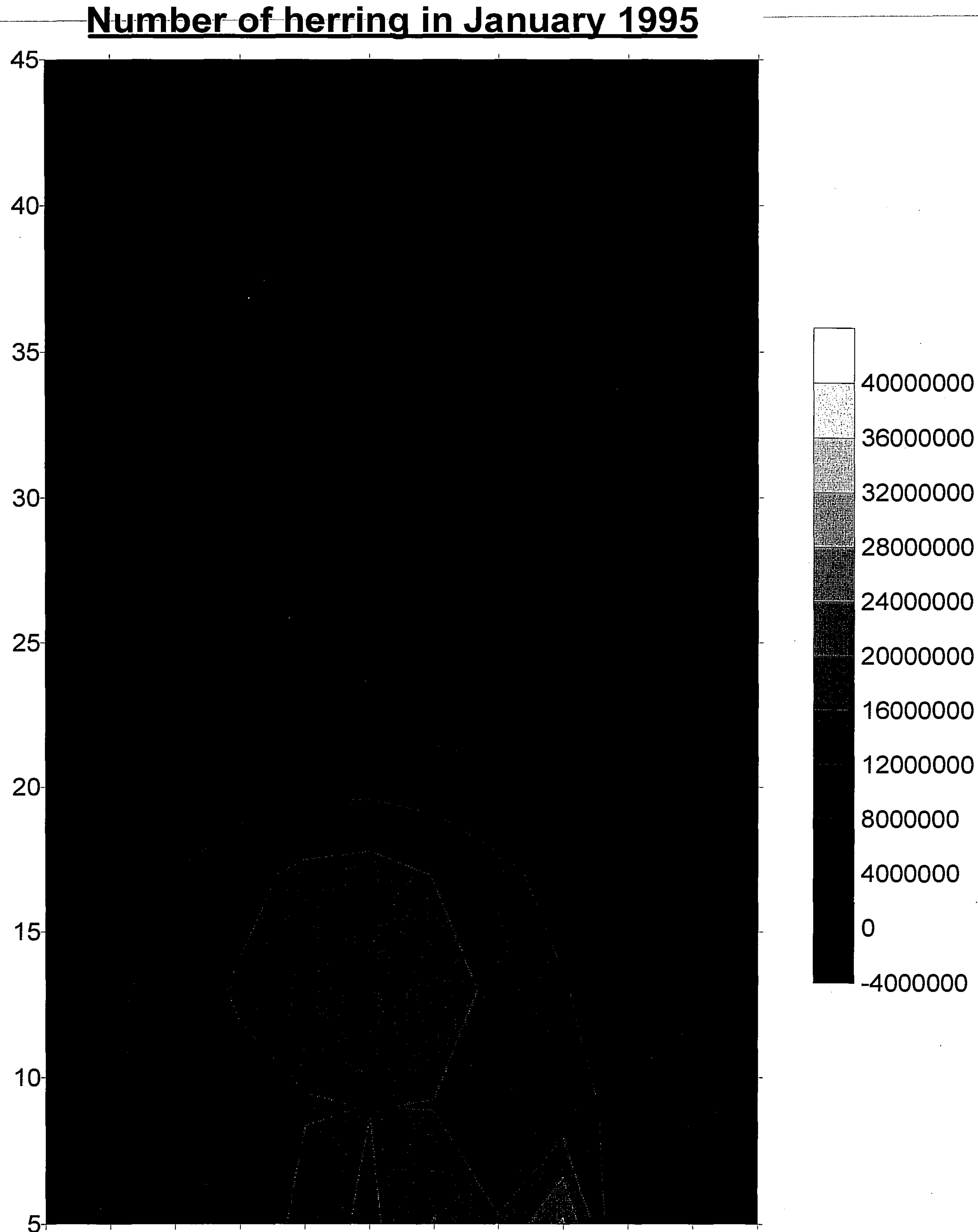


Figure 14. **Number of herring divided by geographical strata and depth strata in the Sound in January 1995. Based on the S-01-95 survey.**

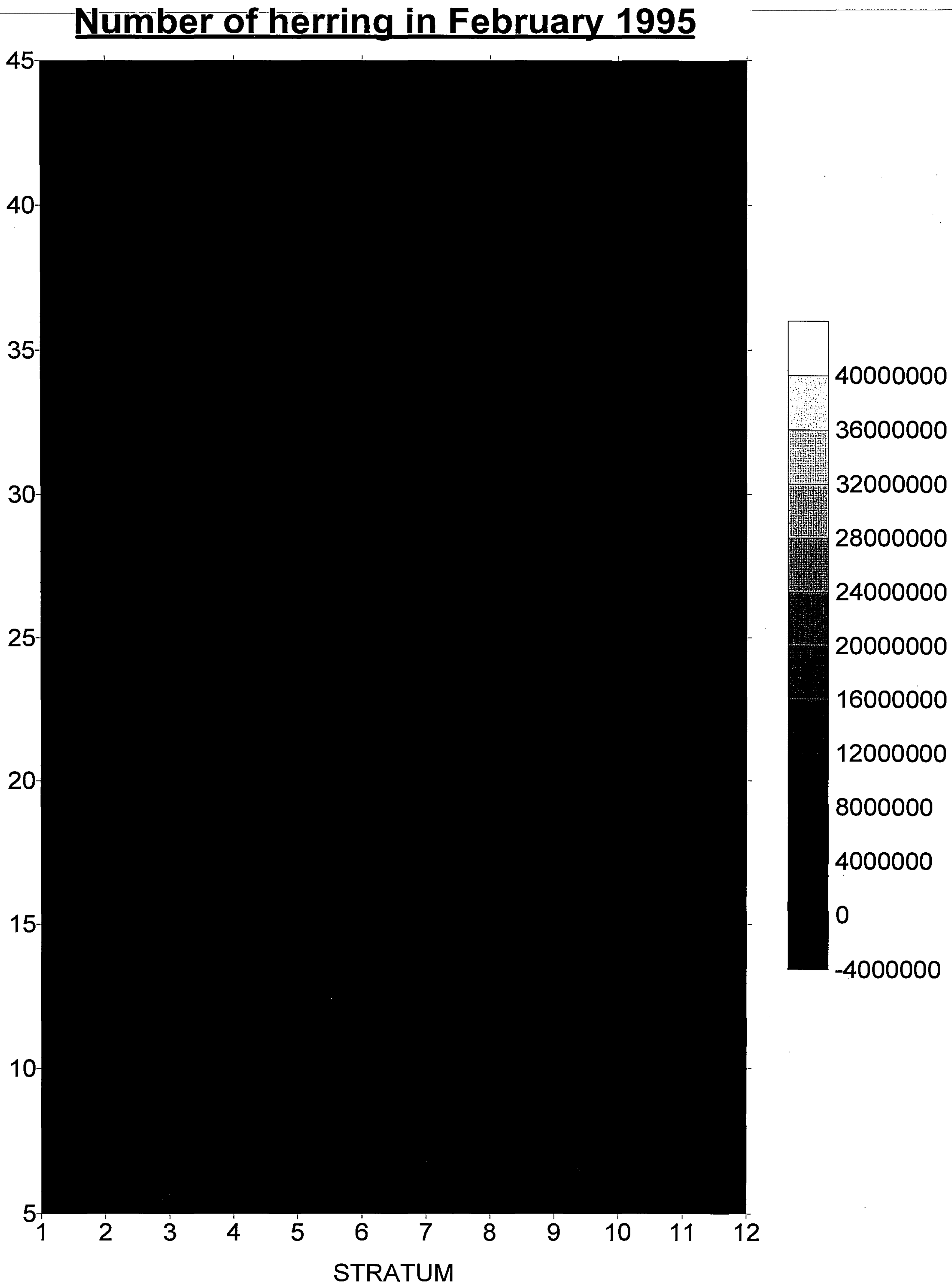


Figure 15. **Number of herring divided by geographical strata and depth strata in the Sound in February 1995. Based on the S-02-95 survey.**

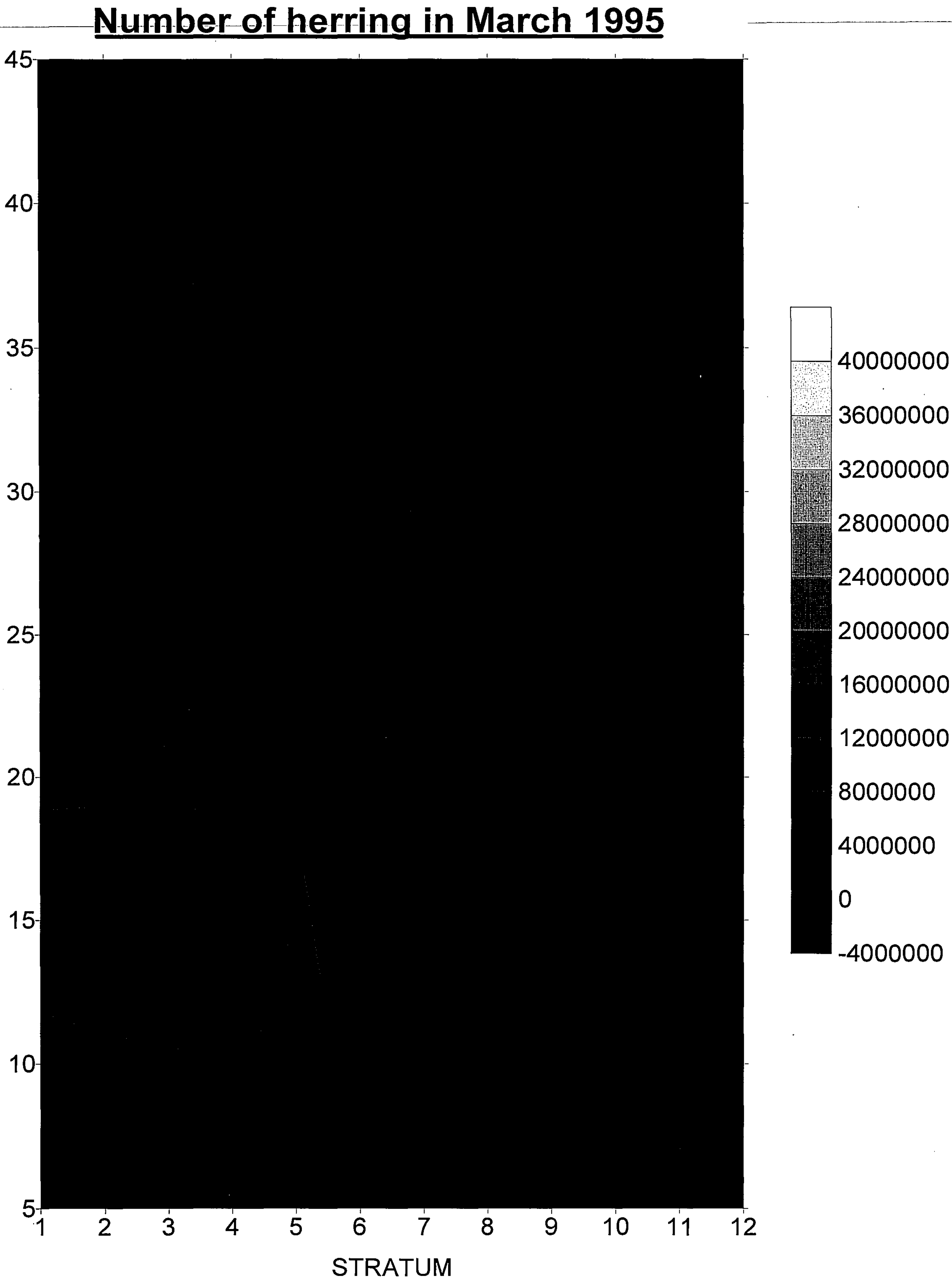


Figure 16. **Number of herring divided by geographical strata and depth strata in the Sound in (February)-March 1995. Based on the S-03-95 survey.**

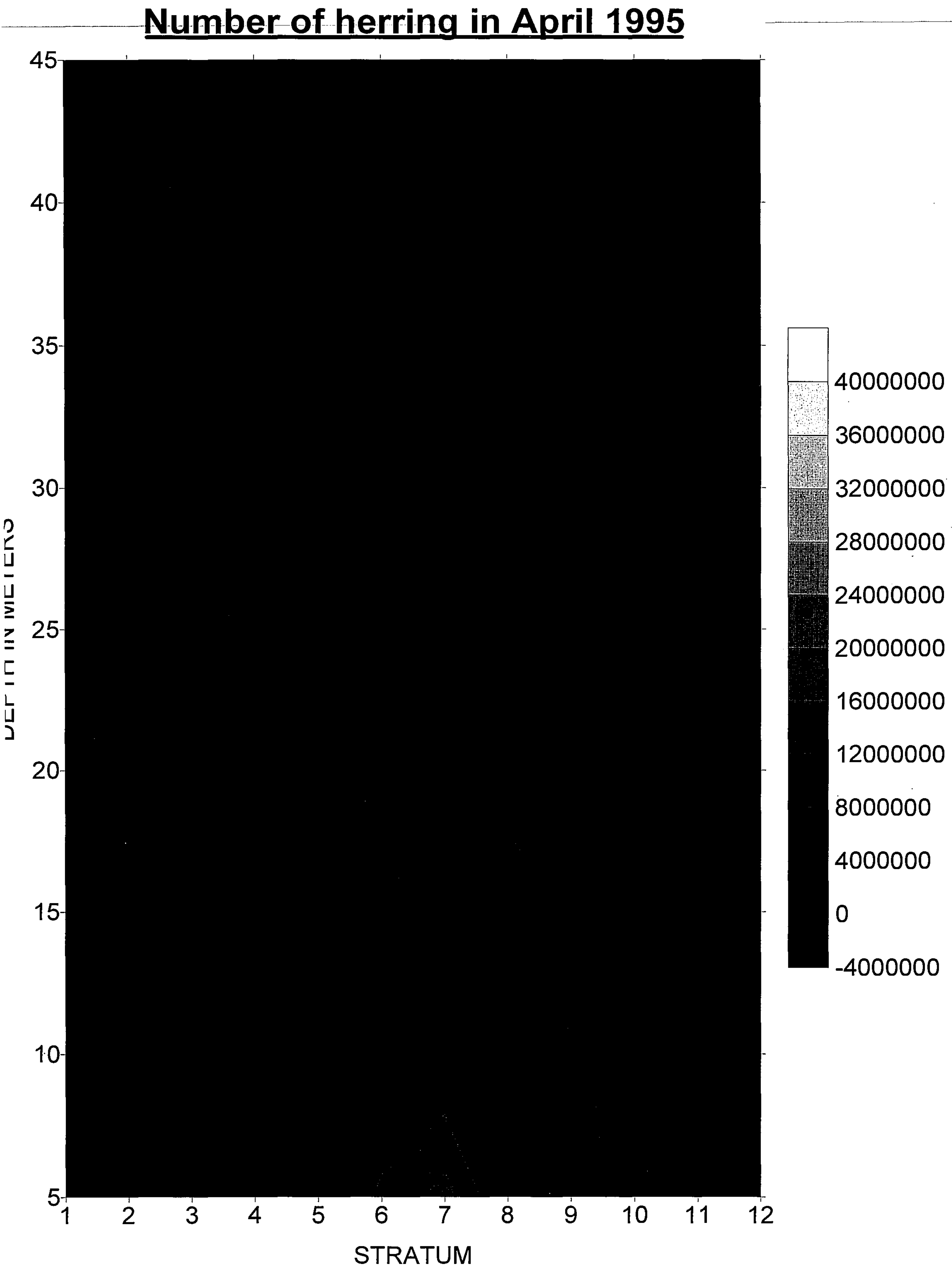


Figure 17. **Number of herring divided by geographical strata and depth strata in the Sound in (March)-April 1995. Based on the S-04-95 survey.**

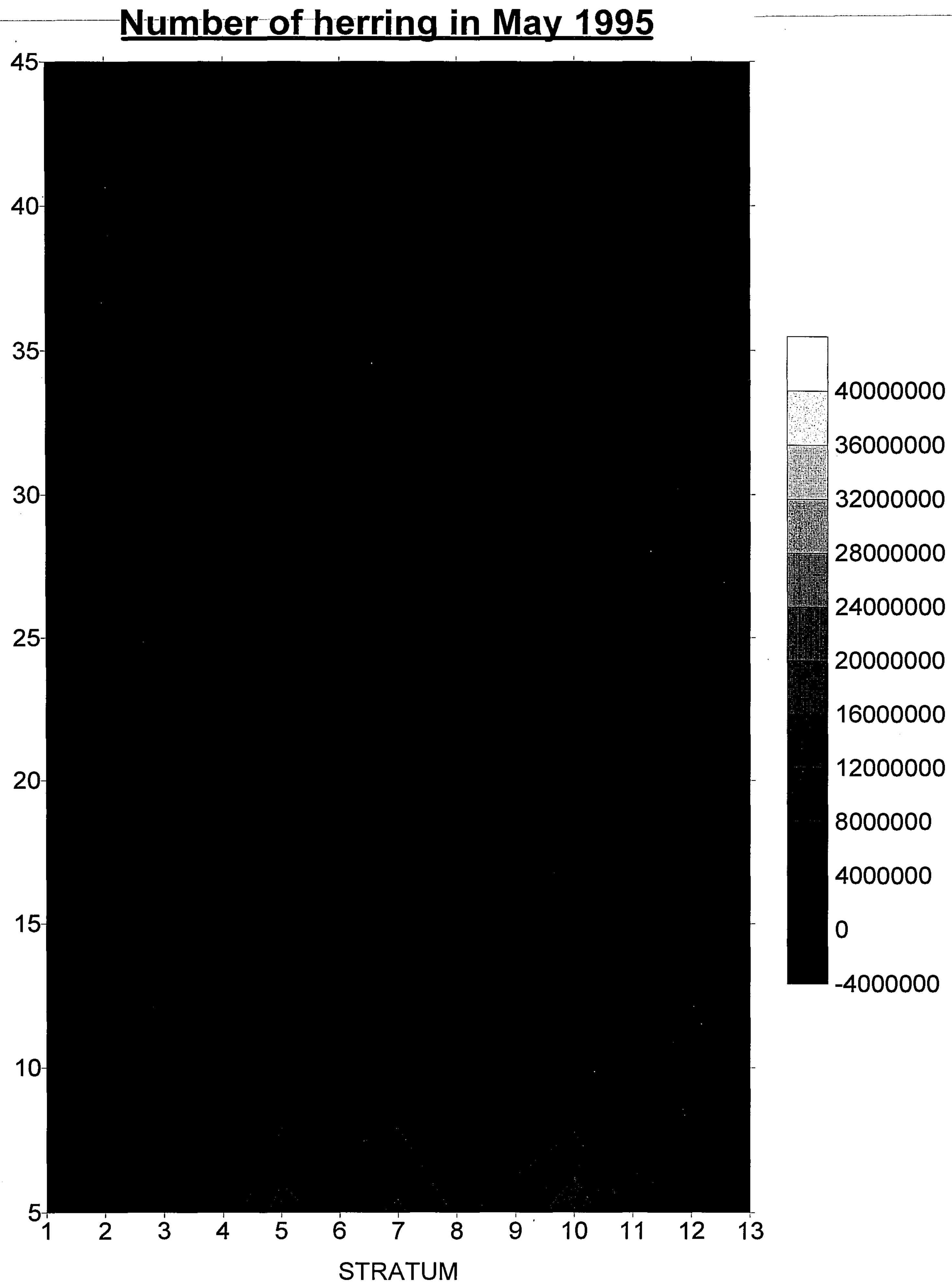
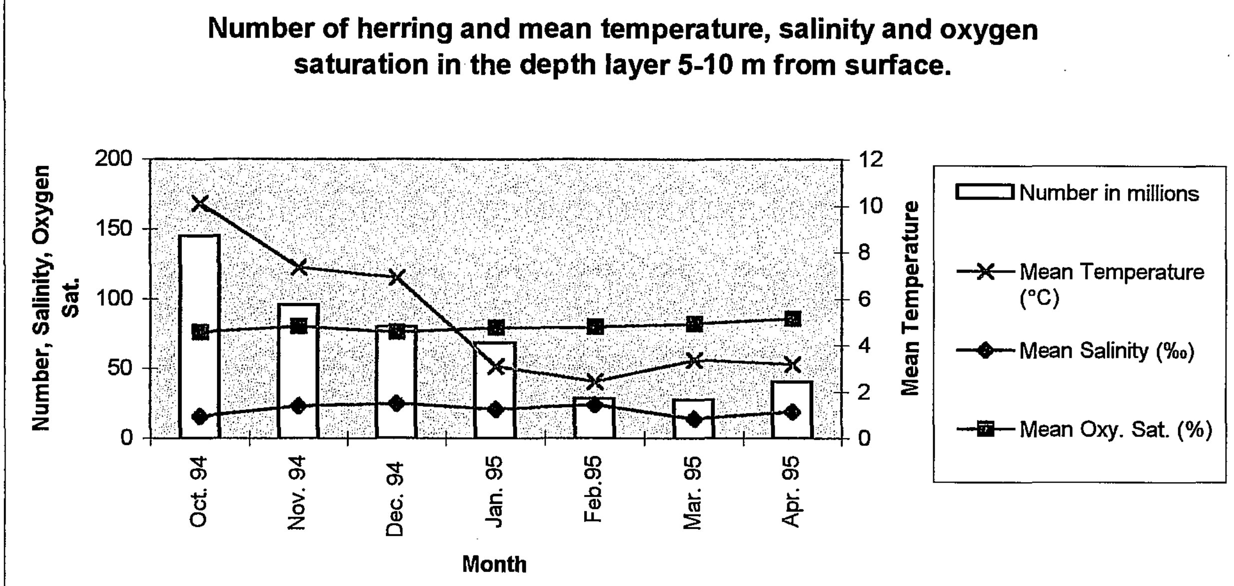
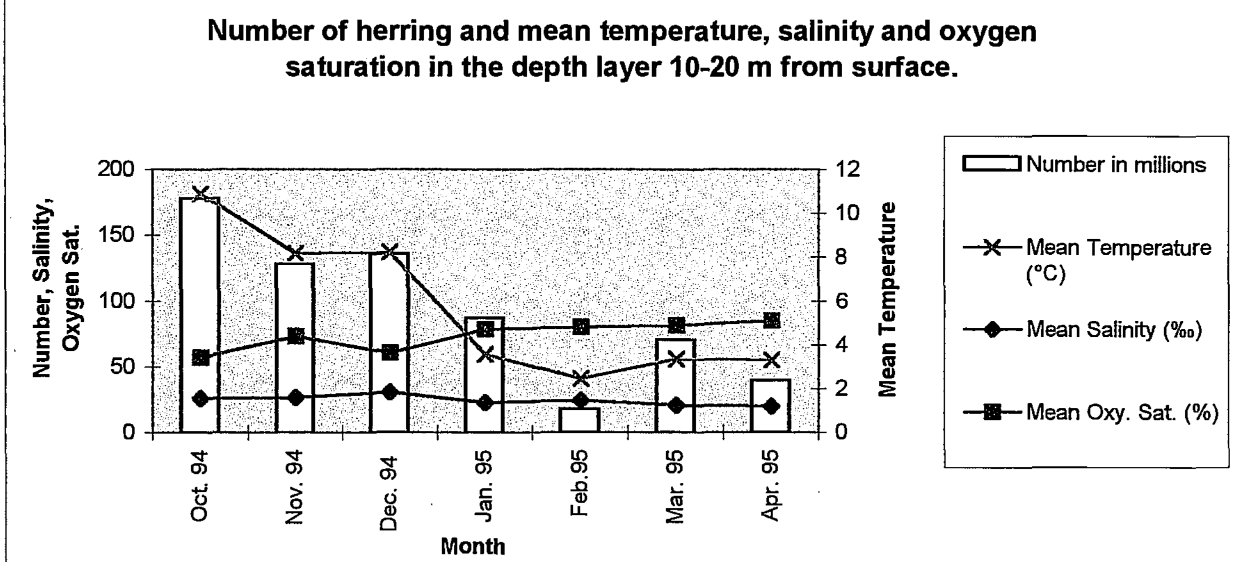


Figure 18. **Number of herring divided by geographical strata and depth strata in the Sound in May 1995. Based on the S-05-95 survey.**





