Northwest Atlantic Fisheries Organization

Serial No. N1451 NAFO SCR Doc. 88/15

SCIENTIFIC COUNCIL MEETING - JUNE 1988

An Application of the Spline Approximation Method for Design and Data Analysis of Trawl Surveys of Commercial Fish Stocks in the Northwest Atlantic

by

D. A. Stolyarenko
All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO)
107140, Moscow, USSR

and

A. K. Chumakov and A. G. Galuso
Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
183763, Murmansk, USSR

ABSTRACT

The method of the spline approximation of stock density (Stolyarenko, 1986, 1987, Stolyarenko, Ivanov, 1987, 1988) is applied to data of the Soviet surveys performed in 1983-1987 on Flemish Cap (NAFO Division 3M). We seek to revise the cod and redfish stock assessments and to construct spatial patterns for stock density and abundance on the basis of the survey data. The spatial patterns were generated on a personal computer with the Spline Survey Designer Software System (Stolyarenko, 1987). We present for comparision tables of biomass and abundance estimates computed using the spline approximation method and the commonly used stratification method.

INTRODUCTION

Stock assessments for groundfish by means of research vessel trawl surveys were carried out in the Northwest Atlantic areas by Polar Institute (PINRO) annually since 1971. During 1971-82, the annual surveys were carried out on a fixed set of trawling stations when all stations were repeated from year to year. To study variations in fish biomass and abundance from year to year they sought to carry out the trawl surveys on the same vessel and in the same period with the same type of groundfish trawl (Chumakov et al., 1984).

Since 1983 survey design was executed using the statification method for random sampling with the stratification scheme that was recommended by NAFO (Doubleday, ed., 1981). A number of stations in a stratum was selected to be proportional to the stratum area. Station selection within a stratum was performed from a list of random numbers. The stratification method has inherent shortcomings discussed below. They have an effect on stock assessment accuracy.

At present the method of the spline approximation of stock density (Stolyarenko, 1986, 1987, Stolyarenko, Ivanov, 1987, 1988) gets extention in the USSR. The method developed for shrimps was carried over to scallops - drag surveys (Stolyarenko, Ivanov, Berenboim, 1988), algae - underwater TV surveys (Stolyarenko, Badulin, 1988) and other commercial objects now. The method provides the opportunity to increase stock assessment accuracy substantially taking into account information about relative positions of measurements for those applications where this information has some value.

It will be a good idea to consider data of preceding surveys from viewpoint of a new advanced method. And our work deal with not only the last survey of 1987 but the previous surveys of 1983-86 with the spline approximation method. These surveys was designed as random-stratified. But the spline approximation method assepts for use unrandomly distributed stations too. Hence the method provides the opportunity to analyze both random surveys and fixed station surveys from the common viewpoint. And from the same viewpoint we can consider data from survey that specially is designed for the spline approximation method (Stolyarenko, 1987).

MATERIAL AND METHOD

Our work is based on data of trawl surveys which were carried out by Polar Institute (PINRO) in 1983-87 on Flemish Cap using random-stratified scheme. The method of analysis of trawl catches and primery statistical treatment of samples that results in weight and number estimations of cod and redfish per tow were detailed earlier (Bulatova, Chumakov, 1986). In 1983-87 about 120-130 stations were executed annually in spring-summer period (Table 1). Stock assessment results for cod and redfish which computed using the stratification method were presented by PINRO in NAFO Sessions (Chumakov, Borovkov, 1986, Chumakov, Borovkov, Noskov, 1987).

We use the following sourse data for the spline approximation method: a position of the middle point of the trawling path, an average depth along the trawling path, weight and number of fish in a catch (cod and redfish separately).

We consider a depth factor for every station to take into account biological and hydrographic conditions. So we have the same predicting basis as the stratification method uses. When we say "predicting basis" we means the information that helps to carry our knowledge about stock density in few points (where trawl stations were executed) over to each point of the area studied. The bottom relief is reconstructed by two dimensional spline with little smoothing on the basis of average trawling depths for all five surveys.