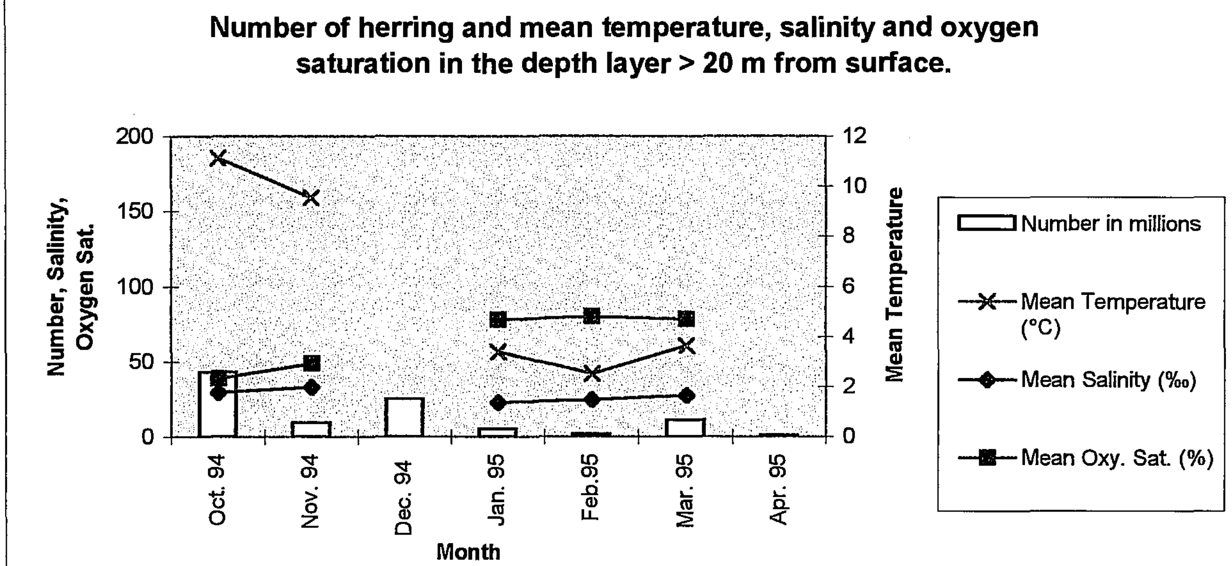
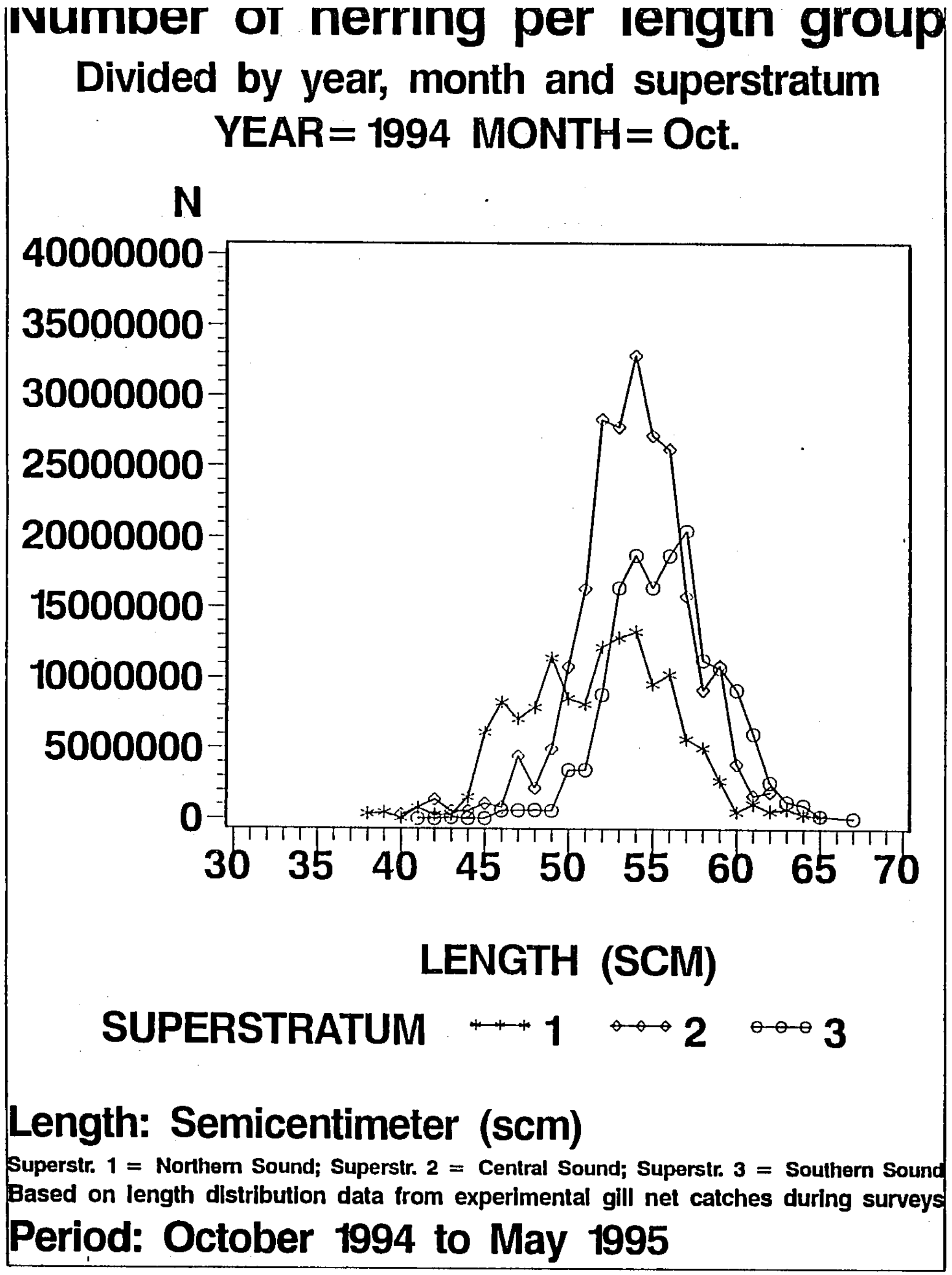


Figure 19. Herring abundance and hydrographical conditions in different depth layers of Superstrata 1 and 2 (combined) divided by month during the latest monitoring period from October 1994 to May 1995.



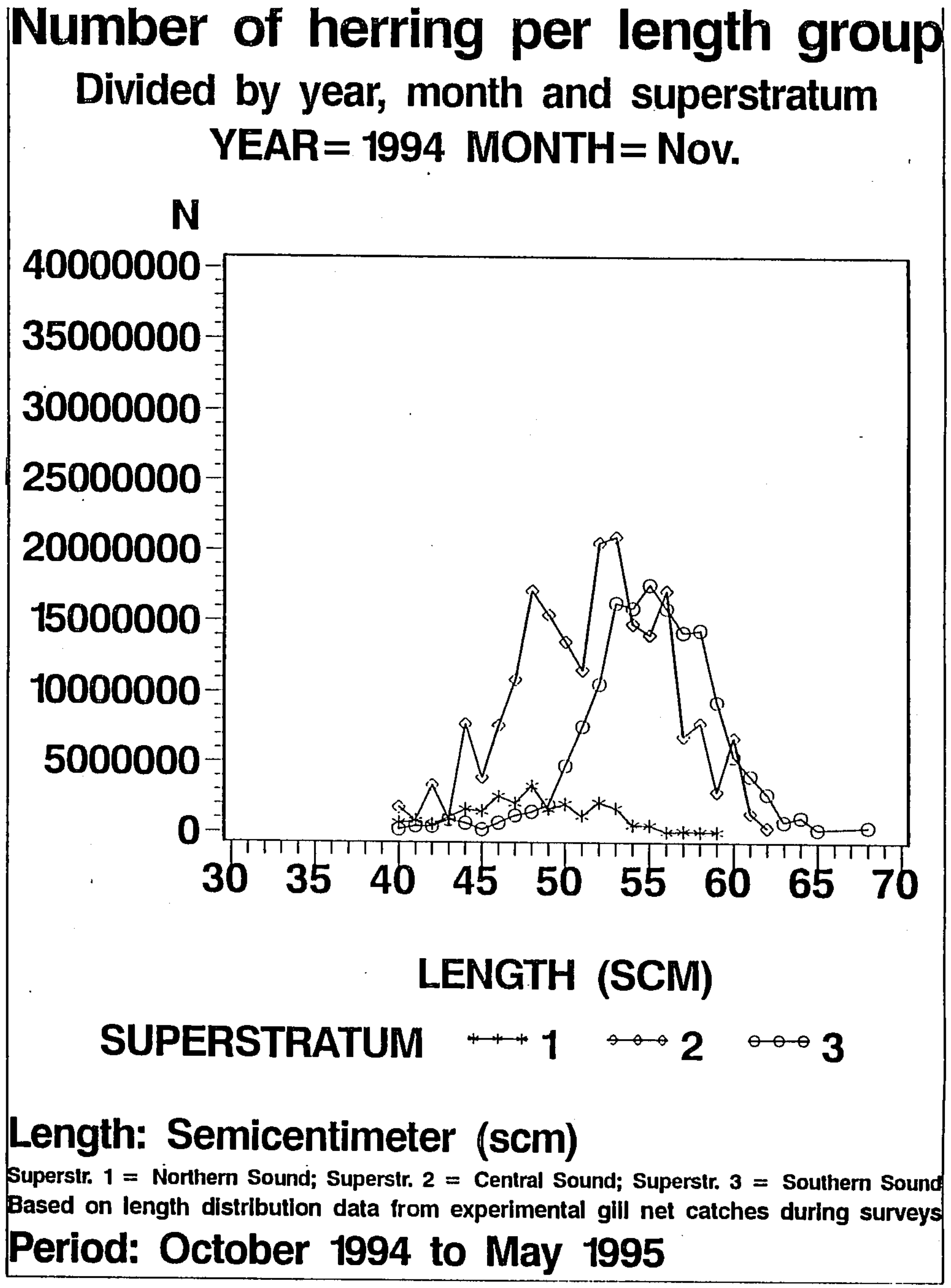
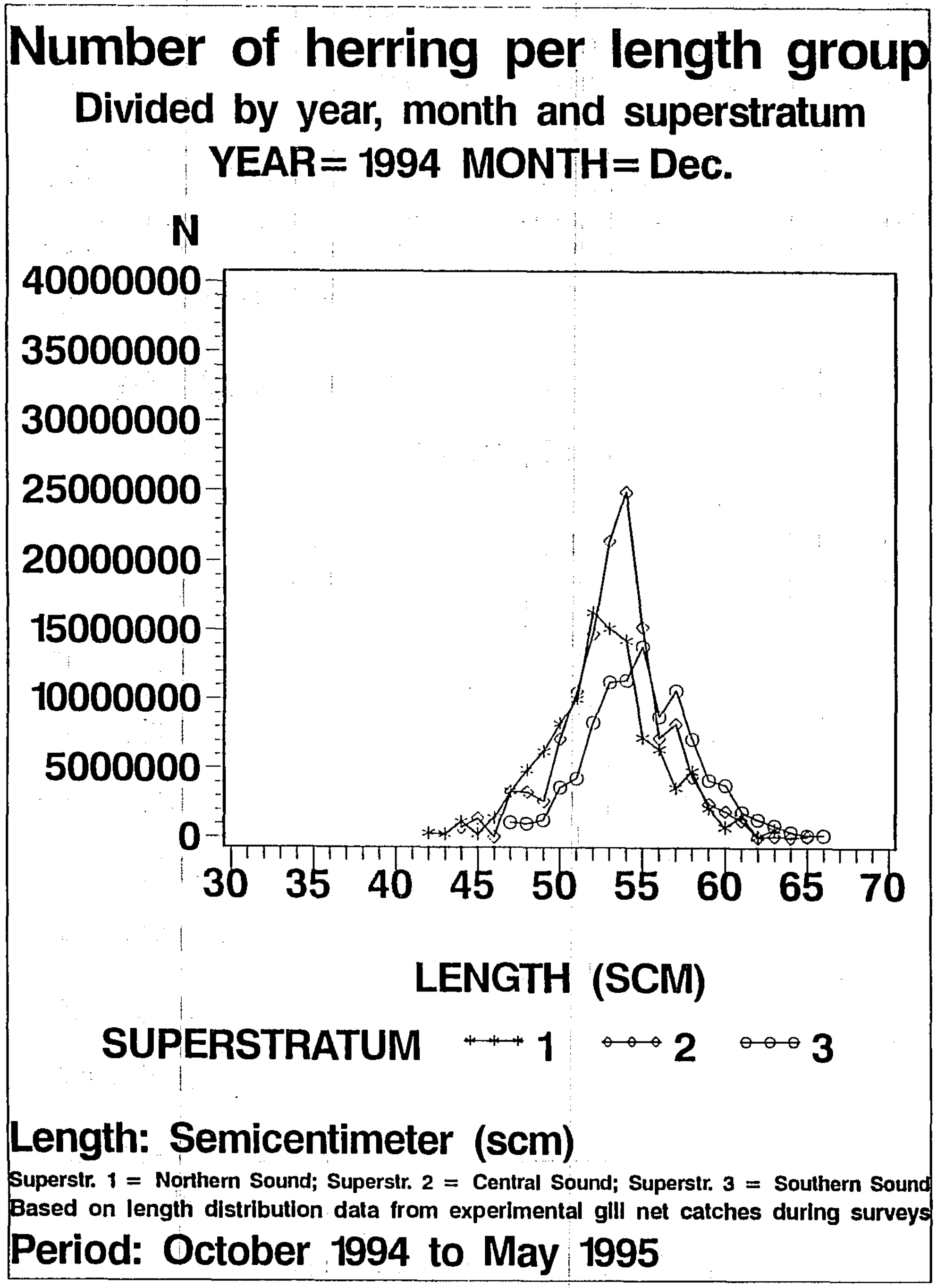


Figure 20. **Herring length frequencies (number of herring per length group) divided by year, month and superstratum from monthly surveys during the period October 1994 and May 1995. Data is based partly on hydro-acoustic echo integration and partly on length distributions from gill net catches from each survey.**



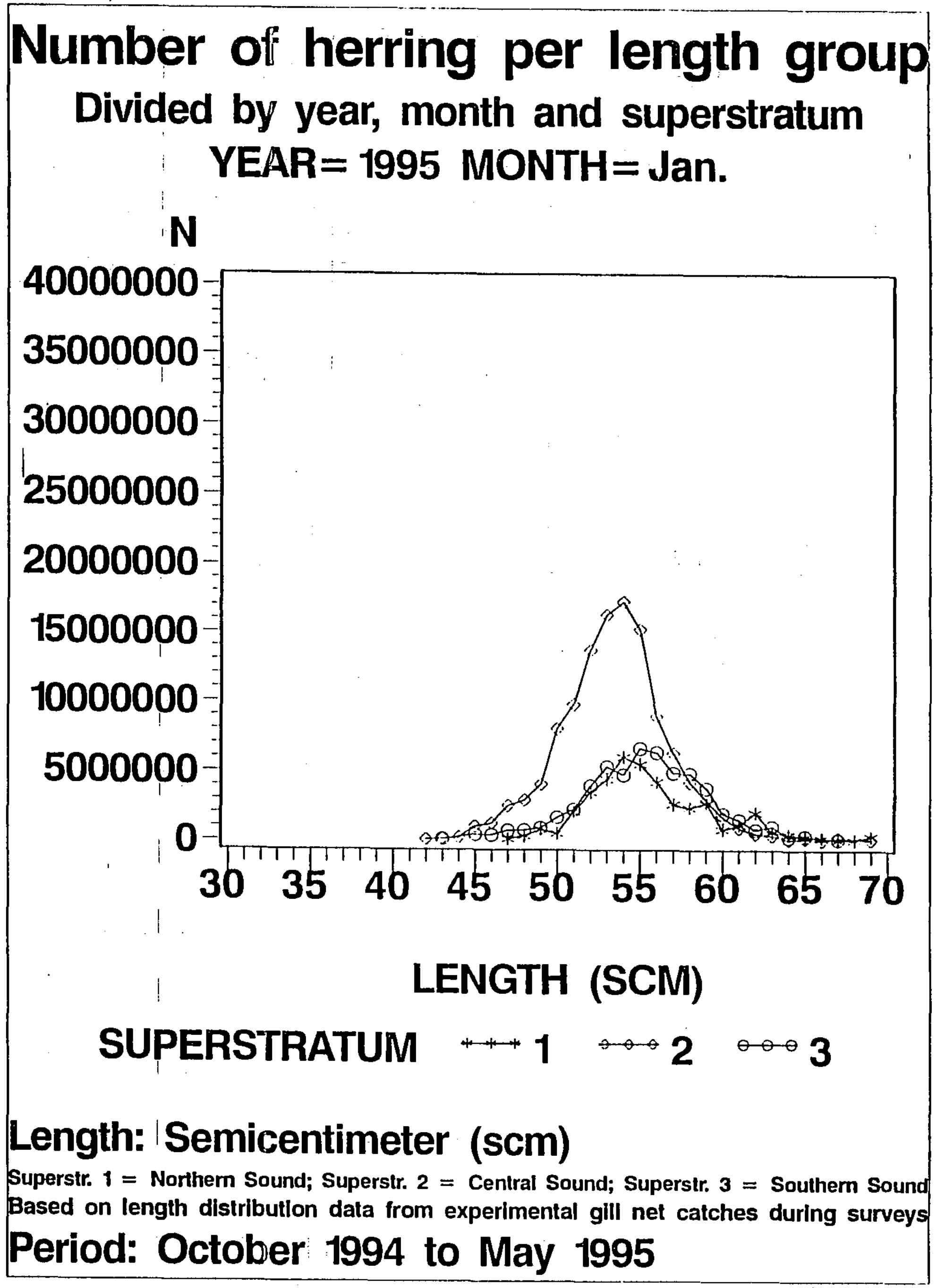
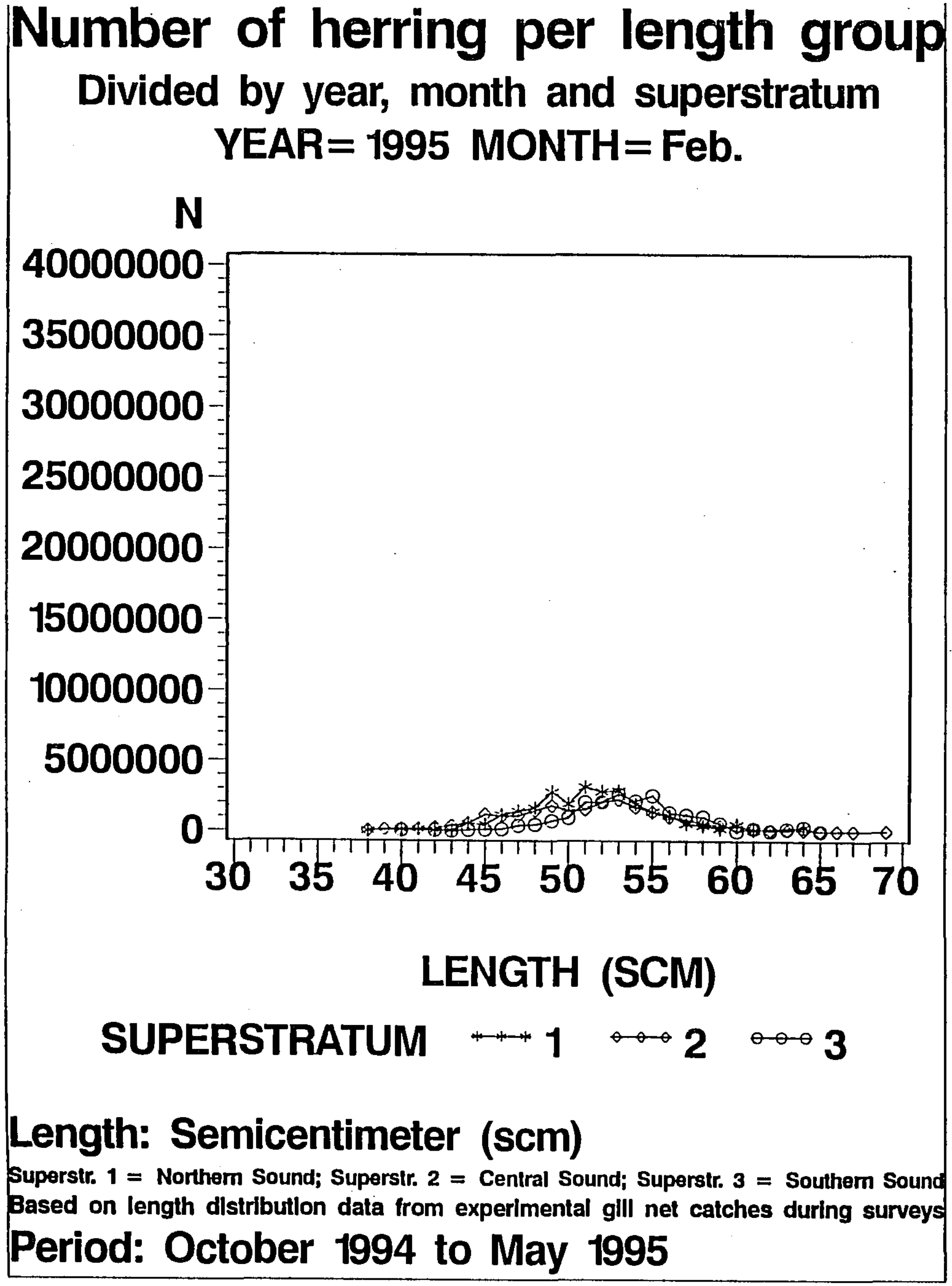


Figure 20. (Continued).



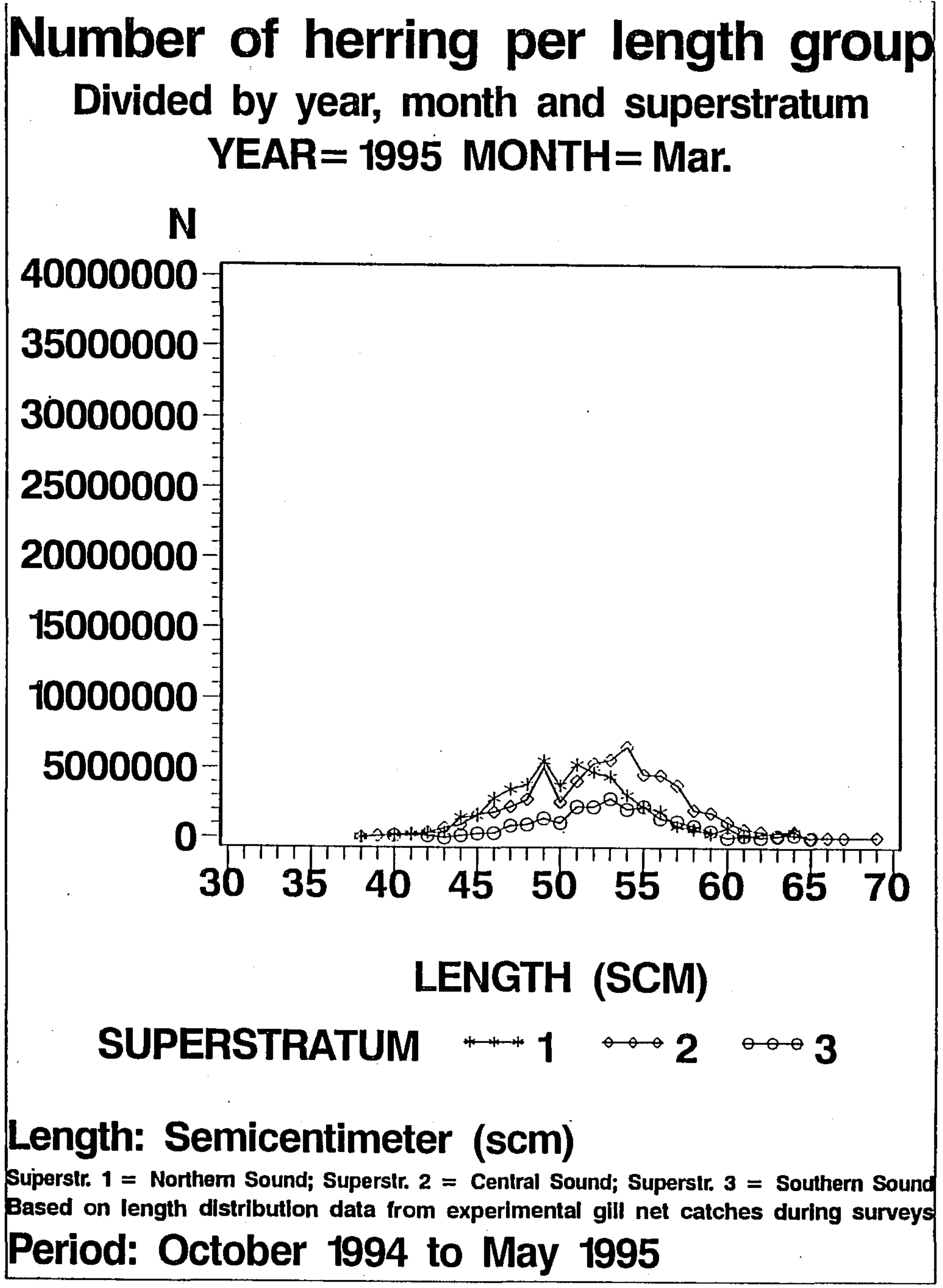
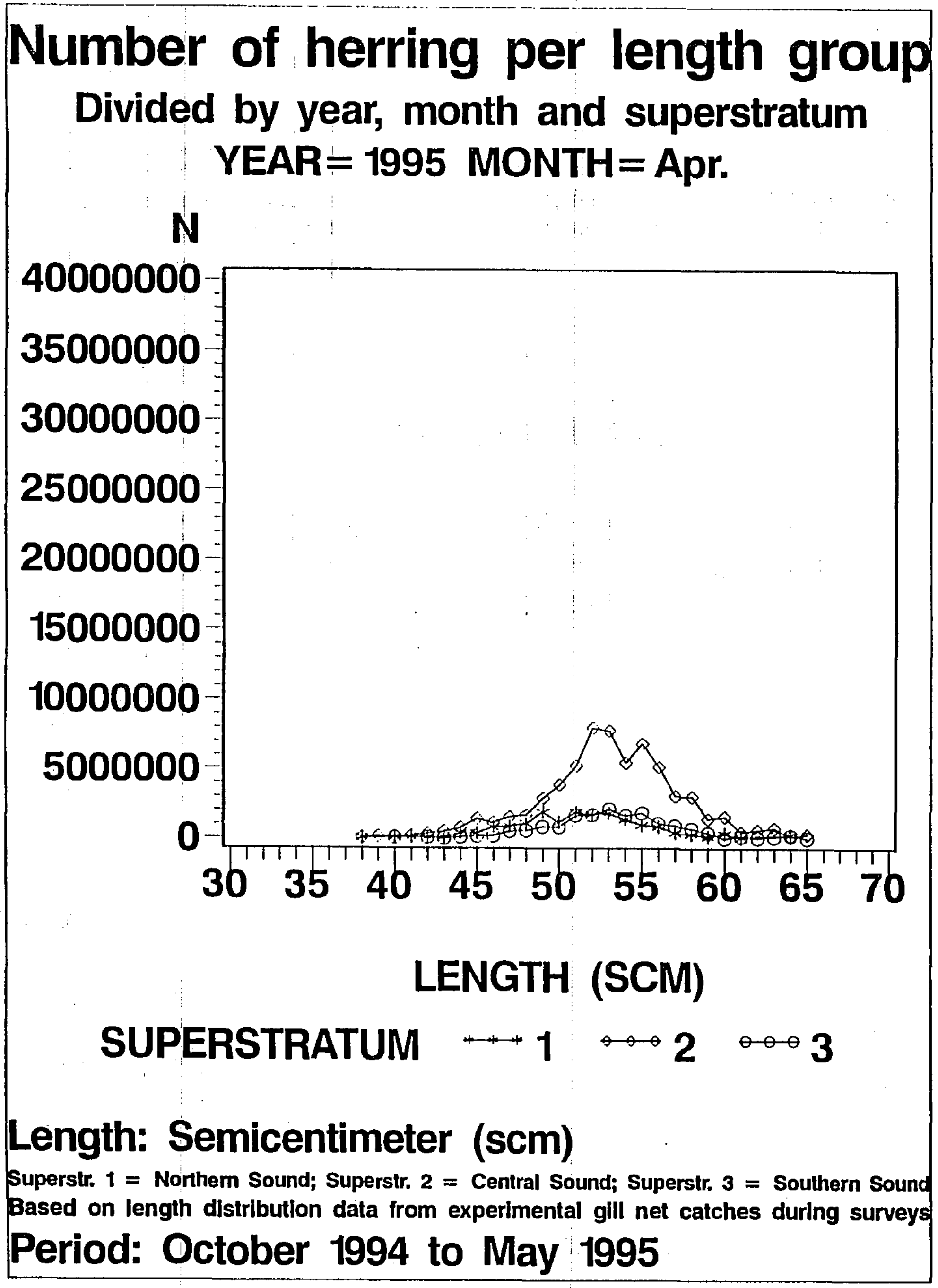


Figure 20. **(Continued).**



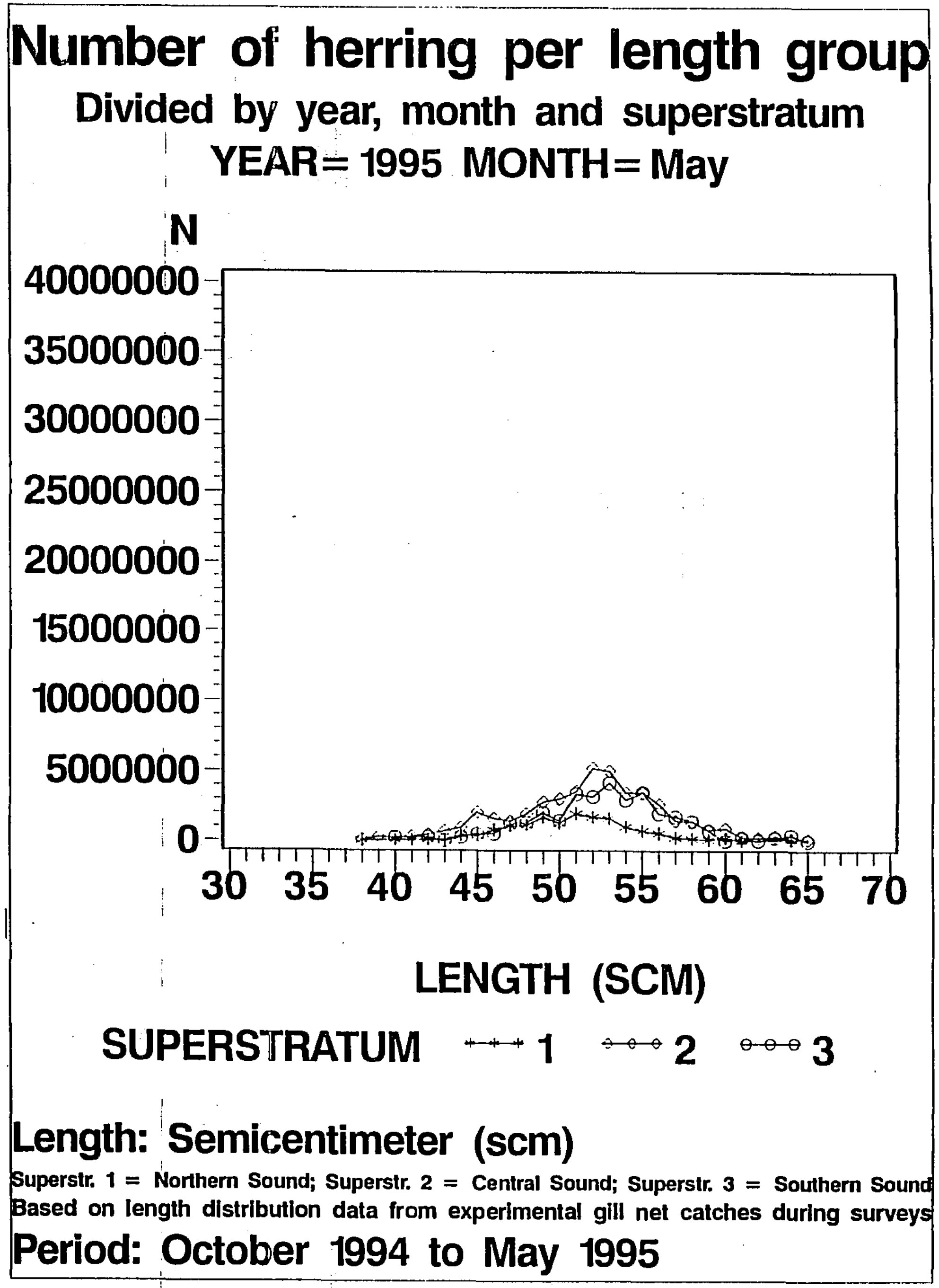
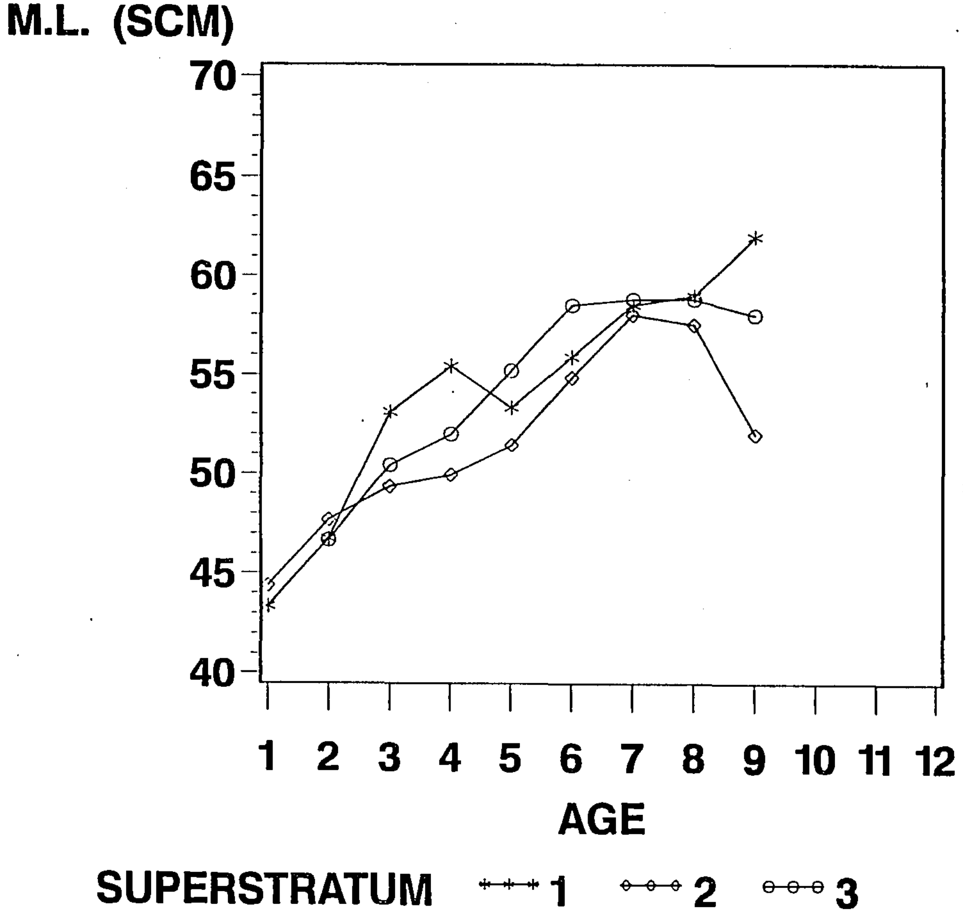


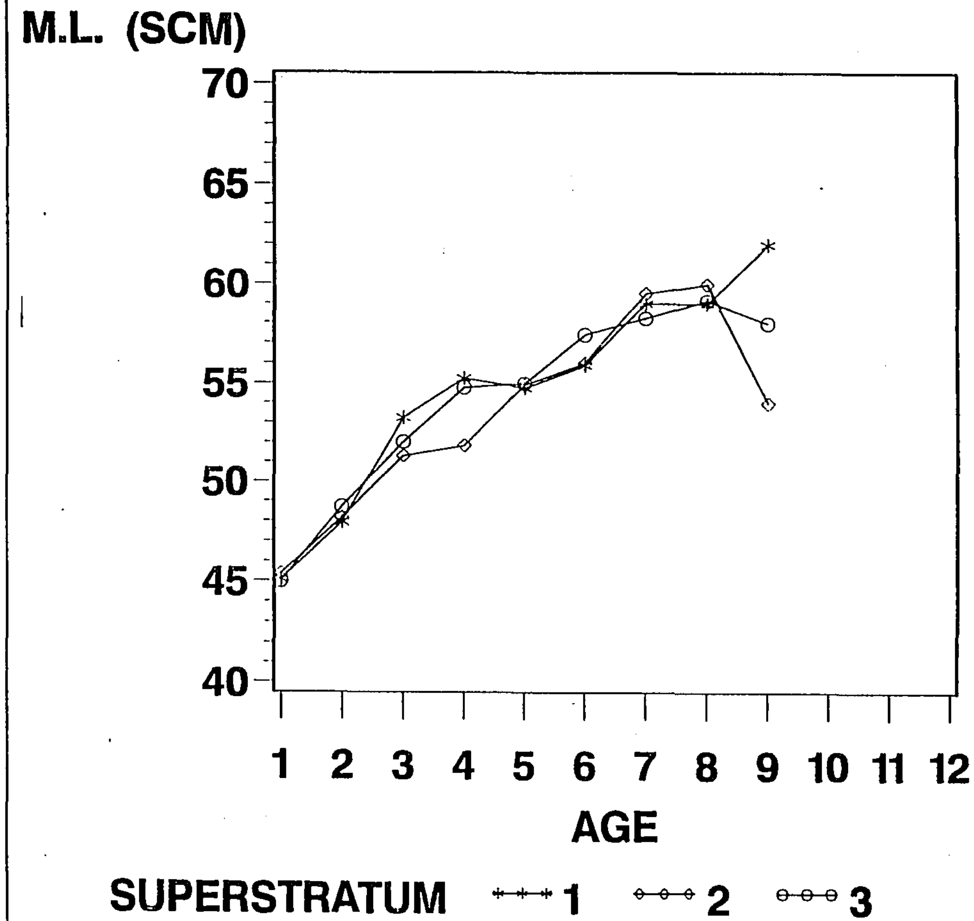
Figure 20. (Continued).

Mean length of herring per age group
Divided by year, month and superstratum
YEAR=1994 MONTH=Oct.



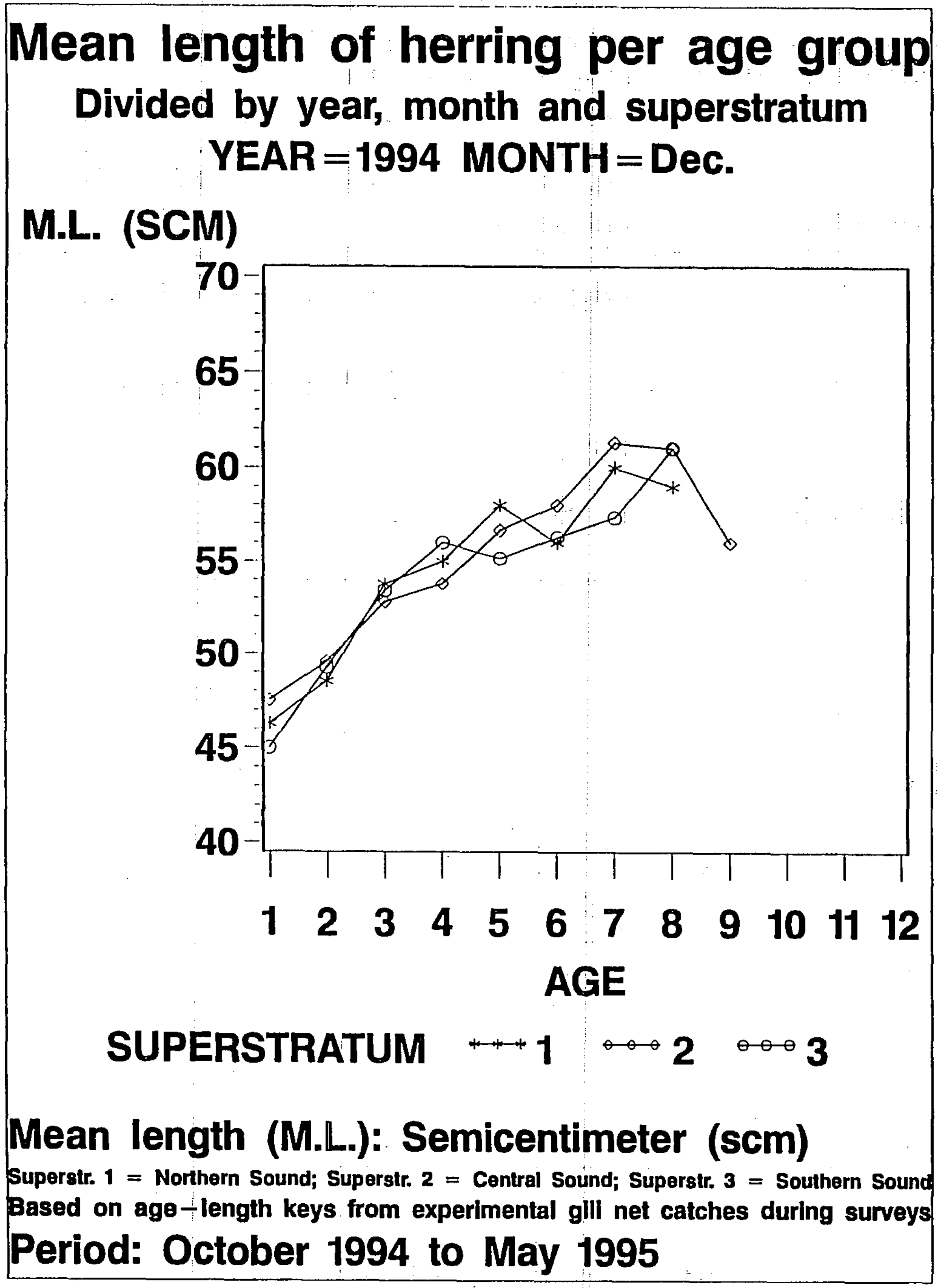
Mean length (M.L.): Semicentimeter (scm)
Superstr. 1 = Northern Sound; Superstr. 2 = Central Sound; Superstr. 3 = Southern Sound
Based on age-length keys from experimental gill net catches during surveys
Period: October 1994 to May 1995

Mean length of herring per age group
Divided by year, month and superstratum
YEAR=1994 MONTH=Nov.



Mean length (M.L.): Semicentimeter (scm)
Superstr. 1 = Northern Sound; Superstr. 2 = Central Sound; Superstr. 3 = Southern Sound
Based on age-length keys from experimental gill net catches during surveys
Period: October 1994 to May 1995

Figure 21. Mean length in semi-centimeter (scm) per age group for herring in the Sound divided by year, month (survey) and superstratum from monthly surveys during the period October 1994 and May 1995. Data is based on length distributions from gill net catches from each survey multiplied into age-length keys established from individual samplings of herring every second survey in each superstratum.



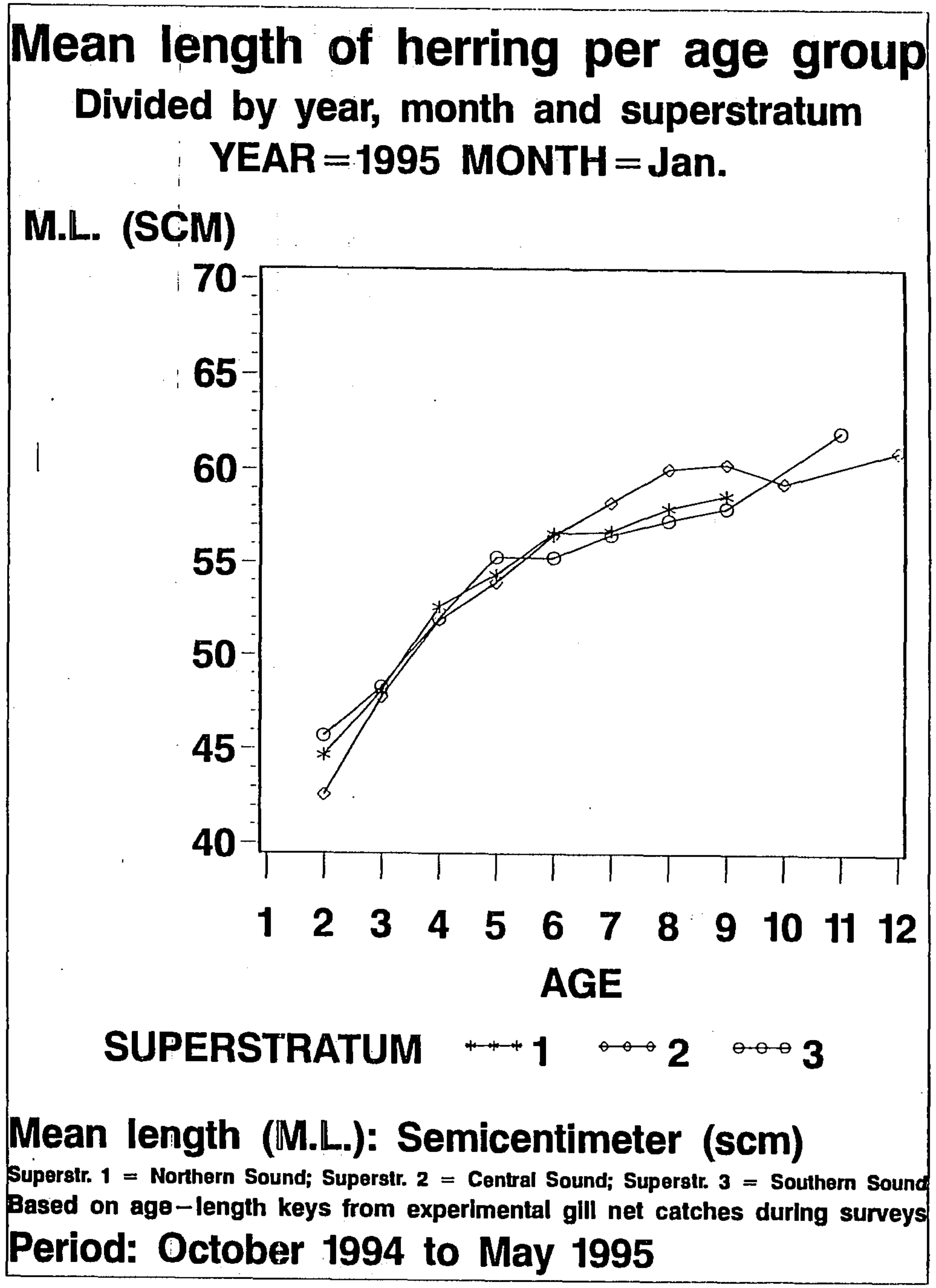


Figure 21. (Continued).