The spline approximation method is provided by use the Spline Survey Designer Software System (SSDSS) (Stolyarenko, 1987) on IBM Personal Computer (or compatible). All results and charts which presented below were generated with SSDSS.

The technique of survey design and survey analysis using a personal computer with special reference to shrimps surveys off Spitsbergen were described by Stolyarenko, Ivanov (1987). The stock distributions of cod and redfish are estimated with smoothing spline: parameter of smoothing is equal 5000 and coefficient that defines the relationship horizontal (distances) and vertical (depth) scales is equal 300.

RESULTS AND DISCUSSION

The spatial patterns for cod stock density and abundance on the basis of the survey data in 1983-87 on Flemish Cap are presented in Fig.1-5 and ones for redfish are in Fig.6-10. The scales for different shading are logarithmic. Note that a choise of scale has not effect on stock assessment because the stock density estimated is a continious function of coordinates (a spline) and namely this fuction is integrated for stock estimating. The discretization is executed for presentation only (for VGA adaptor and monitor with 256 colors we provide the opportunity to have practically a continious scale).

The survey of 1983 have brought to light the shortcoming of survey design that is inherent in the rigid stratification scheme. The survey data is not detect the decreasing of redfish cathes related the increasing of depht above 700m. Because the spline approximation method constructs stock density taking into account trend related the depth then it is advantageous to add a priori information as 7 additional stations with 900m depth and nothing cathes. If we will not use a priori information and use the restriction with 728-m boundary only then we get the redfish stock estimation with 10-percent excess.

We present for comparision tables of biomass and abundance estimates computed using the spline approximation method and the stratification method. Table 2 is for cod and Table 3 is for redfish.

Now we consider errors of the estimations. An estimation method is supported on a model of the real object. If we estimate fish stock then the model is one of stock density. Hence an error of the estimation have two components: the random error (error of the estimation of the model parameters because of inaccuracy of measurements) and the systematic error (error of the model itself). The adequacy of the model is determined by relations of the random and systematic errors: smaller systematic error in relation to random one, higher the adequacy of the model.

Practically, only the random error is estimated in stock assessment often assuming that the model is adequate, i.e. the error of the model is disregarded. Confidence interval costruction for stock estimation with the stratification method is performed by this way (Doubleday, ed., 1981). But error of the model for the stratification method is approximately the same value as the random error (Stolyarenko, Ivanov, 1987). Hence the confidence interval construction from the random error as from only component of the error involves artificial decreasing of the confidence interval.

Sources of error for the stratification method are followed: 1) mistakes in subdivision and errors in boundaries of strata (Pope, Shanks, 1986, Stolyarenko, 1986); 2)assumption of evenly distribution of stock density within a stratum with abrupt changes of the density along boundaries of strata ("the step model") (Stolyarenko, 1986). Other shortcomings are followed: 1)the method is poorly suitable to include an adaptive survey design during surveying and 2)the method is not intended for a study of the stock density at all (Stolyarenko, Ivanov, 1987, 1988).

The method of spline approximation of stock density eliminates these shortcomings. It remove the problems of delimitation of strata and correct stratification scheme. These problems are of great urgency now (Mohn, Robert, Roddock, 1987). It provides the advanced technique for taking into account biological and hydrological conditions and its model of a smooth stock density is much more natural than that of the step stratification. The spline approximation method provides optimal estimates for both stock and stock density (Stolyarenko, 1987). It permits non-random distribution of stations. So survey strategy gets great flexibility because survey design gets the adaptiveness property. The two-stage procedure of survey design consists of constructing the frame plan before surveying on the basis of preceding survey data and adaptive design during surveying. This survey procedure increases effectiveness of the costly trawl surveys because it concentrates the research efforts mainly in most valuable regions of the area studied.