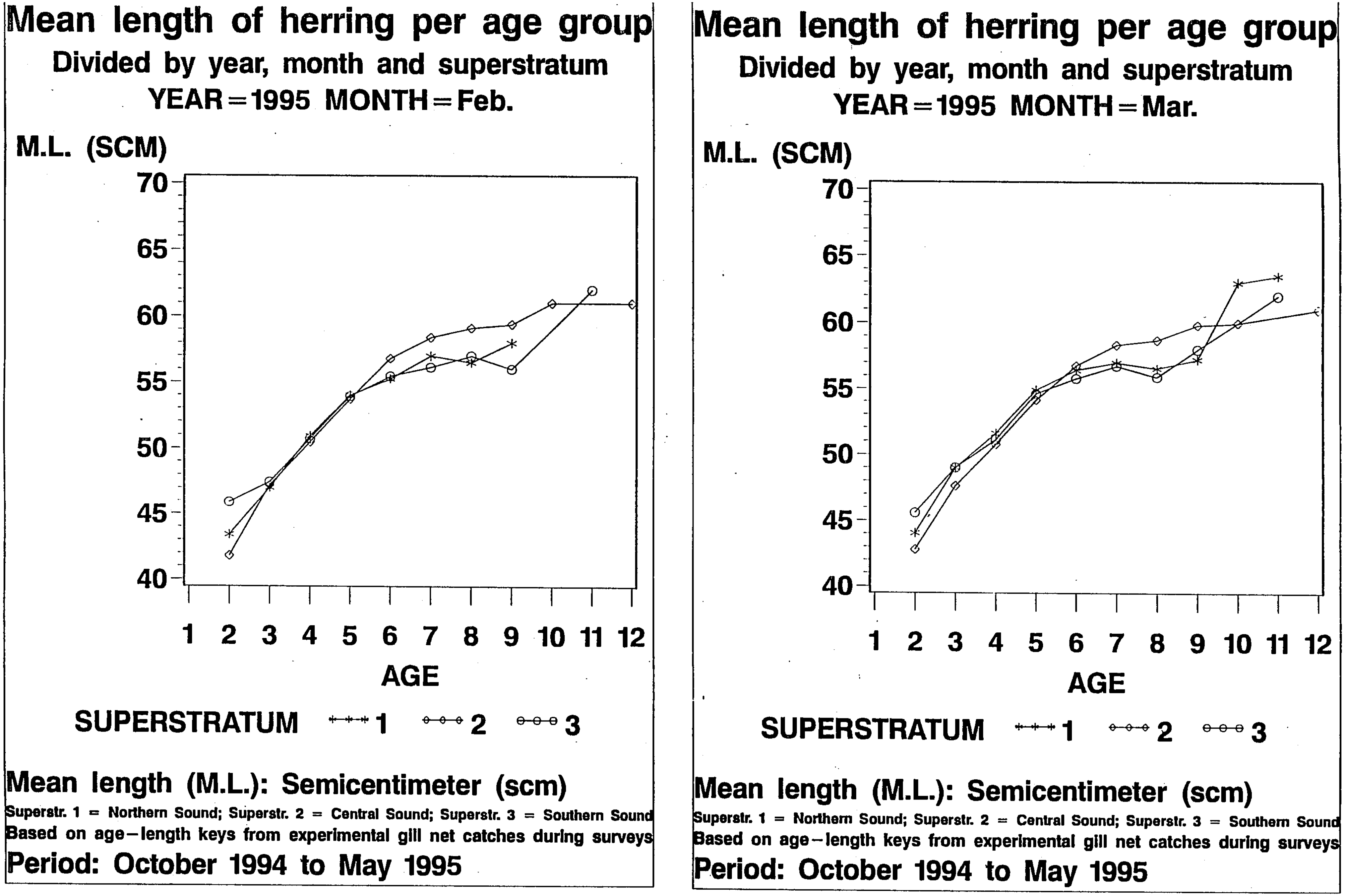
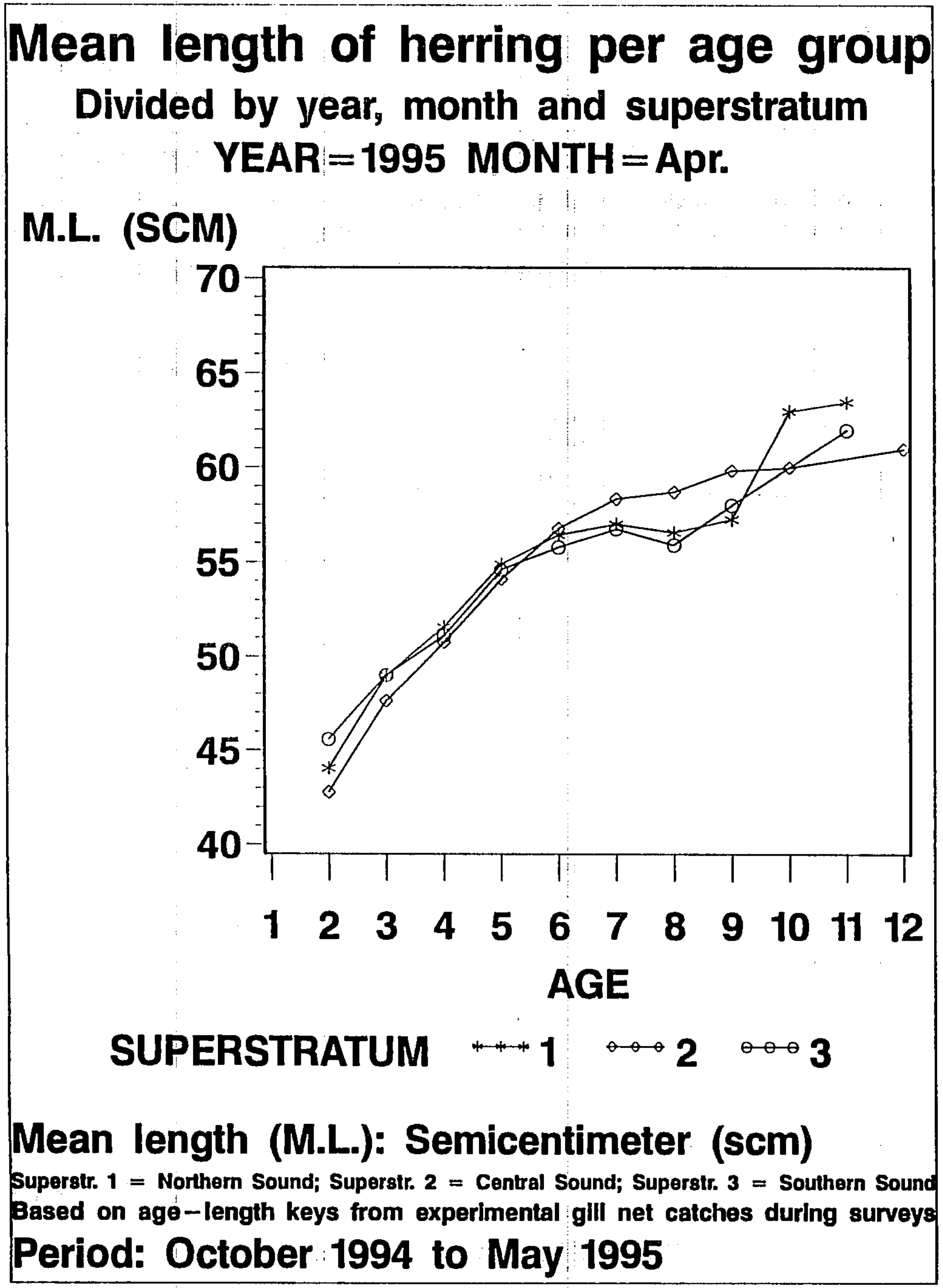


Figure 21. **(Continued).**



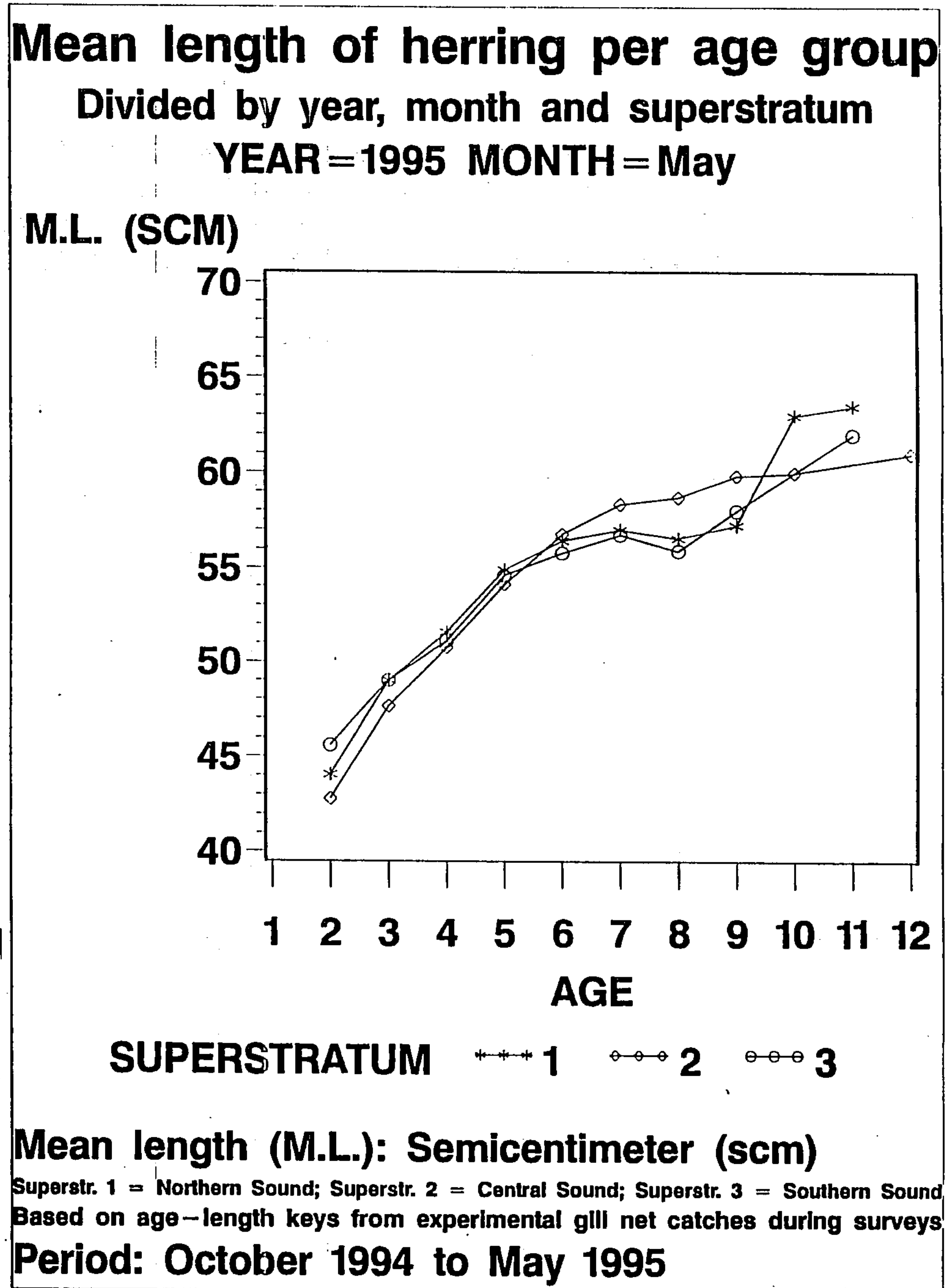


Figure 21. (Continued).

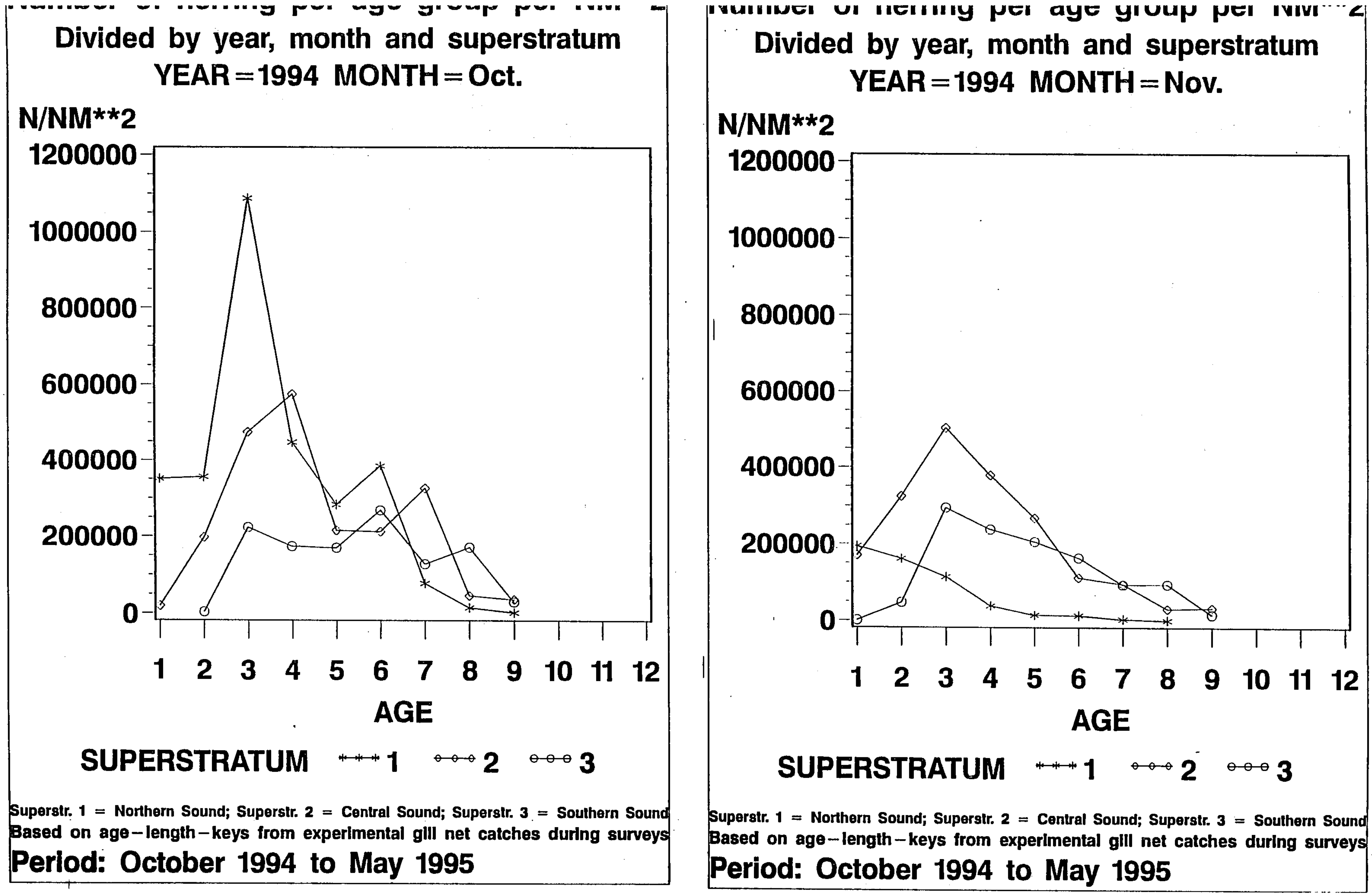
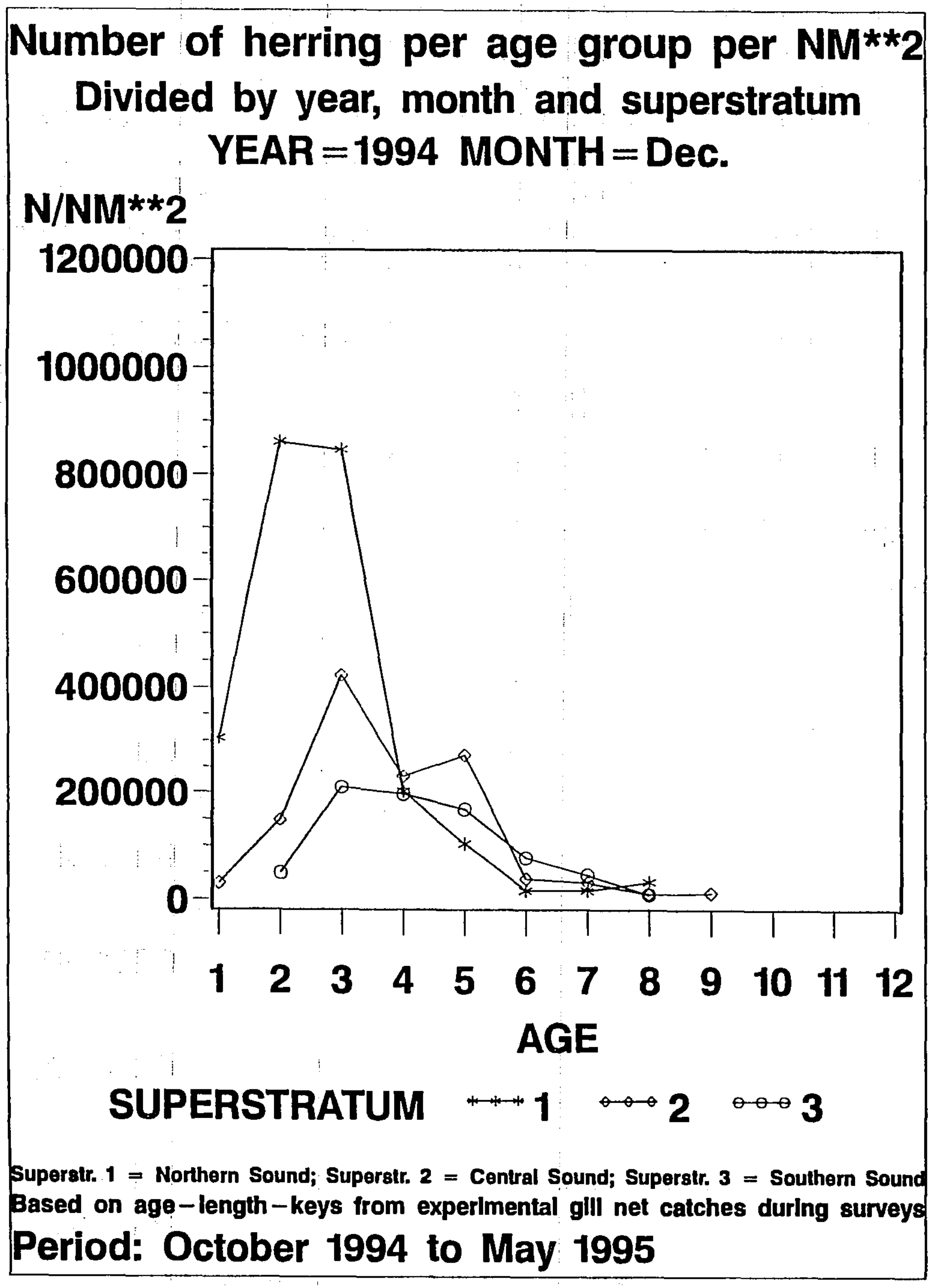


Figure 22. **Herring density (number of herring per age group per NM**2) divided by year, month and superstratum from monthly surveys during the period October 1994 and May 1995. Data is based partly on acoustic echo integration and partly on length distributions from gill net catches from each survey which are multiplied into age-length keys established from individual samplings of herring every second survey in each superstratum.**



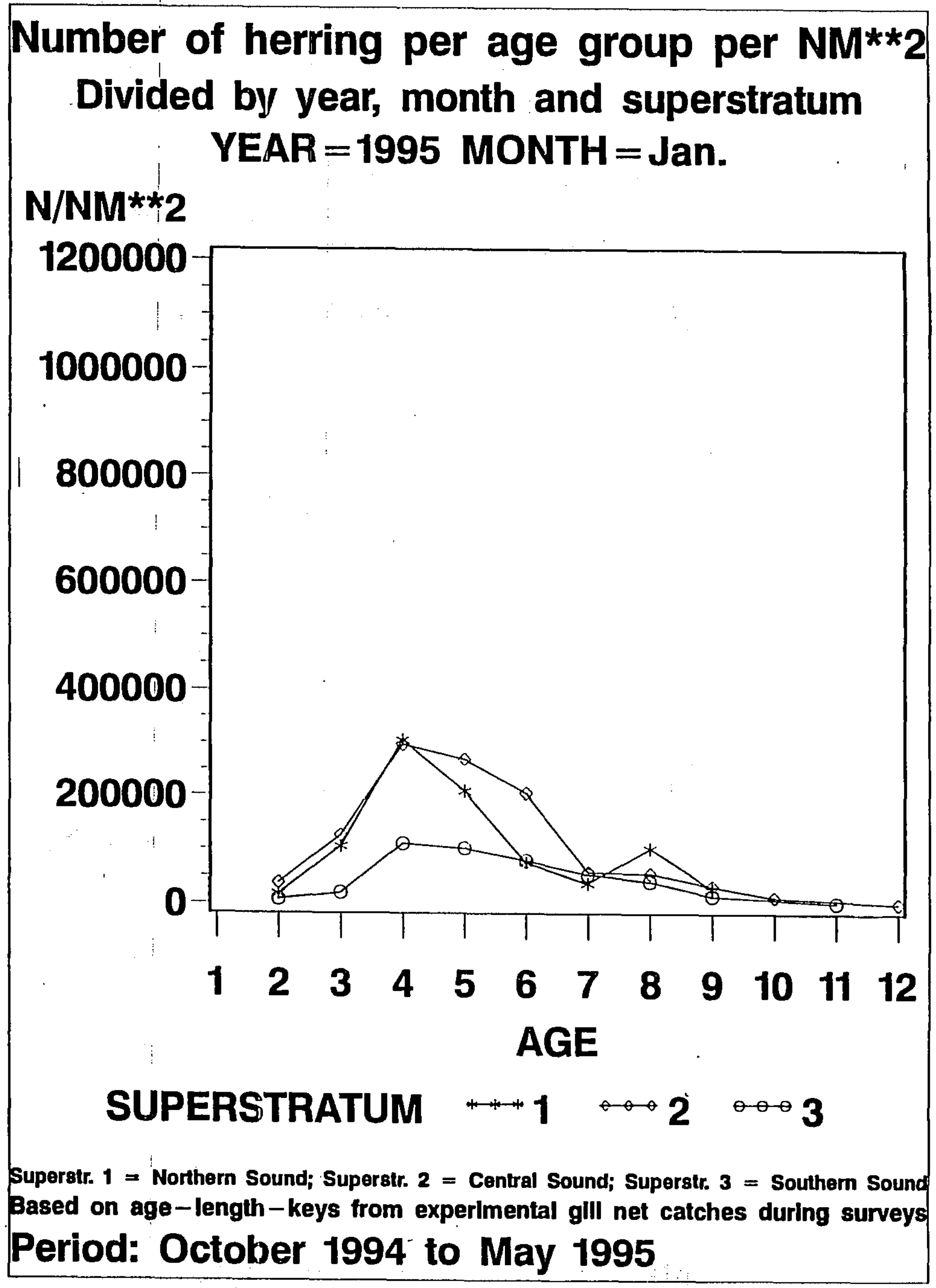
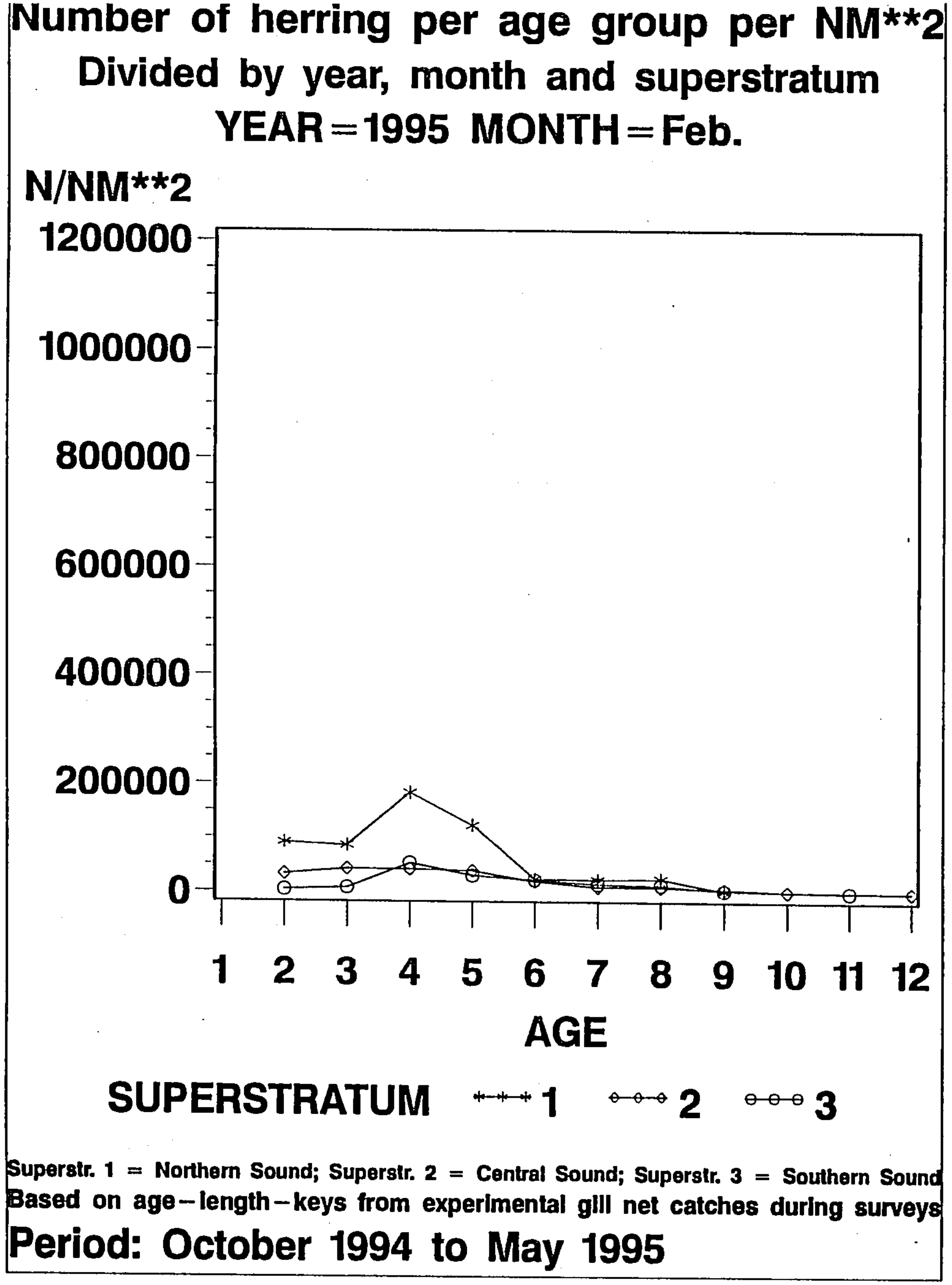


Figure 22. (Continued).



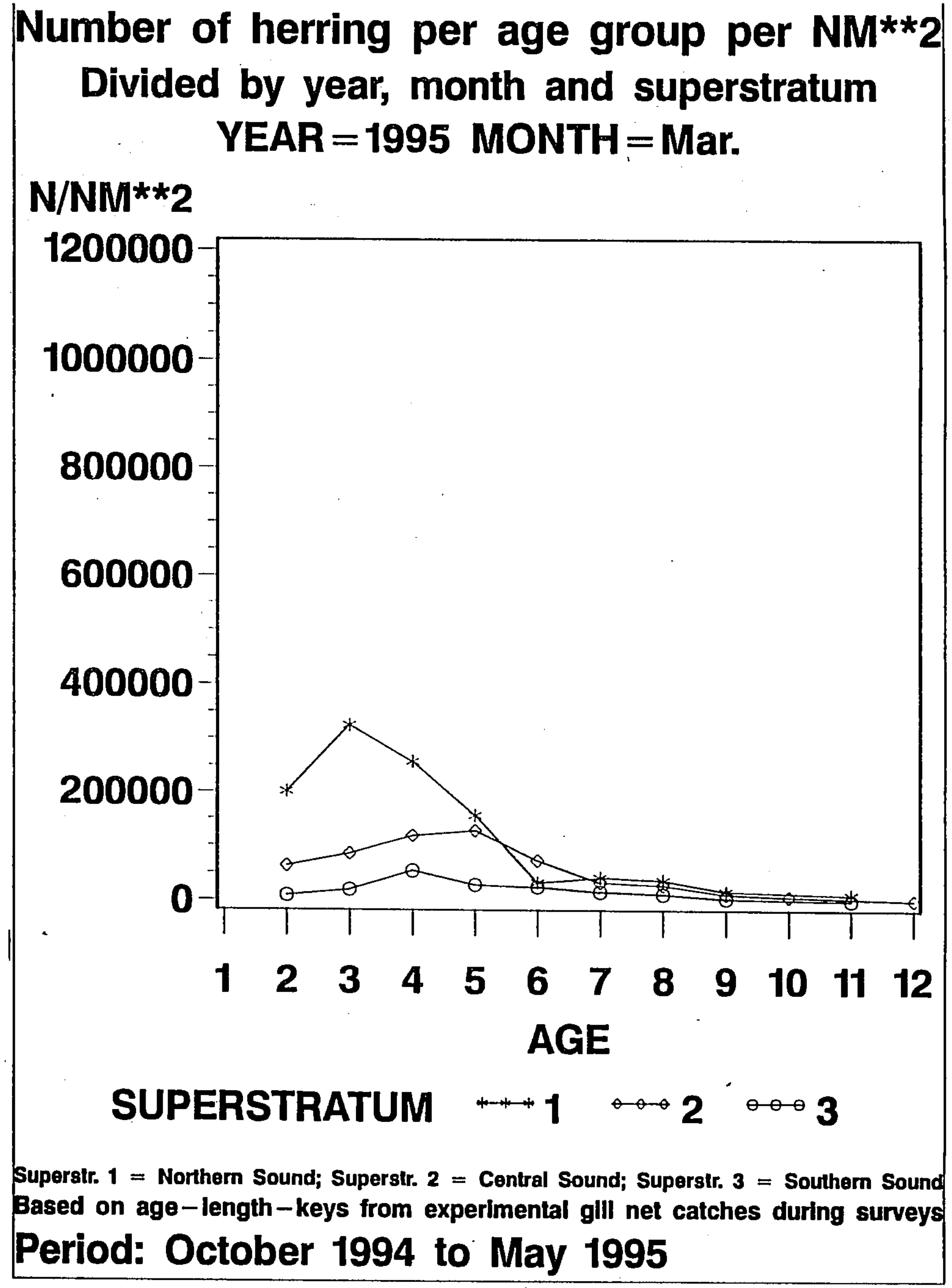
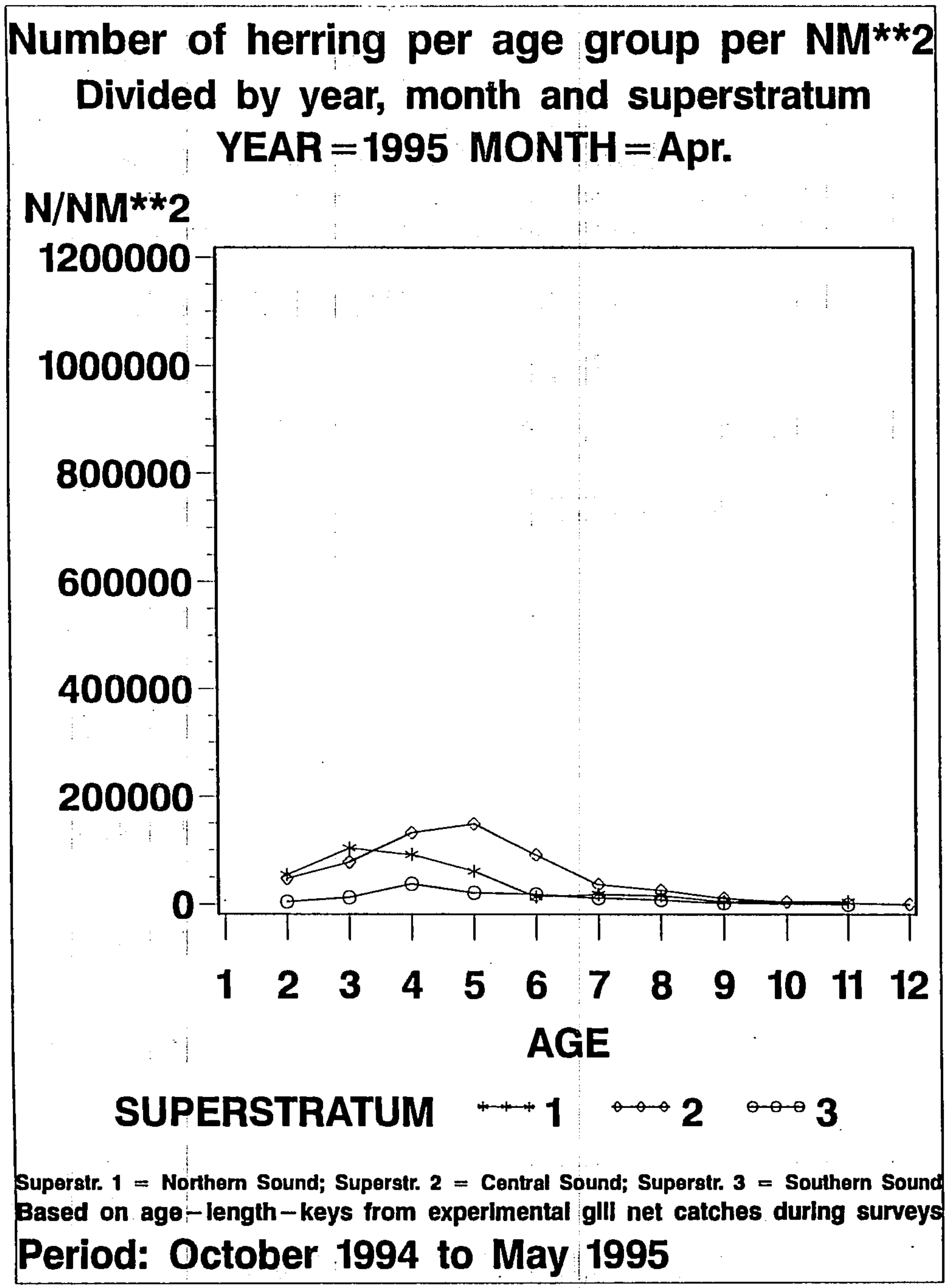


Figure 22. **(Continued).**



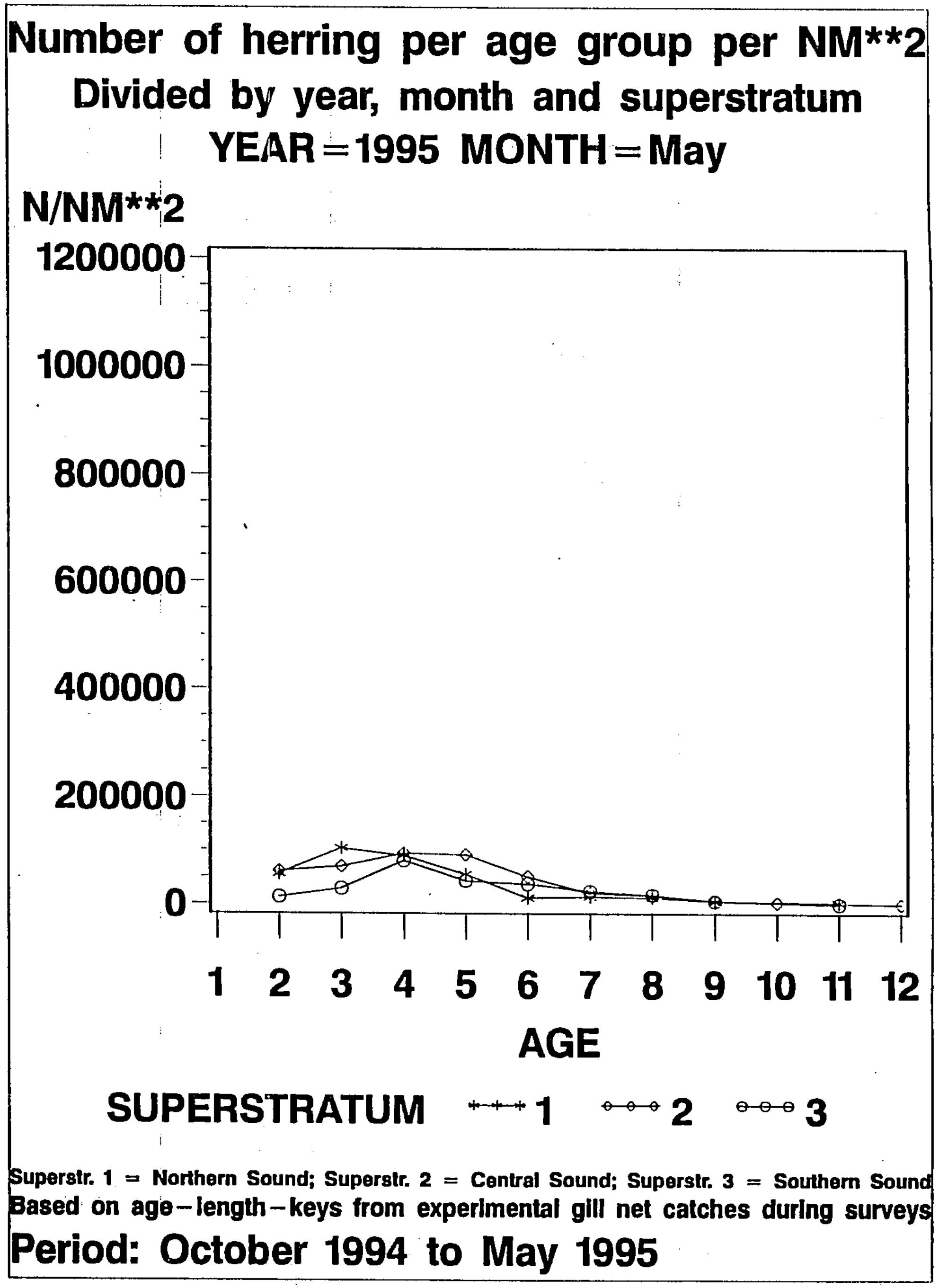


Figure 22. **(Continued).**

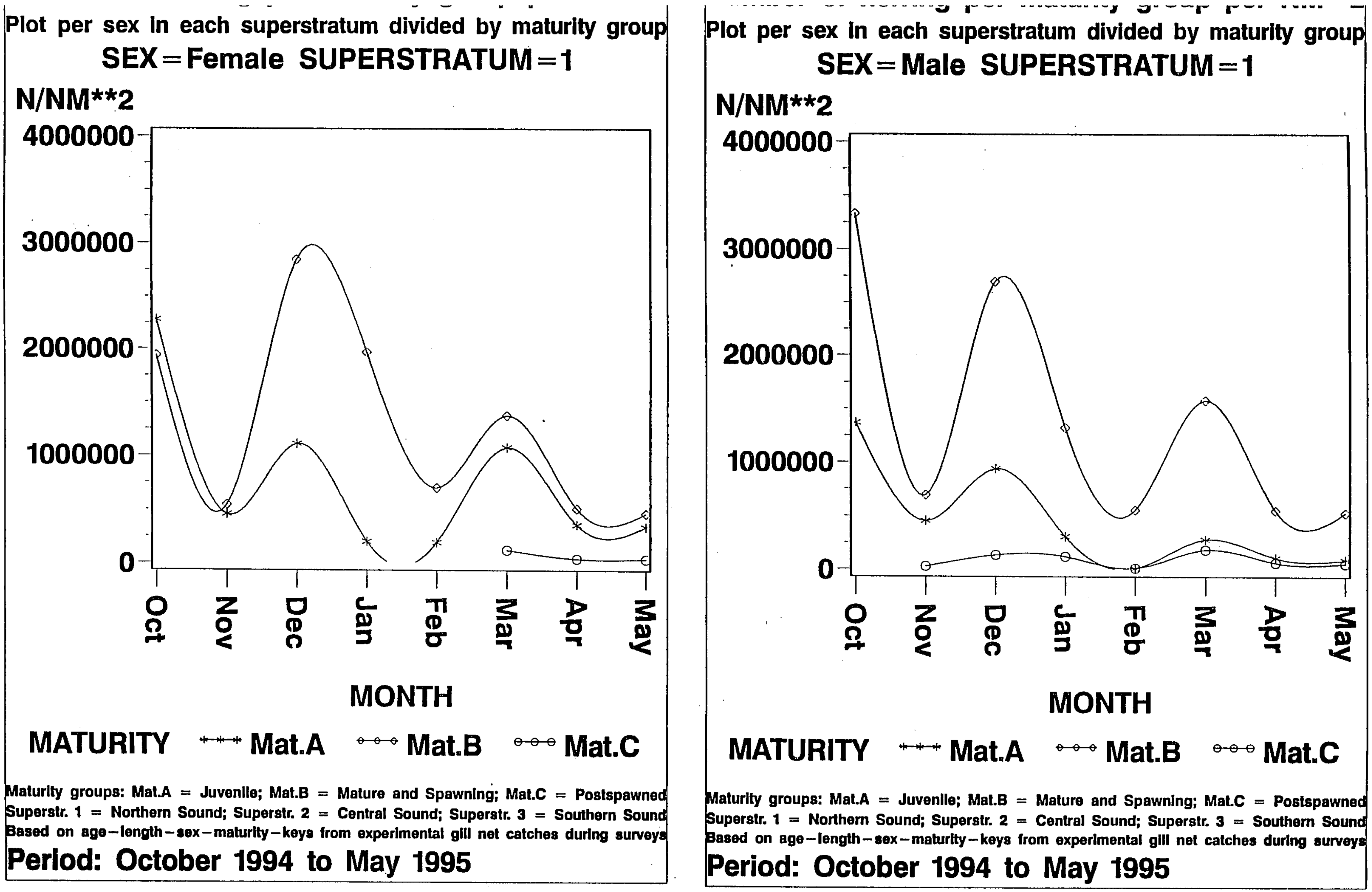
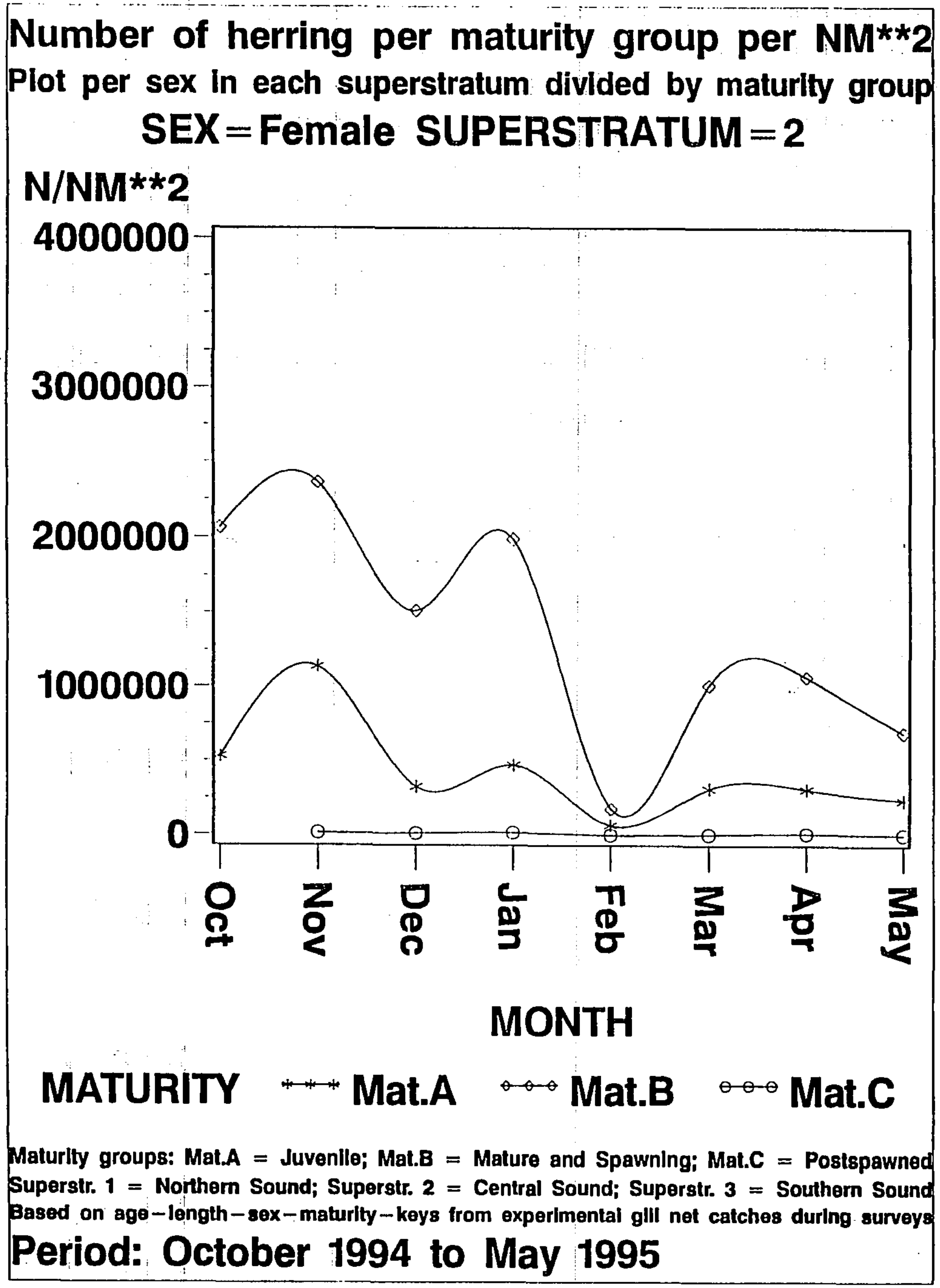


Figure 23. Herring density (number of herring per sex and sexual maturity group per NM**2) divided by month and superstratum from monthly surveys during the period October 1994 and May 1995. Data is based partly on acoustic echo integration and partly on length distributions from gill net catches from each survey which multiplied into maturity-sex-age-length keys established from individual samplings of herring every second survey in each superstratum.