Comparison of the estimates of the spline approximation method and the stratification method (Tables 2 and 3) shows ca. 10-percent deviations. The greater deviation (23 percent) for cod stock in 1985 is explained by defect of survey plan. Small depth strata have only isolated stations and the main assumption of the stratification method about evenly distribution of stock density within these strata and within the strata 8, 10, 14 is significantly violated (see Fig. 2). Therefore the estimate of the stratification method include great error.

Comparision of the estimates from year to year shows great fluctuations of ones of biomass and abundance for cod and redfish. So in 1984 redfish biomass was estimated 120.8 thou.tons, in 1985 - 49.2, in 1986 - 312.5. The such fluctuations is impossible for fish with long-term life cycle and complex age structure of population under condition the relatively constant harvesting level.

Therefore progress in direct methods of stock assessment depends not only on development the methods of design and analysis of trawl surveys. The progress depends on using other sources of measurements such as (in the first place) hydroacoustic information. The using of hydroacoustic data provide the opportunity to decrease influence of vertical migrations on stock estimations. The spline approximation method are extended to hydroacoustic surveys with taking into account the characteristic property of its measurements as local integrals (Stolyarenko, 1988). On our mind design and analysis of trawl-acoustic surveys with the spline approximation method will allow to increase accuracy of stock assessment for commercial groundfish in Northwest Atlantic.

REFERENCES

Bulatova A.Y., Chumakov A.K., 1986. USSR trawl surveys in NAFO Subareas 0,2,3. NAFO SCR Doc. 86/66, Ser. No. N1183. 13p.

Chumakov A.K., Zalmov V.Z., Shafran I.S., 1984. Assessment of groundfish on the Flemish Cap by means of trawl surveys. NAFO SCR Doc. 84/VI/41, Ser. No. N826. 14p.

Chumakov A.K., Borovkov V.A., 1986. USSR research report for 1985. NAFO SCS Doc. 86/17. Ser. No. N1179. 32p.

Chumakov A.K., Borovkov V.A., Noskov A.S., 1987. USSR research report for 1986. NAFO SCS Doc. 87/15, Ser. No. N1328, 39p.

Doubleday W.G. (Ed.), 1981. Manual on grounfish survey in the Northwest Atlantic. NAFO SCS Doc. 81/2, 60p.

Mohn R.K., Robert G., Roddick D.L., 1987. Research sampling and survey design for sea scallops (Placopecten magellanicus) on Georges Bank. J. Northw. Atl. Fish., 1987, No.2, p.117-121.

Pope J.A., Shanks A.M., 1986. Assessing sampling errors of surveys. ICES C.M. 1986/G:2, 12p.

Stolyarenko D.A., 1986. Data analysis of trawl shrimp survey with spline approximation of stock density. ICES C.M. 1986/K:25. 16p.

Stolyarenko D.A., 1987. The spline approximation method and survey design using interaction with a microcomputer: Spline Survey Designer Software System. ICES C.M. 1987/K:29, 24p.

Stolyarenko D.A., Ivanov B.G., 1987. The new approach to bottom trawl surveys with special reference to deep water shrimp (Pandalus borealis) off West Spitsbergen. ICES C.M. 1987/K:30, 36p.

Stolyarenko D.A., Ivanov B.G., 1988. [The method of spline approximation of density for stock assessment for results of bottom trawl surveys with special reference to shrimps Pandalus borealis off Spitsbergen.] In: "Commercial shellfish. Proceedings of VNIRO", pp.49-76 (in Russian)

Stolyarenko D.A., 1988. [Trawl, hydroacoustic and TV fish stock surveying as measuring local integrals: stock assessment and survey design.] In: "Papers of III All-Union conference on experimental design and analysis of random fields and processes. Grodno, 1988" (in Russian)

Stolyarenko D.A., Ivanov B.G., Berenboim B.I., 1988. [Scallops survey and stock assessment off Bear Island: applications of the new methods.] In: "Papers of II All-Union conference on ecology of the Barents Sea. Murmansk, 1988" (in Russian)