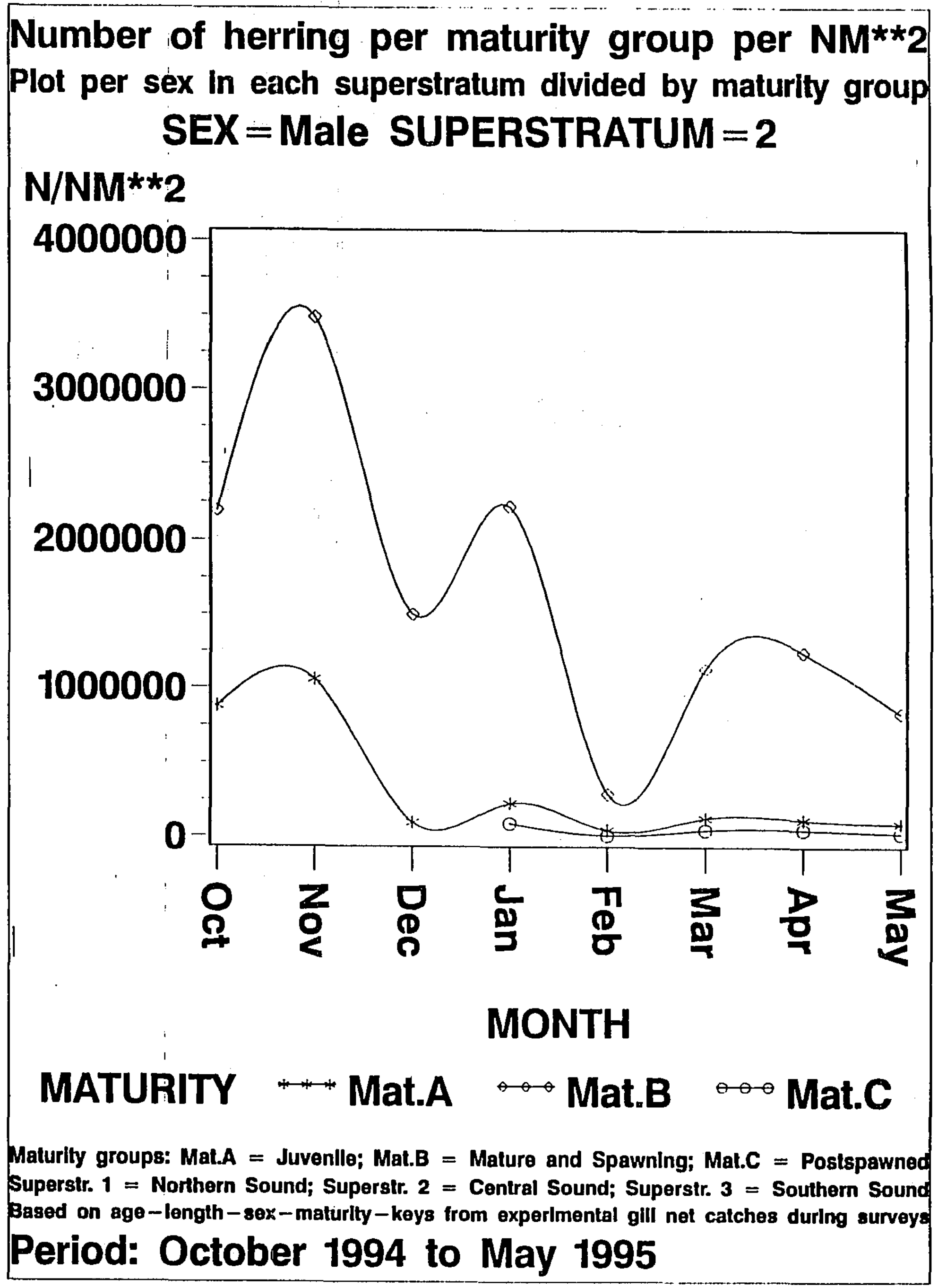
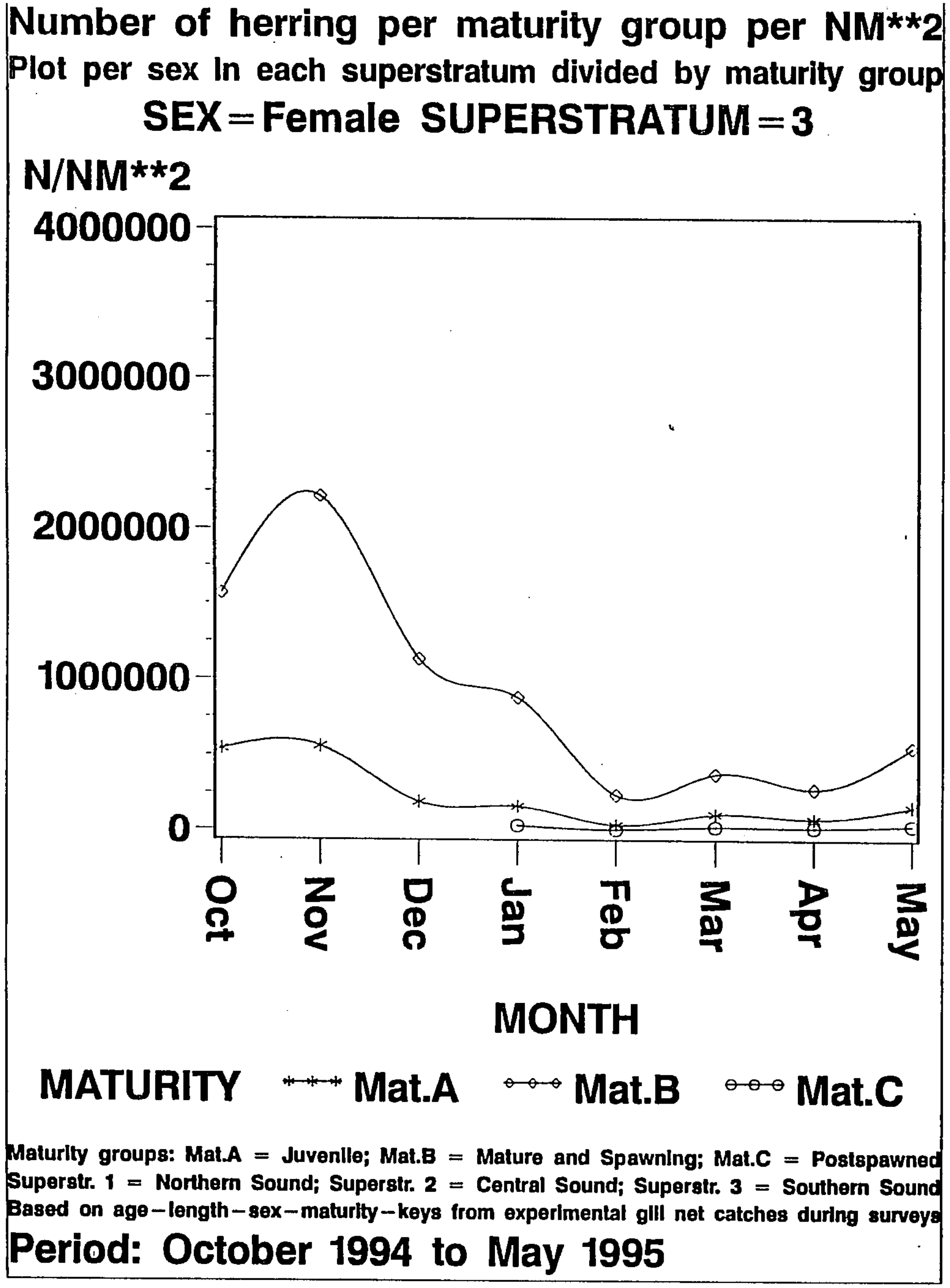


Figure 23. (Continued).



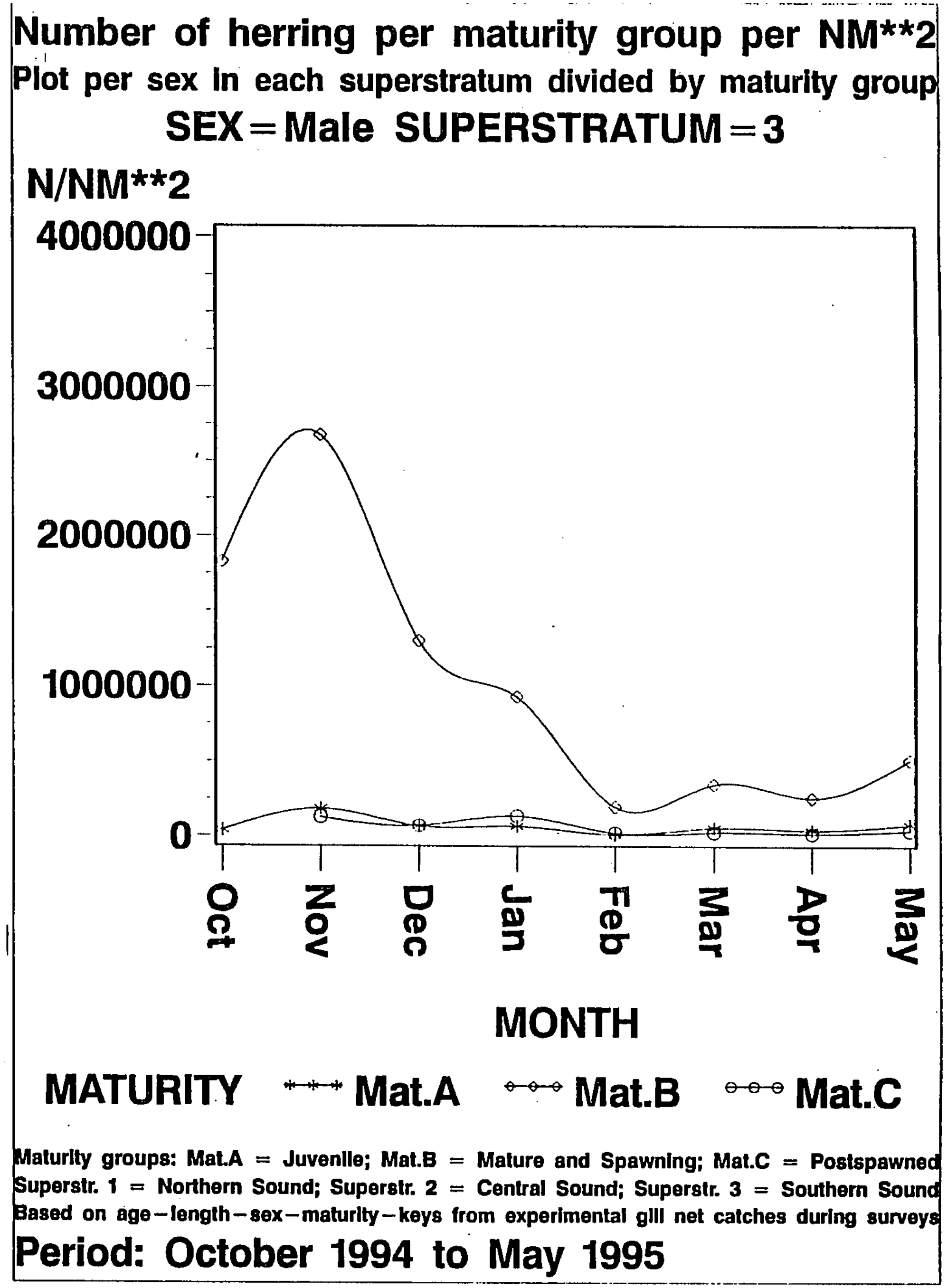


Figure 23. (Continued).

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APPENDIX

Herring in Skagerrak and Kattegat and in the Western Baltic Sea (ICES Division IIIa and ICES Subdivisions 22-24)

Characteristics: Herring in the Skagerrak, Kattegat and in the western Baltic Sea area, comprises a shared stock complex managed through trilateral agreements between Denmark, Norway and Sweden and through bilateral agreements between Denmark and Sweden, and finally through Agreed Record between EEC, Norway and Sweden (generally based on the first Agreed Record from May 1982, which has been revised yearly). Management of herring in the Baltic Sea area is performed by the International Baltic Sea Fishery Commission (IBSFC). Assessment and biological advice for herring in the area are given by ICES to the North-East Atlantic Fisheries Commission and to IBSFC. The fishery on herring in Skagerrak, Kattegat and the western Baltic Sea is dominated by Denmark and Sweden, and with important catches taken by Germany in the western Baltic Sea.

Distribution, migrations and stock structures: By analogy with the North Sea herring, the herring in Skagerrak and Kattegat and the western Baltic Sea comprises several local spawning stocks which are dominated by the group of winter and spring spawning populations, which can not easy be distinguished and separated using a combination of modal length analysis and mean numbers of vertebrae. Therefore, these herring are treated as one unity in fishery advising and management. The spring spawners in the western Baltic Sea (i.e. the western Baltic herring or the Rügen herring) is the far most dominant stock component among these winter and spring spawning populations, and has in later years (since the late 1970s) been the only important stock component for the fishery in the area. Today, the local spring spawning herring stocks in Kattegat are on a very low level. Besides the local spawning herring stocks, Skagerrak and Kattegat are important nursery-areas for North Sea herring. In the later years nearly all 0- and 1-group herring occurring in Skagerrak and Kattegat are North Sea herring. The North Sea herring emigrates from Skagerrak and Kattegat as 1- and 2-group to deeper waters to join the adult population. Local Skagerrak spring spawning stocks are found in at least three groups: a) along the Norwegian south-east coast, in the Oslo Fjord, off the Swedish west coast; b) Swedish coast with same origin as the Kattegat and the Belt Sea spring spawners; c) Jammer Bay on the Danish north-west coast. Several other stocks spawning outside the Skagerrak spend part of their feeding or over-wintering periods in the Skagerrak. The more important of these stocks besides North Sea herring are: a) Kattegat spring spawners; b) spring spawners of the western Baltic Sea; c) Longshore herring of the Danish west coast (Limfjord, Nissum Fjord, Ringkøbing Fjord, Ho Bay, and even the Elb River; d) local autumn spawners from Kattegat. The migratory behaviour of the small autumn-spawning herring stocks in ICES Subdivisions 22-24 is not so well known. Spawning areas are located in the coastal areas of Mecklenburg Bay, on the Banks of the Arkona Basin, and at the coast of Bornholm in deeper waters than the spring spawners. The spawning migration occurs during summer and early autumn. After spawning in August-November they mainly migrate to feeding areas around Bornholm.

Another over-wintering herring in the Skagerrak and Kattegat area is the Kobber-ground herring, which spawns on the edge of the Kobber-ground in the western part of Kattegat in September - November (with an spawning peak in October), and after over-wintering in Skagerrak (probably joining the over-wintering North Sea herring in the Egersund area), it performed feeding migration to the North Sea. This stock collapsed in the early 1970s, but is possible to recover and return. Earlier, a large consumption fishery on adult, over-wintering North Sea herring were performed in Skagerrak and northern Kattegat. In the 1950s and 1960s over-wintering herring of North Sea autumn spawners (Bank- and Buchan Shetland spawners) played a major role in the Skagerrak fishery for adult herring. These herring concentrated in the area of Egersund Bank from about October to March and penetrated into the westernmost Skagerrak. In periods of high abundance, the over-wintering shoals of North Sea herring even reached inside the Swedish skerries. The famous "Swedish herring periods" are explained in this way.

Thus, the stock identities, delimitations and relative stock sizes in the Skagerrak-Kattegat area and in the western Baltic area are rather complex, and are now much different from those 15-20 years ago. This is also reflected in the herring fishery. The fishery on the spring spawning western Baltic herring stock is performed in three management areas: Western Baltic Sea (ICES Subarea 22-23-24); Skagerrak-Kattegat (ICES Subdivision IIIa); North Sea (ICES Division IV). The present landings of herring caught in Division IIIa (and the North Sea) are a mixture of western Baltic spring spawners and North Sea autumn spawners. (See map in App. Fig. A8).

The present herring catches in Division IIIa (and the North Sea) are taken mainly in three types of fisheries:

a) A directed human consumption fishery for herring in which trawlers (with 32 mm mesh size gears) and purse seiners participate.

b) The mixed clupeoid fishery in Skagerrak and Kattegat is carried out under a special "sprat" TAC for all species caught in this fishery. The catch is used for reduction purposes. Danish boats are obliged to use gears with 32 mm mesh size (since 1 Jan. 1991). The Swedish fishery includes purse seiners fishing for sprat along the coast and trawlers using small meshed gears (gears with mesh size less than 32 mm). The Norwegian fishery is a purse seine sprat fishery for canning industry.

c) Other industrial herring landings from fishery in Skagerrak and Kattegat: catches of herring also occur as by-catches in other fisheries such as the Norway pout and sandeel fisheries and, further, herring caught in consumption trawl fisheries which because of fish size or quality is landed as industrial catch (whole catch or part of catch).

In ICES Subdivisions 22-24 all herring catches are taken in a directed fishery for herring:

d) Directed fishery for herring in Subdivisions 22-24.

The industrial fishery for reduction purposes on small herring is performed in July-September in near coastal areas of Skagerrak and the northern Kattegat and is mainly based on immature/juvenile 0- and 1-group North Sea herring. These herring have drifted from the spawning areas in the western North Sea to the west coast of Jutland and the Skagerrak - Kattegat area. Some of these reach as far as to the Belt Sea and the Sound. This immigration occurs in the winter period when the herring are larvae less than 5 cm in size (3-4 cm). In the following summer they have reached a size of 10-15 cm and contributes as such to a major part of the industrial catches in the area. In the first part of the year, the catch of the 2-group in Skagerrak and Kattegat consists of a mixture of North Sea herring and local spring spawners, while the amount of 2-group in the catch in the second part of the year consists of very few North Sea herring. During the following winter and the following spring period, they have reached a size of 15-25 cm, and the successively emigrate to the North Sea. This emigration is completed during the following winter.

The fishery on adult herring for consumption in Skagerrak and Kattegat occurs in May/June-November in Skagerrak and the northern Kattegat on greater depths. The catches in this fishery constitute for a major part of the spring spawning western Baltic herring and of local spring spawning herring. The main spawning grounds of the western Baltic spring spawning herring stock are in the coastal waters of the south-western Baltic, Greifswalder Bodden and the coastal areas of Rügen, in Pomorska Bay and in the Firth of Szczecin. Further, smaller local spawning grounds are scattered along the western Baltic Sea coasts. After spawning, the majority of these herring perform feeding migrations directed northwards through the Belt Sea and the Sound to Skagerrak and Kattegat, and some of them reach as far as around 3°E longitude in the North Sea. The fishery on these herrings starts in the end of May and is mainly located in the western part of Skagerrak, and in later years, also extends into the North Sea. This fishery continues until August - September. The fishery on the northward migrating herring to Skagerrak and Kattegat in the spring is rather limited, which probably is because of continuous and quick migration, and because of lack of gathering in large shoals before and during this migration. As the herring gather into larger shoals and starts the migration back to the western Baltic Sea in late summer and in the autumn, the fishery moves in an easterly direction. The last western Baltic spring spawning herring leave Skagerrak and the northern Kattegat in November. In the southern part of Kattegat, in the Sound and in the Belt Sea the fishery starts on the returning herring in September and continues until early-mid winter. The relative importance of the different over-wintering areas for these herring is not known into detail but they constitute the southern Kattegat, the Sound and (maybe) the Belt Sea, and the deeper parts of the western Baltic Sea. A minority of the spawning western Baltic herring migrate eastwards to feeding areas around Bornholm, Rønne Bank, Oder Bank off the Polish coast and Hanö Bay near the Swedish coast via the coastal waters of Germany, Poland to the west and east, and the Bornholm Basin open sea areas. In these waters, the western Baltic spring spawning herring mixes with populations that spawn in Bornholm coastal waters, in the north-western part of the Hanö Bay, in the Blekinge Archipelago and in Polish coastal waters. The young age groups are more local and coast bound than the older specimens, migrating closer to the coastline to the west and the south along the coast. Later in the autumn, the young age groups leave the coastal areas heading to the open sea to join the adult stock. However, the migration habits of the young western Baltic spring spawning herring is not well known. Biological tags (parasite infestation with larvae of *Anisakis sp.*) shows that juvenile 0- and 1-group western Baltic herring never are infested while fish which has performed their first migration after spawning (2+-group) are infested. The first host of *Anasakis* is an euphausid which do not occur in the Baltic but in Kattegat. This support the theory that juvenile western Baltic herring stays in the western Baltic until they mature.

Biological advising and catch: Uncertainties in data sources preclude an analytical assessment of the western Baltic herring stock by the ICES herring assessment group during the 1995 meeting and no direct biological advise and forecast for the stock is given by the ICES Advisory Committee for Fisheries Management (ACFM) in 1995. The evaluation of stock development for the later years is uncertain as available information is conflicting. There are problems with stock separation in historical data and with independent survey indices. Catch-at-age data are uncertain due to under sampling of landings. Particularly in ICES Division IIIa catch information and biological sampling from several herring fisheries are inadequate. Even though data on landings has been improved since 1993 misreporting of fishing grounds still occurs. The sampling intensity by quarter over all landings is acceptable with a mean of more than one sample per 1000 tonnes landed, but the distribution over areas, fishing fleets and seasons needs to be improved. The fishery independent stock estimates (i.e. survey indices from acoustic surveys and trawl surveys) did not indicate the same development as the data from the commercial fishery. Furthermore, the five survey indices considered showed a somewhat conflicting picture, and inconsistencies were also observed within the surveys. Finally, the Danish sampling system was changed in 1988, and catch data before 1988 is considered questionable. In the 1990s the sampling has been stratified on fleets. Age composition data from the Swedish industrial landings were not sampled before 1994.

However, some qualitative statements can be made about the state of the western Baltic herring stock: After a period of high landings in the early 1980s the landings have decreased to the long term average. Landings have decreased in spite of increasing abundance indices and apparently large stock size. The stock appears not to be in immediate danger of collapse. It is more likely that the stock is relatively lightly exploited and that the spawning stock biomass is at high level. Looking at the catch at age there are indications that the younger age groups have made up a smaller proportion in recent years compared to earlier years (before 1989). To what degree this picture is real or caused by inadequate sampling in earlier years is not known. Looking at the landings it can be seen that catches has been higher in the past, but there is no indication that the recent reduction in landings is caused by increased fishing mortality. Thus, the ICES working group believes that the reduction in landings is due to reduced fishing activity. The combined data from five fishery independent surveys indicate that fishing mortality is low and stock size is high. However, data does not allow for a precise quantification of this statement. To conclude, the working group and ACFM is not overwhelmingly concerned about the state of the western Baltic herring stock. It is most probably in a healthy state. If a precautionary TAC is required ACFM advises that it should be established such that the catch does not exceed recent levels.

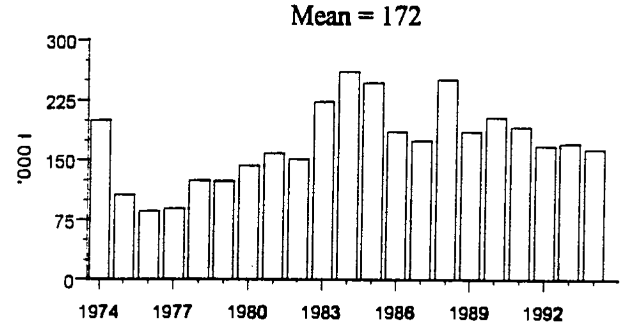
References: Anon. 1978; Anon. 1979; Anon. 1980; Anon. 1990; Anon 1991; Anon. 1992 (1); Anon. 1992 (2); Anon. 1992 (3); Anon. 1993 (1); Anon. 1993 (2); Anon. 1993(1); Anon. 1993 (2); Anon. 1993 (3); Anon. 1993 (4); Anon. 1993 (5); Anon. 1995(1); Anon 1995(2); Aro 1989; Biester 1979; Degnbol 1995; Degnbol and Kirkegaard 1995; Kirkegaard and Degnbol 1993; Knijn et al. 1993; Kühlmorgen-Hille (1983); Madsen, K.P. DIFRES, pers. comm.; Nielsen and Lassen 1993; Nielsen 1994; Otterlind 1984.

Year	Rec. TAC[2]	ACFM catch of stock[1]
1987	-	175
1988	196	251
1989	174	186
1990	131	204
1991	178	192
1992	170	168
1993	150-181	171
1994	130-180	164
1995	-[3]	
1996	-[3]	

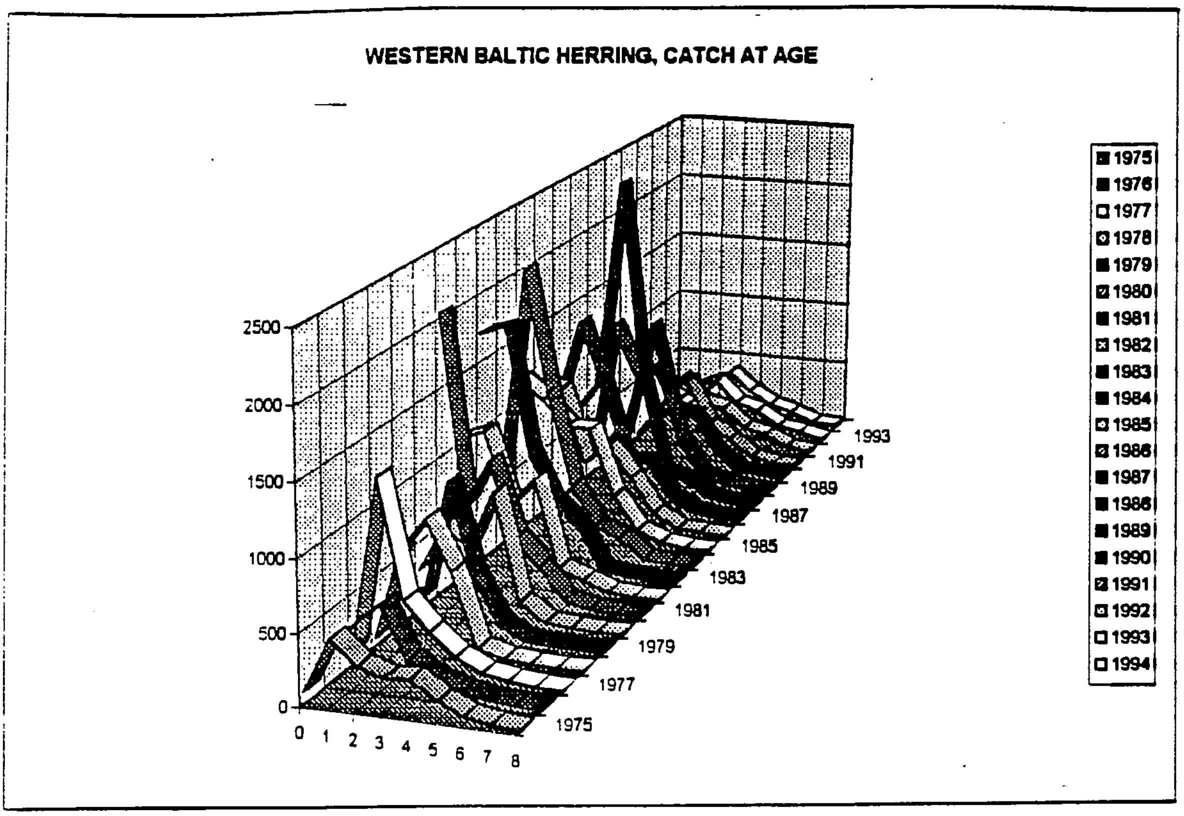
[1]Including North Sea. [2]Spring-spawners in IIIa and 22-24. [3]Not exceeding recent catch levels. Weights in '000 t.