Stolyarenko D.A., Badulin V.V., 1988. [A new approach to algae stock assessment with special reference to Baltic algae.] In: "Papers of III All-Union conference on marine biology. Sebastopol, 1988" (in Russian)

Table 1

Number of trawl stations and period for the Soviet surveys on Flemish Cap in 1983-87

Year	Vessel, voyage	Period	Number of trawl stations	Depth range
1983	Suloy, 27	24.04 - 24.05	122	127 - 728
1984	Suloy, 30	30.03 - 25.04	124	127 - 728
1985	Genichesk, 2	31.03 - 16.04 25.04 - 01.05	126	127 - 728
1986	Kononov, 34	17.06 - 05.07	127	127 - 728
1987	Perseus-III, 37	21.06 - 04.07	130	127 - 728

Table 2

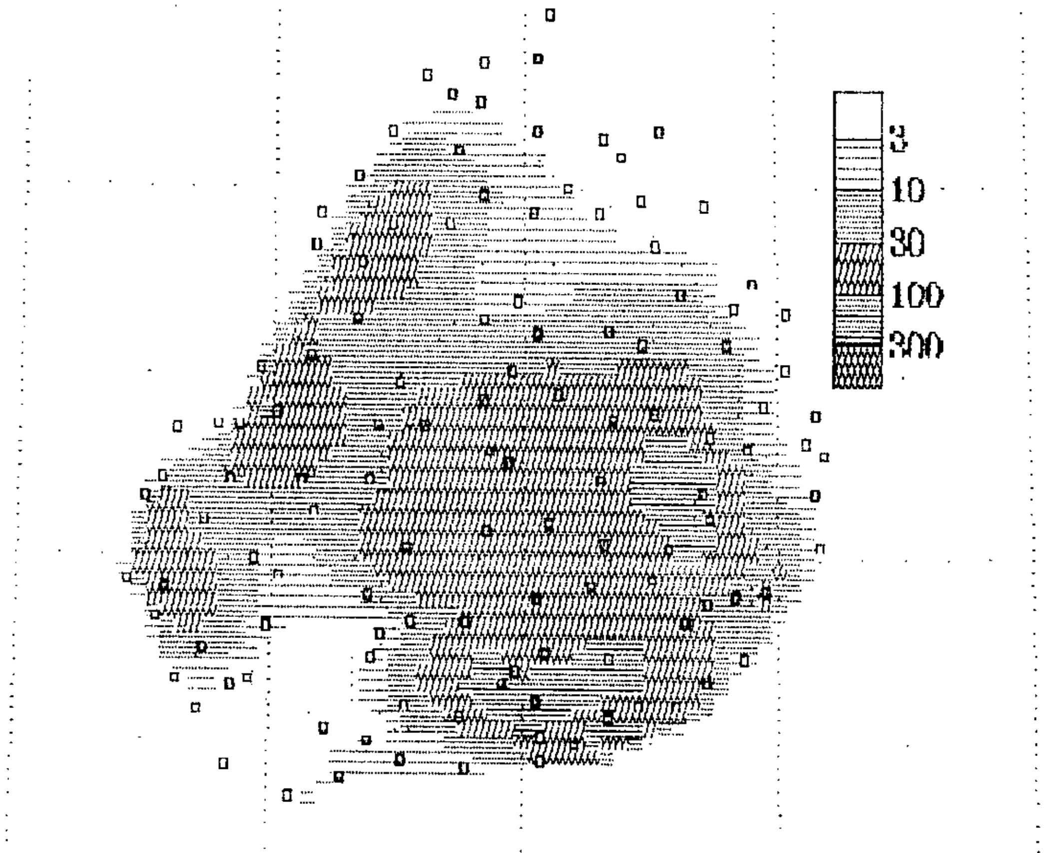
Cod biomass and abundance estimations on Flemish Cap in 1983-87 with the spline approximation method and the stratification method