Landings

Mean = 172



Year	Landings
1974	200
1975	106
1976	86
1977	89
1978	124
1979	124
1980	143
1981	158
1982	151
1983	224
1984	261
1985	247
1986	186
1987	175
1988	251
1989	186
1990	204
1991	192
1992	168
1993	171
1994	164
Average	172
Unit	1000 tonnes



App. Figure A1. **Landings in tonnes during the period 1974-1994 of western Baltic spring spawning herring from the western Baltic Sea, Skagerrak-Kattegat and the North Sea according to ACFM and the ICES Working Group (Anon. 1995(2)+(1)). Catch at age for the same stock in the same areas according to the ICES Working Group (Anon. 1995(1)).**

Survey activities and background material

App. Table A2. Schematic presentation of survey activities.

Survey	Reference	Period(s)	Activities/Monitoring
Sound 10/94	S-10-94	17-20/10 1994 24-26/10 1994	Acoustic integration survey (night) Gill net survey (night) Sampling of herring for individual analyses in the 3 superstrata Hydrographical CTD-samples
Sound 11/94	S-11-94	21-27/11 1994	Acoustic integration survey (night) Gill net survey (night) Hydrographical CTD-samples
Sound 12/94	S-12-94	12-16/12 1994	Acoustic integration survey (night) Gill net survey (night) Sampling of herring for individual analyses in the 3 superstrata Hydrographical CTD-samples
Sound 01/95	S-01-95	9-16/1 1995	Acoustic integration survey (night) Gill net survey (night) Hydrographical CTD-samples
Sound 02/95	S-02-95	6-10/2 1995	Acoustic integration survey (night) Gill net survey (night) Sampling of herring for individual analyses in the 3 superstrata Hydrographical CTD-samples
Sound 03/95	S-03-95	27/2-4/3 1995	Acoustic integration survey (night) Gill net survey (dusk/night/dawn) Hydrographical CTD-samples
Sound 04/95	S-04-95	27/3-2/4 1995	Acoustic integration survey (night) Gill net survey (dusk/night/dawn) Sampling of herring for individual analyses in the 3 superstrata Hydrographical CTD-samples
Sound 05/95	S-05-95	25/5 1995 and 30-31/5 1995	Acoustic integration survey (night)

App. Table A3. **Details of each gill net fishing station regarding settings in geographical stratum, fishing positions (start/end), fishing depth and layer and fishing time. Further, area adaption between biological data (samples of fishing data) and acoustic integration data is presented for each survey.**

Fishing stations on survey S-10-94:

Station	Startpos.	Endpos.	Layer	F.time	Depth	Area
01K52	55.33.50-12.49.95	55.34.04-12.50.34	SURF.	0.5 H	09 M	G12
02K52	55.36.53-12.55.40	55.36.85-12.56.00	SURF.	0.5 H	11 M	G11
03K52	55.39.36-12.56.20	55.39.57-12.56.19	BOTT.	1.5 H	16 M	G10
04K52	55.42.24-12.51.87	55.42.45-12.51.82	BOTT.	1.5 H	15 M	G09
05K52	55.43.17-12.54.23	55.43.49-12.53.42	SURF.	0.5 H	17 M	G08
06K52	55.47.47-12.41.31	55.47.64-12.41.17	BOTT.	2.0 H	12 M	G07-/G06
07K52	55.51.00-12.41.00	55.51.19-12.40.86	BOTT.	.	15 M	G05
08K52	55.56.42-12.37.20	55.56.64-12.37.31	BOTT.	2.1 H	18 M	G03
09K52	55.58.12-12.38.76	55.58.32-12.38.90	BOTT.	2.0 H	17 M	G02
10K52	56.00.39-12.38.15	56.00.21-12.38.12	BOTT.	1.7 H	11 M	G01
11K52	55.59.30-12.42.69	55.59.43-12.42.97	BOTT.	1.0 H	15 M	G02
12K52	55.53.83-12.40.22	55.53.97-12.40.05	BOTT.	1.3 H	18 M	G04
13K52	55.57.00-12.40.38	55.57.18-12.40.43	BOTT.	1.5 H	24 M	G03
14K52	55.53.83-12.43.60	55.53.93-12.43.85	BOTT.	1.7 H	22 M	G04
15K52	55.44.00-12.45.00	55.44.19-12.44.97	BOTT.	1.3 H	10 M	G08
16K52	55.41.50-12.56.00	55.41.50-12.56.20	BUND	1.2 H	14 M	G09
17K52	55.36.16-12.50.55	55.35.70-12.50.50	SURF.	0.7 H	07 M	G11

Spreading and number of settings per stratum on survey S-10-94:

G01:	1	G06:	½	G11:	2
G02:	2	G07:	½	G12:	1
G03:	2	G08:	2		
G04:	2	G09:	2		
G05:	1	G10:	1		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

Night 1: Waypoint 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 -10 - 11 - 12
Night 2: Waypoint 44 - 43 - 42 - 41 - 40 - 39 - 38 - 37 - 36 - 35-34-33
Night 3: Waypoint 33 - 32 - 31 - 30 - 29 - 28 - 27 - 26 - 25 - 24 - 23 - 22 - 21 - 20 - 19 - 18
Night 4: Waypoint 44-45-46
Waypoint 12 -13 - 14 - 15 - 16 - 17 - 18

App. Table A3. (Continued).

Fishing stations on survey S-11-94:

Station	Startpos.	Endpos.	Layer	F.time	Depth	Area
01HII	55.34.12-12.41.38	55.33.68-12.41.39	SURF.	0.25 H	07 M	G12
02HII	55.50.45-12.46.00	55.50.28-12.46.18	BOTT.	1.0 H	18 M	G05
03HII	55.52.71-12.35.93	55.52.50-12.35.98	BOTT.	1.3 H	09 M	G04
04HII	55.55.27-12.34.87	55.55.07-12.34.89	BOTT.	2.9 H	09 M	G03
05HII	55.59.47-12.35.41	55.59.36-12.35.44	BOTT.	2.0 H	11 M	G02
06HII	55.55.04-12.34.81	55.54.93-12.35.08	BOTT.	0.8 H	08 M	G03
07HII	55.56.21-12.35.27	55.56.18-12.35.27	BOTT.	1.0 H	12 M	G03/-04
08HII	55.51.75-12.37.06	55.51.87-12.37.17	BOTT.	1.8 H	09 M	G05
09HII	55.51.76-12.37.11	55.52.43-12.37.21	BOTT.	11.9 H	08 M	G05
10HII	55.49.68-12.37.74	55.49.84-12.37.70	BOTT.	11.7 H	09 M	G06
11HII	55.47.44-12.39.74	55.47.68-12.39.68	BOTT.	5.5 H	08 M	G07
12HII	55.44.94-12.43.92	55.45.22-12.44.06	BOTT.	1.2 H	12 M	G08
13HII	55.43.80-12.46.35	55.44.05-12.46.49	BOTT.	1.4 H	09 M	G08
14HII	55.36.91-12.56.23	55.37.15-12.56.59	BOTT.	1.6 H	14 M	G11
15HII	55.39.31-12.57.46	55.39.44-12.57.69	BOTT.	3.0 H	14 M	G10

Spreading and number of settings per stratum on survey S-11-94:

G01:	0	G06:	1	G11:	1
G02:	1	G07:	1	G12:	1
G03:	2½	G08:	2		
G04:	1½	G09:	0		
G05:	3	G10:	1		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

Night 1: Waypoint 1 - 2 - 3 - 4 - 5 - 6 - 7 - 9 - 10
Night 2: Waypoint 10 - 11 - 12 - 13 - 14 - 15 - 16 - 17 - 18 - 19 - 20 - 21 - 22
Night 3: Waypoint 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34 - 35 - 36 - 37
Night 4: Waypoint 37 - 38 - 39 - 41 - 42 - 43 - 45 - 46 - 47

App. Table A3. (Continued).

Fishing stations on survey S-12-94:

Station	Startpos.	Endpos.	Layer	F.time	Depth	Area
01HII	55.47.57-12.37.64	55.47.57-12.37.64	BUND	2.8 H	10 M	G08
02HII	55.46.03-12.41.36	55.45.86-12.41.54	BUND	1.5 H	12 M	G07
03HII	55.48.31-12.41.27	55.48.05-12.41.36	BUND	1.8 H	11 M	G06
04HII	55.33.82-12.41.37	55.33.65-12.41.33	BUND	1.5 H	08 M	G12
05HII	55.51.54-12.35.10	55.51.34-12.35.27	BUND	2.8 H	11 M	G05
06HII	55.52.88-12.34.34	55.52.69-12.34.51	BUND	2.2 H	11 M	G04
07HII	55.57.68-12.34.57	55.57.57-12.34.80	BUND	2.0 H	12 M	G02
08HII	56.00.22-12.35.86	56.00.35-12.35.36	BUND	2.5 H	10 M	G01
09HII	55.55.81-12.34.74	55.55.69-12.34.96	BUND	2.8 H	11 M	G03
10HII	55.59.86-12.42.32	55.59.72-12.42.16	BUND	0.5 H	20 M	G02
11HII	55.59.50-12.43.38	55.59.30-12.43.20	BUND	1.2 H	14 M	G02
12HII	55.50.65-12.45.98	55.50.65-12.45.98	BUND	2.5 H	08 M	G05
13HII	55.53.71-12.46.20	55.53.71-12.46.20	BUND	1.3 H	15 M	G04
14HII	55.41.48-12.56.38	55.41.48-12.56.38	BUND	1.8 H	15 M	G09
15HII	55.39.72-12.57.79	55.39.72-12.57.79	BUND	2.0 H	13 M	G10

Spreading and number of settings per stratum on survey S-12-94:

G01:	1	G06:	1	G11:	0
G02:	3	G07:	1	G12:	1
G03:	1	G08:	1		
G04:	2	G09:	1		
G05:	2	G10:	1		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

Night 1: Waypoint 1 - 2 - 3 - 4 - 5 - 6 - 7 - 9 - 10
Night 2: Waypoint 47 - 46 - 45 - 44 - 43 - 42 - 41 - 40 - 39 - 38 - 37 - 36 - 35
Night 3: Waypoint 35 - 34 - 33 - 32 - 31 - 30 - 29 - 28 - 27 - 26 - 25 - 24 - 23 - 22 - 21 - 20 - 19 - 18
Night 4: Waypoint 18 - 17 - 16 - 15 - 14 - 13 - 12 - 11 - 10

App. Table A3. (Continued).

Fishing stations on survey S-01-95:

Station	Startpos.	Endpos.	Layer	F.time	Depth	Area
01HII	55.40.28-12.39.11	55.40.13-12.39.44	BOTT.	2.0 H	06 M	G09
02HII	55.44.20-12.37.60	55.44.43-12.37.63	BOTT.	1.2 H	08 M	G08
03HII	55.51.04-12.45.80	55.51.24-12.45.85	BOTT.	1.5 H	11 M	G05
04HII	55.54.96-12.46.48	55.55.20-12.46.48	BOTT.	2.0 H	13 M	G03/-G04
05HII	55.59.28-12.43.70	55.59.49-12.43.82	BOTT.	2.0 H	13 M	G02
06HII	55.49.64-12.36.72	55.49.62-12.37.06	BOTT.	2.1 H	10 M	G06
07HII	55.46.52-12.37.24	55.46.53-12.37.59	BOTT.	1.0 H	07 M	G07
08HII	55.43.33-12.48.39	55.43.43-12.48.59	BOTT.	2.0 H	11 M	G08
09HII	55.41.70-12.56.20	55.41.84-12.56.06	BOTT.	1.0 H	15 M	G09
10HII	55.39.23-12.58.12	55.39.43-12.58.26	BOTT.	1.0 H	14 M	G10
11HII	55.37.00-12.56.03	55.37.20-12.56.31	BOTT.	1.0 H	15 M	G11

Spreading and number of settings per stratum on survey S-01-95:

G01:	0	G06:	1	G11:	1
G02:	1	G07:	1	G12:	0
G03:	½	G08:	2	G13:	0
G04:	½	G09:	2		
G05:	1	G10:	1		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

Night 1: Waypoint 47 - 46 - 45 - 44
Night 2: Waypoint 44 - 43 - 42 - 41 - 38 - 37 - 36 - 35 - 34 - 31 - 30 - 28 - 27 - 26 - 25 - 24
Night 3: Waypoint 27 - 26 - 25 - 24 - 23 - 22 - 21 - 20 - 19 - 18- 17 - 16 - 15 - 14 - 13 - 12
Night 4: Waypoint 12 - 11 - 10 - 8 - 6 - 5 - 4 - 3 - 1

App. Table A3. (Continued).

Fishing stations on survey S-02-95:

Station	Startpos.	Endpos.	Layer	F.time	Depth	Area
01HII	55.46.11-12.37.28	55.46.45-12.37.53	BOTT.	2.0 H	07 M	G07
02HII	55.40.29-12.38.94	55.40.08-12.39.11	BOTT.	0.5 H	05 M	G09
03HII	55.49.69-12.36.42	55.49.50-12.36.65	BOTT.	2.0 H	09 M	G06
04HII	55.51.80-12.35.51	55.51.73-12.35.79	BOTT.	2.0 H	12 M	G05
05HII	55.53.29-12.34.34	55.53.23-12.34.64	BOTT.	1.6 H	12 M	G04
06HII	55.55.33-12.35.16	55.55.46-12.34.90	BOTT.	1.1 H	11 M	G03
07HII	56.00.32-12.35.59	56.00.12-12.35.68	BOTT.	1.0 H	09 M	G01
08HII	55.59.21-12.34.76	55.59.00-12.34.77	BOTT.	1.1 H	09 M	G02
09HII	55.44.13-12.37.60	55.44.32-12.37.62	BOTT.	0.3 H	08 M	G08
10HII	55.55.03-12.46.50	55.55.21-12.46.38	BOTT.	1.0 H	12 M	G03
11HII	55.50.48-12.46.24	55.50.63-12.46.03	BOTT.	1.0 H	13 M	G05
12HII	55.39.59-12.57.59	55.39.82-12.57.79	BOTT.	0.4 H	13 M	G10

Spreading and number of settings per stratum on survey S-02-95:

G01:	1	G06:	1	G11:	0
G02:	1	G07:	~~1~~	G12:	0
G03:	2	G08:	1	G13:	0
G04:	1	G09:	1		
G05:	2	G10:	1		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

Night 1: Waypoint 1 - 2 - 3 - 4
Night 2: Waypoint 4 - 5 - 6 - 7 - 9
Night 3: Waypoint 47 - 46 - 45 - 44 - 43 - 42 - 41 - 38 - 37 - 36 - 35 - 34 - 33 - 32 - 31 - 30 - 28
Night 4: Waypoint 28 - 27 - 26 - 25 - 24 - 23 - 22 - 21 - 20 - 19 - 18- 17 - 16 - 15 - 14
Night 5: Waypoint 14 - 13 - 12 - 11 - 10 - 9 - 8 - 7

App. Table A3. (Continued).

Fishing stations on survey S-03-95:

Station	Startpos.	Endpos.	Layer	F.time	Depth	Area
01HII	55.33.29-12.49.72	55.33.51-12.49.75	BOTT.	. H	10 M	G12
02HII	55.37.34-12.56.00	55.37.50-12.56.33	BOTT.	0.5 H	16 M	G11
03HII	55.43.93-12.37.12	55.43.76-12.37.34	BOTT.	1.0 H	06 M	G08
04HII	55.41.97-12.41.52	55.41.75-12.41.60	BOTT.	0.4 H	16 M	G09
05HII	55.46.54-12.38.80	55.46.40-12.39.04	BOTT.	2.0 H	08 M	G07
06HII	55.49.34-12.38.92	55.49.53-12.38.93	BOTT.	6.3 H	09 M	G06
07HII	55.51.59-12.38.83	55.51.83-12.38.83	BOTT.	7.1 H	18 M	G05
08HII	55.54.02-12.39.84	55.54.19-12.39.63	BOTT.	2.3 H	18 M	G04
09HII	55.56.55-12.35.75	55.56.75-12.35.70	BOTT.	1.2 H	16 M	G03
10HII	55.57.86-12.34.92	55.58.09-12.34.93	BOTT.	1.5 H	14 M	G02

Spreading and number of settings per stratum on survey S-03-95:

G01:	0	G06:	1	G11:	1
G02:	1	G07:	1	G12:	1
G03:	1	G08:	1	G13:	0
G04:	1	G09:	1		
G05:	1	G10:	0		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

Night 1: Waypoint 1 - 2 - 3 - 4
Night 2: Waypoint Kongedybet
Night 3: Waypoint 47 - 46 - 45 - 42 - 41 - 38 - 37
Night 4: Waypoint 37 - 36 - 35 - 34 - 33 - 30 - 28 - 27 - 26 - 25 - 24- 23 - 22 - 21 - 20
19 - 18
Night 5: Waypoint 18 - 17 - 16 - 15 - 14 - 13 - 10 - 9 - 8 - 5 - 4 - 3

App. Table A3. (Continued).

Fishing stations on survey S-04-95:

Station	Startpos.	Endpos.	Layer	F.time	Depth	Area
01HII	55.36.98-12.56.13	55.37.12-12.55.83	BOTT.	1.0 H	14 M	G11
02HII	55.33.14-12.51.19	55.33.03-12.51.51	BOTT.	0.6 H	08 M	G12
03HII	55.39.33-12.57.71	55.39.16-12.57.46	BOTT.	0.5 H	14 M	G10
04HII	55.41.01-12.58.17	55.41.00-12.57.80	BOTT.	1.0 H	13 M	G09
05HII	55.42.89-12.54.35	55.43.06-12.54.07	BOTT.	1.0 H	15 M	G08
06HII	55.46.84-12.42.93	55.46.64-12.42.94	BOTT.	0.7 H	18 M	G07
07HII	55.50.54-12.46.39	55.50.70-12.46.10	BOTT.	1.0 H	10 M	G05
08HII	55.55.71-12.46.68	55.55.92-12.46.67	BOTT.	1.0 H	12 M	G03
09HII	55.59.38-12.43.59	55.59.54-12.43.43	BOTT.	2.0 H	12 M	G02
10HII	56.00.30-12.36.37	56.00.51-12.36.57	BOTT.	1.0 H	17 M	G01
11HII	55.52.52-12.34.55	55.52.71-12.34.72	BOTT.	2.0 H	10 M	G04
12HII	55.56.85-12.34.36	55.57.07-12.34.25	BOTT.	2.7 H	08 M	G03
13HII	55.51.69-12.35.27	55.51.86-12.35.53	BOTT.	2.2 H	11 M	G05
14HII	55.48.20-12.37.00	55.48.36-12.37.27	BOTT.	1.0 H	08 M	G06
15HII	55.44.65-12.36.64	55.44.48-12.36.90	BOTT.	1.0 H	06 M	G08
16HII	55.46.62-12.36.76	55.46.52-12.37.01	BOTT.	1.0 H	07 M	G07

Spreading and number of settings per stratum on survey S-04-95:

G01:	1	G06:	1	G11:	1
G02:	1	G07:	2	G12:	1
G03:	2	G08:	2	G13:	0
G04:	1	G09:	1		
G05:	2	G10:	1		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

Night 1: Waypoint 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 12 - 13 - 14
Night 2: Waypoint 14 - 15 - 16 - 17 - 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 30 - 31 - 32 - 33 - 34 - 35
Night 3: Waypoint 47 - 46 - 45 - 44 - 43 - 42 - 41 - 40 - 39 - 38 - 37 - 36 - 35

App. Table A3. (Continued).

Fishing stations on survey S-05-95:

No fishing from R/V DANA was performed on this survey (see the material and method section). Fishing from survey S-04-95 is used (presented above).

Spreading and number of settings per stratum on survey S-04-95:

Settings from fishing stations on survey S-04-95 were used which are given below:

G01:	1	G06:	1	G11:	1
G02:	1	G07:	2	G12:	1
G03:	2	G08:	2	G13:	0
G04:	1	G09:	1		
G05:	2	G10:	1		

Sailing route and sequence of waypoints during acoustic integration (weather and water current dependent):

The usual sailing route with R/V HAVFISKEN could not be used with R/V DANA because of depth. An alternative sailing-route covering the Sound as well as possible with the used research vessel were taken, which roughly is as follows:

Night 1: Waypoint 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 12 - 13 - 14 - 15 - 16 - 17 - 18 - 19

App. Table A4. **Hydrographical data sampling: Details related to each hydrographical profile / station regarding station number, date, UTC time, geographical position and maximum depth from surface for each survey. All hydrographical sampling are taken from R/V HAVFISKEN with small SEACAT SBE 19-03 CTD.**

Survey number: **S-10-94**

No.	St. no.	Date	Time	Latitude	Longitude	Depth (m)
01	506	17.10.94	20.56	55.36.81	12.55.75	12.7
02	513	18.10.94	02.27	55.43.09	12.53.60	13
03	515	18.10.94	17.00	55.45.83	12.38.53	13
04	520	18.10.94	20.00	55.50.86	12.40.26	20
05	523	18.10.94	22.40	55.51.23	12.36.46	10
06	532	24.10.94	18.35	55.57.93	12.37.47	18
07	539	24.10.94	22.50	55.59.17	12.43.21	13
08	545	25.10.94	01.54	55.54.58	12.45.57	24
09	548	25.10.94	03.40	55.51.82	12.39.97	14
10	549	25.10.94	18.00	55.45.88	12.38.70	7
11	552	25.10.94	20.30	55.43.16	12.41.48	14
12	553	25.10.94	21.18	55.45.41	12.50.88	16
13	560	26.10.94	04.00	55.51.82	12.39.75	14

App. Table A4. (Continued).

Survey number: **S-11-94**

No.	St. no.	Date	Time	Latitude	Longitude	Depth (m)
01	1701	21.11.94	20.50	55.32.31	12.43.95	8.2
02	1706	22.11.94	00.55	55.36.63	12.56.32	12.3
03	1709	22.11.94	03.25	55.39.79	13.01.67	5.4
04	1714	22.11.94	17.45	55.42.30	12.49.56	7.0
05	1723	23.11.94	02.45	55.51.56	12.39.98	14.6
06	1729	23.11.94	17.40	55.55.16	12.42.94	35.0
07	1733	23.11.94	20.25	55.58.79	12.44.48	7.6
08	1738	23.11.94	22.55	56.00.81	12.39.37	15.5
09	1748	24.11.94	07.00	55.53.31	12.34.81	12.3
10	1754	24.11.94	20.33	55.48.42	12.37.16	6.2
11	1757	25.11.94	22.25	55.45.84	12.47.13	15.5
12	1760	25.11.94	23.40	55.43.11	12.41.53	14.7

App. Table A4. (Continued).

Survey number: S-12-94

No.	St. no.	Date	Time	Latitude	Longitude	Depth (m)
01	4622	12.12.94	17.35	55.32.34	12.43.69	9.5
02	4627	12.12.94	22.40	55.36.67	12.56.41	12.0
03	4631	13.12.94	02.00	55.39.82	13.01.70	6.0
04	4636	13.12.94	16.40	55.43.12	12.41.60	15.0
05	4640	13.12.94	20.25	55.49.04	12.44.40	21.0
06	4649	14.12.94	05.50	55.54.70	12.34.40	18.0
07	4652	14.12.94	17.40	55.55.34	12.34.50	7.0
08	4658	14.12.94	20.52	55.58.50	12.41.60	29.0
09	4662	14.12.94	23.05	56.00.74	12.38.17	9.5
10	4674	15.12.94	05.00	55.51.57	12.39.88	14.5
11	4679	15.12.94	20.20	55.46.47	12.42.54	13.5
12	4685	16.12.94	01.32	55.42.25	12.47.90	5.9

App. Table A4. (Continued).

Survey number: S-01-95

No.	St. no.	Date	Time	Latitude	Longitude	Depth (m)
1	4686	09.01.95	16.50	55.43.90	12.41.60	13.0
2	4690	13.01.95	16.10	55.49.15	12.44.53	19.5
3	4697	13.01.95	21.50	55.54.69	12.39.50	16.0
4	4703	14.01.95	01.25	56.01.52	12.38.86	14.0
5	4707	14.01.95	03.31	55.58.68	12.44.72	6.0
6	4712	14.01.95	18.55	55.56.89	12.40.21	21.5
7	4719	14.01.95	22.55	55.51.82	12.39.92	13.0
8	4726	15.01.95	16.43	55.45.48	12.51.02	14.5
9	4730	15.01.95	21.04	55.41.65	13.00.88	5.0
10	4732	15.01.95	22.35	55.38.87	12.51.55	11.0
11	4735	15.01.95	23.45	55.36.72	12.56.52	12.5
12	4738	16.01.95	03.05	55.32.67	12.43.75	8.5

App. Table A4. (Continued).

Survey number: S-02-95

No.	St. no.	Date	Time	Latitude	Longitude	Depth (m)
1	4788	06.02.95	17.00	55.32.63	12.43.37	6.75
2	4792	07.02.95	19.32	55.36.49	12.56.40	8.5
3	4796	08.02.95	15.40	55.43.10	12.41.48	17.0
4	4800	08.02.95	19.10	55.49.15	12.44.73	20.0
5	4805	08.02.95	23.09	55.54.05	12.40.85	17.0
6	4815	09.02.95	16.22	56.01.47	12.38.91	15.0
7	4819	09.02.95	17.44	55.58.84	12.44.37	11.0
8	4823	09.02.95	19.43	55.55.24	12.43.04	37.0
9	4828	09.02.95	22.17	55.51.82	12.39.92	11.5
10	4833	10.02.95	02.14	55.46.47	12.42.64	13.0
11	4839	10.02.95	21.56	55.42.38	12.49.46	7.5
12	4842	10.02.95	23.43	55.39.82	13.01.78	6.0

App. Table A4. (Continued).

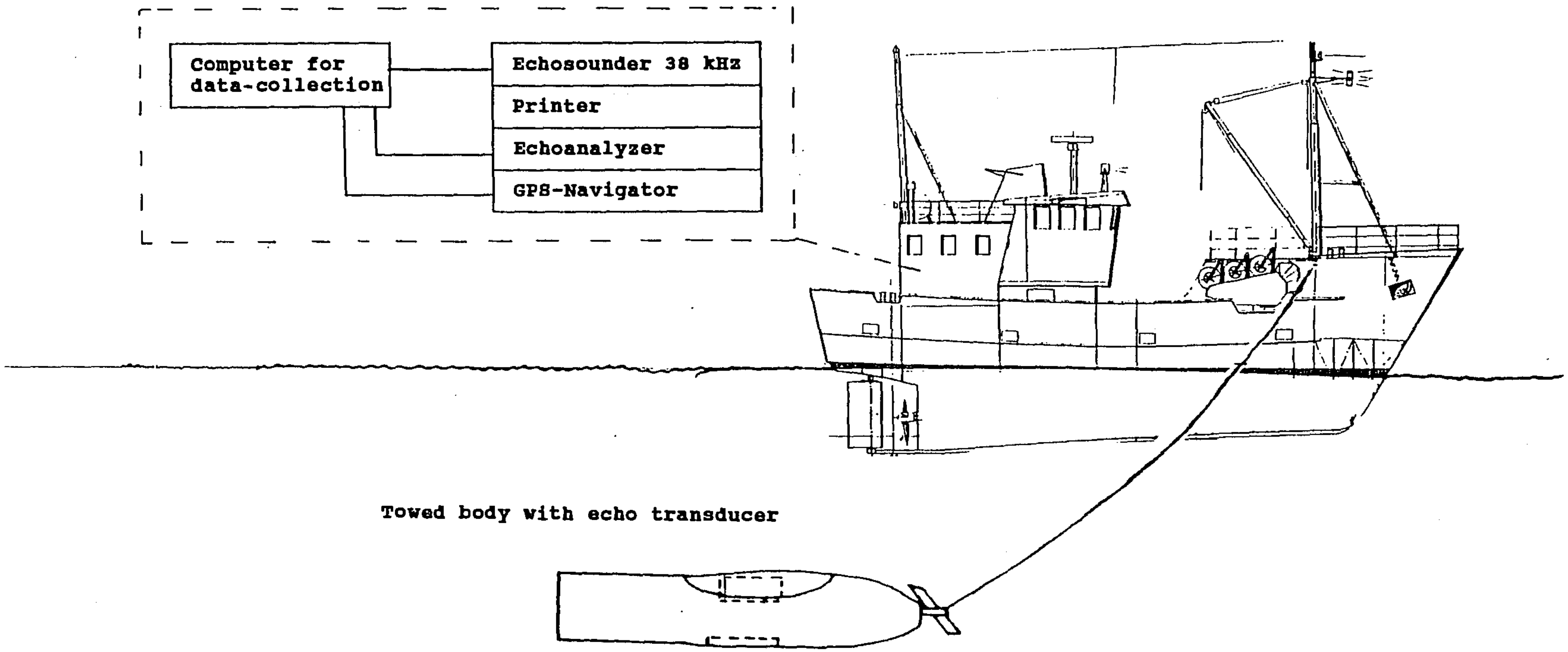
Survey number: S-03-95

No.	St. no.	Date	Time	Latitude	Longitude	Depth (m)
1	4843	27.02.95	16.45	55.32.45	12.43.83	11.0
2	4847	28.02.95	16.54	55.42.09	12.37.90	11.5
3	4849	28.02.95	17.45	55.43.04	12.41.52	15.5
4	4852	02.03.95	00.07	55.45.98	12.38.80	6.0
5	4853A	02.03.95	01.30	55.51.08	12.41.64	13.0
6	4860	02.03.95	19.20	55.55.95	12.40.50	30.0
7	4864	02.03.95	22.15	56.01.13	12.08.98	16.0
8	4868	02.03.95	23.40	55.58.64	12.44.51	11.0
9	4874	03.03.95	03.05	55.53.86	12.45.67	11.0
10	4882	03.03.95	23.17	55.48.70	12.54.45	7.5
11	4886	04.03.95	04.45	55.37.77	12.52.49	8.0
12	4889	04.03.95	06.34	55.35.85	12.51.69	6.0

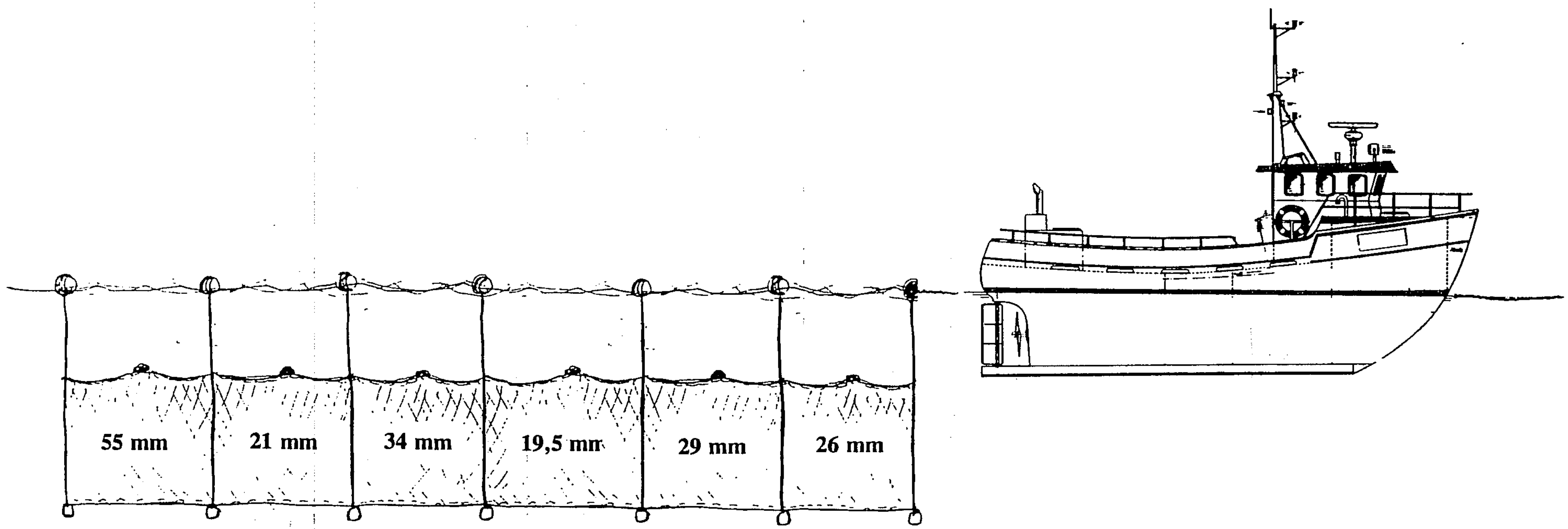
App. Table A4. (Continued).

Survey number: S-04-95

No.	St. no.	Date	Time	Latitude	Longitude	Depth (m)
1	4918	28.03.95	19.05	55.35.00	12.47.40	5.0
2	4919	28.03.95	20.50	55.36.55	12.56.37	10.0
3	4922	28.03.95	22.50	55.39.89	13.01.64	7.0
4	4924	29.03.95	00.34	55.42.40	12.49.10	8.0
5	4927	29.03.95	02.28	55.45.60	12.50.90	15.0
6	4933	29.03.95	20.20	55.51.88	12.40.11	15.0
7	4938	29.03.95	22.35	55.56.87	12.44.83	16.0
8	4943	30.03.95	00.50	56.01.43	12.38.99	17.0
9	4945	30.03.95	02.00	55.59.45	12.35.08	7.0
10	4950	30.03.95	17.00	55.44.05	12.34.84	13.0
11	4953	30.03.95	21.35	55.48.74	12.37.76	6.0
12	1	31.03.95	10.50	55.32.5	12.44	11.0
13	2	31.03.95	11.10	55.32.5	12.46	10.5
14	3	31.03.95	11.30	55.32.5	12.49	8.4
15	4	31.03.95	11.50	55.32.5	12.52	6.5



Appendiks Figure A5. **Schematic diagram of the hydro-acoustic echo integration system on board R/V HAVFISKEN including the mobile, scientific SIMRAD EY-200 38 kHz single beam echo sounder, the ECHOANN echo analyzing system, the GPS Navigation System, the PC-unit and the towed body with transducer.**



Appendiks Figure A6. Schematic diagram of the biological sampling on board R/V HAVKATTEN: Fishing surveys with experimental (scientific) gill nets. Each setting comprise 7-9 nets (panels) with mesh sizes 19.5 mm, 21.0 mm, 26.0 mm, 27.0 mm, 28.0 mm, 29.0 mm, 34.0 mm, 46.0 mm, 55.0 mm and 60.0 mm. Usually fishing is performed with standard sets of 8 nets (panels) with mesh size 19.5, 21, 26, 27, 28, 29, 34 and 55 mm.

App. Table A7. Number of fish caught per species divided by year, survey, gill net code and mesh size (in mm knot to knot). Abbreviations: S=Herring; T=Cod; V=Whiting; HF=Garfish; IS=Dab; SK=Flounder; ULK=Sculpin; M=Mackerel.

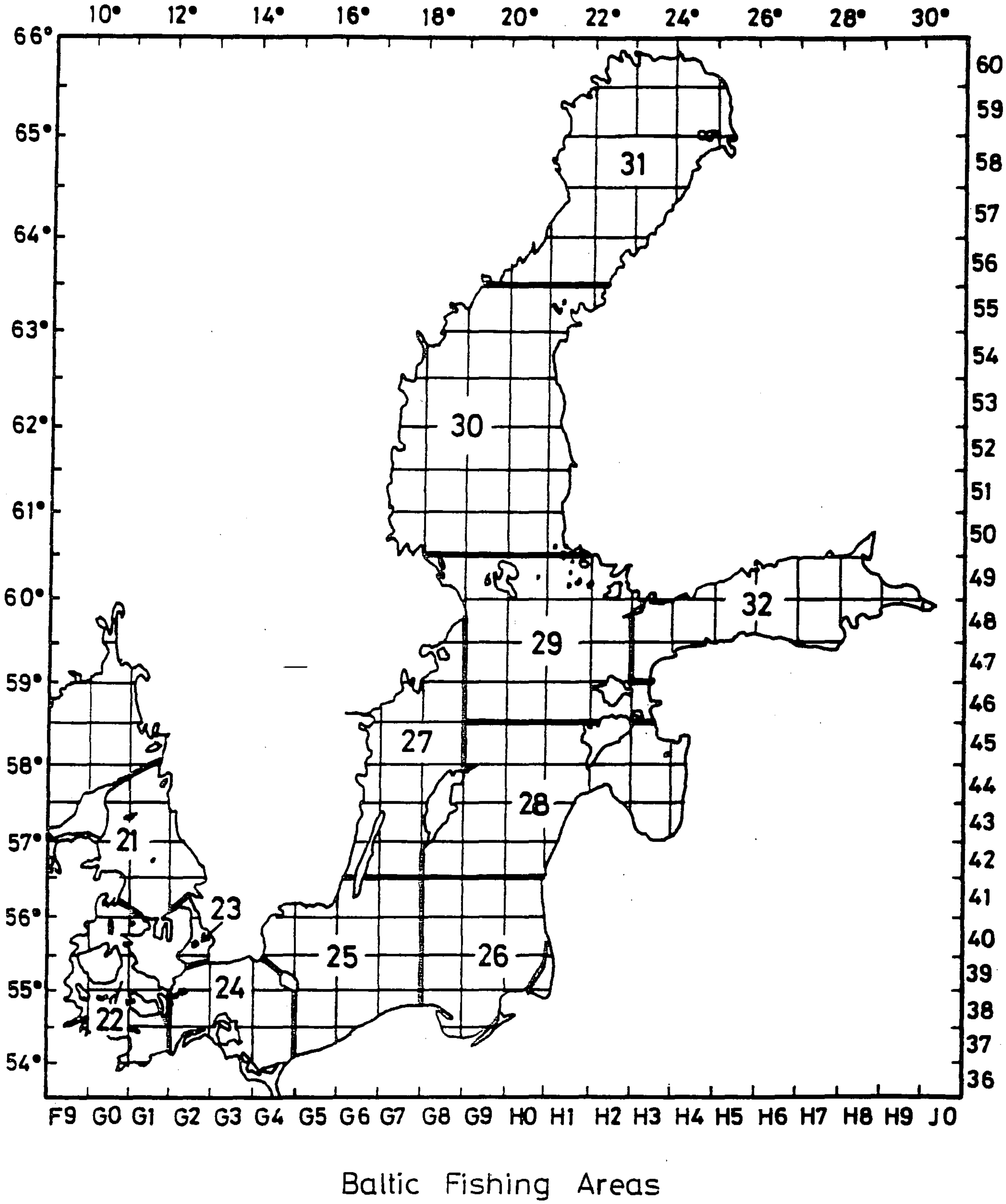
YEAR	SURVEY	MESH SIZE	SPE.	NUMBER
1993	S 0993	CO 27-28MM	HF	37
1993	S 0993	CO 27-28MM	IS	1
1993	S 0993	CO 27-28MM	M	7
1993	S 0993	CO 27-28MM	S	856
1993	S 0993	CO 27-28MM	T	2
1993	S 1093	K52-19MM	S	249
1993	S 1093	K52-26MM	S	516
1993	S 1093	K52-28MM	S	536
1993	S 1093	K52-34MM	S	7
1993	111293	K52-19MM	S	15
1993	111293	K52-26MM	S	45
1993	111293	K52-27MM	S	26
1993	111293	K52-27MM	V	1
1993	111293	K52-28MM	S	29
1993	111293	K52-29MM	S	25
1993	111293	K52-34MM	S	1
1993	111293	K52-55MM	T	1
1994	S 0194	K52-19,5MM	S	105
1994	S 0194	K52-26MM	S	394
1994	S 0194	K52-26MM	T	1
1994	S 0194	K52-27MM	S	370
1994	S 0194	K52-27MM	T	3
1994	S 0194	K52-27MM	V	1
1994	S 0194	K52-28MM	S	332
1994	S 0194	K52-28MM	T	3
1994	S 0194	K52-29MM	S	346
1994	S 0194	K52-45MM	T	1
1994	S 0194	K52-46MM	S	1
1994	S 0194	K52-60MM	T	2
1994	S 0394	K52-19,5MM	S	70
1994	S 0394	K52-19,5MM	SK	1
1994	S 0394	K52-19,5MM	T	2
1994	S 0394	K52-26MM	S	106
1994	S 0394	K52-26MM	T	3
1994	S 0394	K52-27MM	AA	1
1994	S 0394	K52-27MM	S	73
1994	S 0394	K52-27MM	T	1
1994	S 0394	K52-27MM	V	1

1994	S 0394	K52-28MM	S	134
1994	S 0394	K52-28MM	T	1
1994	S 0394	K52-28MM	V	1
1994	S 0394	K52-29MM	S	116
1994	S 0394	K52-46MM	S	1
1994	S 0394	K52-55MM	T	2
1994	S 0394	K52-60MM	SK	3
1994	S 0394	K52-60MM	T	3
1994	S 0494	K52-19,5MM	S	56
1994	S 0494	K52-19,5MM	T	1
1994	S 0494	K52-19,5MM	V	3
1994	S 0494	K52-21MM	S	204
1994	S 0494	K52-21MM	T	1
1994	S 0494	K52-26MM	S	143
1994	S 0494	K52-26MM	T	1
1994	S 0494	K52-27MM	S	160
1994	S 0494	K52-27MM	T	6
1994	S 0494	K52-27MM	V	2
1994	S 0494	K52-28MM	S	133
1994	S 0494	K52-28MM	T	4
1994	S 0494	K52-28MM	V	2
1994	S 0494	K52-29MM	E	1
1994	S 0494	K52-29MM	S	100
1994	S 0494	K52-29MM	T	3
1994	S 0494	K52-46MM	T	1
1994	S 0494	K52-55MM	IS	1
1994	S 0494	K52-55MM	T	1
1994	S 1094	K52-19,5MM	S	97
1994	S 1094	K52-19,5MM	V	3
1994	S 1094	K52-21MM	S	407
1994	S 1094	K52-21MM	V	4
1994	S 1094	K52-26MM	S	385
1994	S 1094	K52-26MM	T	2
1994	S 1094	K52-26MM	V	1
1994	S 1094	K52-27MM	S	429
1994	S 1094	K52-27MM	T	3
1994	S 1094	K52-27MM	V	5
1994	S 1094	K52-28MM	HF	1
1994	S 1094	K52-28MM	S	593
1994	S 1094	K52-28MM	V	10
1994	S 1094	K52-29MM	S	532
1994	S 1094	K52-29MM	T	1
1994	S 1094	K52-29MM	V	14
1994	S 1094	K52-60MM	T	2
1994	S 1194	K52-19,5MM	S	137
1994	S 1194	K52-19,5MM	T	1
1994	S 1194	K52-21MM	S	239

1994	S 1194	K52-26MM	S	187
1994	S 1194	K52-26MM	T	1
1994	S 1194	K52-27MM	S	382
1994	S 1194	K52-27MM	T	1
1994	S 1194	K52-27MM	V	1
1994	S 1194	K52-28MM	S	302
1994	S 1194	K52-28MM	T	2
1994	S 1194	K52-28MM	V	1
1994	S 1194	K52-29MM	S	205
1994	S 1194	K52-29MM	T	5
1994	S 1194	K52-29MM	V	1
1994	S 1194	K52-34MM	S	13
1994	S 1194	K52-46MM	IS	1
1994	S 1194	K52-46MM	T	1
1994	S 1194	K52-55MM	T	4
1994	S 1194	K52-60MM	IS	1
1994	S 1194	K52-60MM	T	3
1994	S 1294	K52-19,5MM	S	63
1994	S 1294	K52-19,5MM	V	1
1994	S 1294	K52-21MM	S	156
1994	S 1294	K52-21MM	T	5
1994	S 1294	K52-26MM	S	468
1994	S 1294	K52-26MM	T	6
1994	S 1294	K52-26MM	ULK	1
1994	S 1294	K52-27MM	S	541
1994	S 1294	K52-27MM	T	4
1994	S 1294	K52-28MM	S	463
1994	S 1294	K52-28MM	T	8
1994	S 1294	K52-28MM	V	1
1994	S 1294	K52-29MM	S	588
1994	S 1294	K52-29MM	T	7
1994	S 1294	K52-34MM	S	22
1994	S 1294	K52-34MM	T	2
1994	S 1294	K52-46MM	T	2
1994	S 1294	K52-55MM	IS	1
1994	S 1294	K52-55MM	T	4
1994	S 1294	K52-60MM	E	1
1994	S 1294	K52-60MM	T	3
1995	S 0195	K52-19,5MM	S	133
1995	S 0195	K52-19,5MM	T	1
1995	S 0195	K52-21MM	S	225
1995	S 0195	K52-21MM	T	2
1995	S 0195	K52-26MM	S	434
1995	S 0195	K52-27MM	S	504
1995	S 0195	K52-27MM	T	5
1995	S 0195	K52-28MM	S	580
1995	S 0195	K52-28MM	T	3

1995	S 0195	K52-29MM	S	637
1995	S 0195	K52-29MM	T	3
1995	S 0195	K52-34MM	S	166
1995	S 0195	K52-34MM	SK	1
1995	S 0195	K52-34MM	T	2
1995	S 0195	K52-55MM	IS	1
1995	S 0195	K52-55MM	S	1
1995	S 0195	K52-55MM	T	10
1995	S 0295	K52-19,5MM	S	510
1995	S 0295	K52-19,5MM	T	3
1995	S 0295	K52-21MM	S	580
1995	S 0295	K52-21MM	T	2
1995	S 0295	K52-26MM	S	400
1995	S 0295	K52-26MM	T	3
1995	S 0295	K52-27MM	S	376
1995	S 0295	K52-27MM	T	16
1995	S 0295	K52-28MM	S	404
1995	S 0295	K52-28MM	T	14
1995	S 0295	K52-28MM	V	1
1995	S 0295	K52-29MM	S	419
1995	S 0295	K52-29MM	T	6
1995	S 0295	K52-34MM	S	34
1995	S 0295	K52-34MM	T	3
1995	S 0295	K52-55MM	SK	1
1995	S 0295	K52-55MM	T	8
1995	S 0395	K52-19,5MM	S	3
1995	S 0395	K52-21MM	S	15
1995	S 0395	K52-21MM	T	4
1995	S 0395	K52-26MM	S	75
1995	S 0395	K52-26MM	T	3
1995	S 0395	K52-27MM	S	48
1995	S 0395	K52-27MM	T	8
1995	S 0395	K52-27MM	V	1
1995	S 0395	K52-28MM	S	68
1995	S 0395	K52-28MM	T	22
1995	S 0395	K52-29MM	S	60
1995	S 0395	K52-29MM	T	21
1995	S 0395	K52-34MM	S	9
1995	S 0395	K52-34MM	T	5
1995	S 0495	K52-19,5MM	S	4
1995	S 0495	K52-19,5MM	T	2
1995	S 0495	K52-19,5MM	V	2
1995	S 0495	K52-21MM	S	57
1995	S 0495	K52-21MM	T	3
1995	S 0495	K52-26MM	S	158
1995	S 0495	K52-26MM	T	1
1995	S 0495	K52-27MM	S	82

1995	S 0495	K52-27MM	T	4
1995	S 0495	K52-27MM	V	1
1995	S 0495	K52-28MM	S	58
1995	S 0495	K52-28MM	T	9
1995	S 0495	K52-29MM	S	78
1995	S 0495	K52-29MM	SBD	1
1995	S 0495	K52-29MM	T	10
1995	S 0495	K52-34MM	S	3
1995	S 0495	K52-34MM	T	1
1995	S 0495	K52-55MM	IS	2
1995	S 0495	K52-55MM	T	2



App. Figure A8. **Geographical map of the Sound area (ICES Subdivision 23) and surrounding waters (ICES Subdivisions 21-32) divided by ICES statistical areas.**