Year	Abundance, 10		Biomass, thou.tons	
	spline	strat	spline	strat
1983	66.7	65.4	22.8	23.0
1984	63.3	60.5	32.3	31.1
1985	30.9	37.1	22.9	28.1
1986	35.9	37.2	25.4	26.1
1987	41.7	36.8	11.4	12.3

Table 3

Redfish biomass and abundance estimations on Flemish Cap in 1983-87 with the spline approximation method and the stratification method

Year	Abundance, 10		Biomass, thou.tons	
	spline	strat	spline	strat
1983	886.9	644.0	165.7	154.9
1984	334.8	376.7	120.8	132.3
1985	169.0	177.3	49.2	51.9
1986	1222.3	1200.2	312.5	309.5
1987	477.7	463.1	109.0	106.4



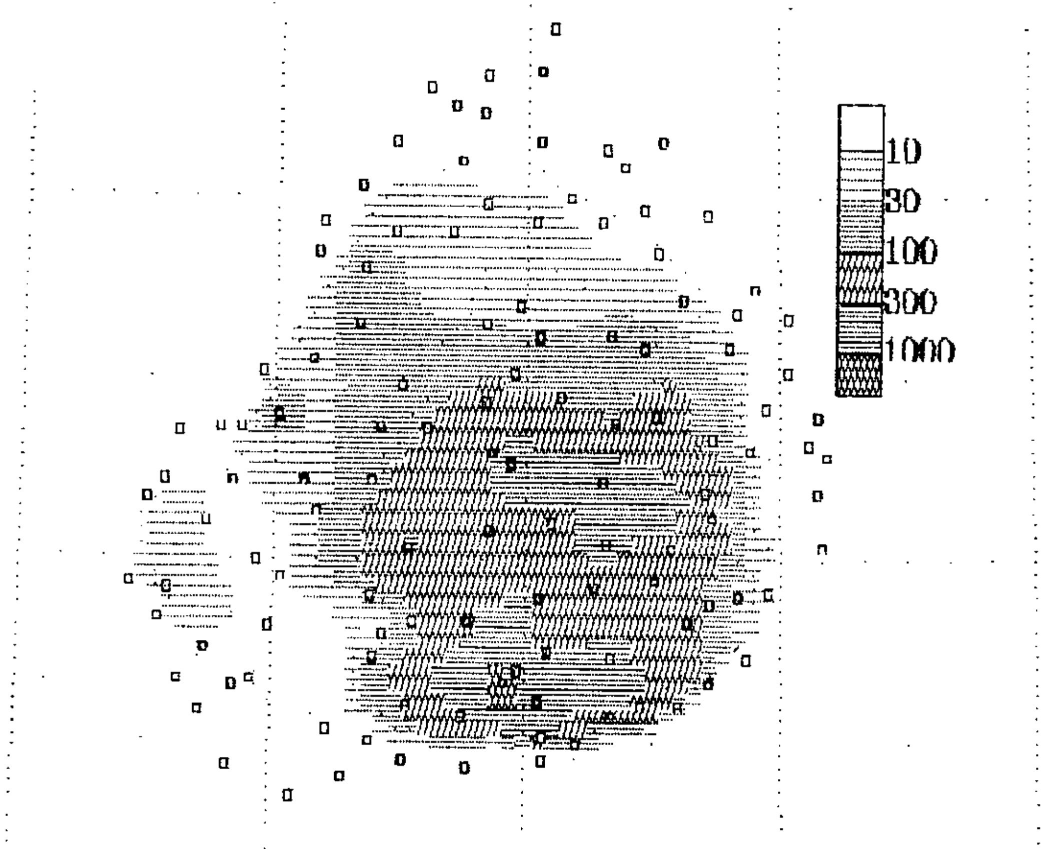


Fig.1. The spatial pattern for cod stock density and abundance in 1983. Legend - kg per tow for biomass and number per tow for abundance

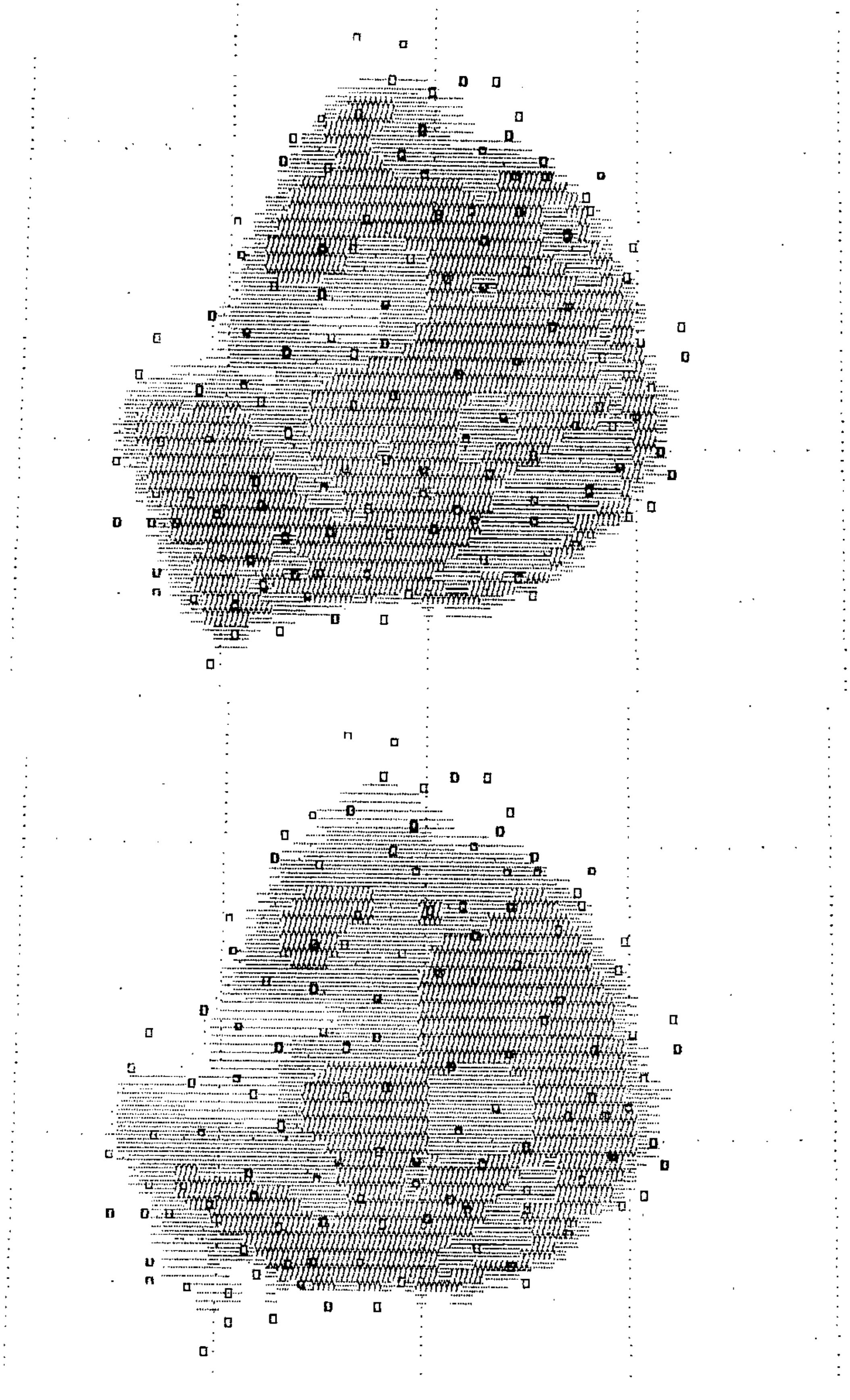


Fig.2. The spatial pattern for cod stock density and abundance in 1984

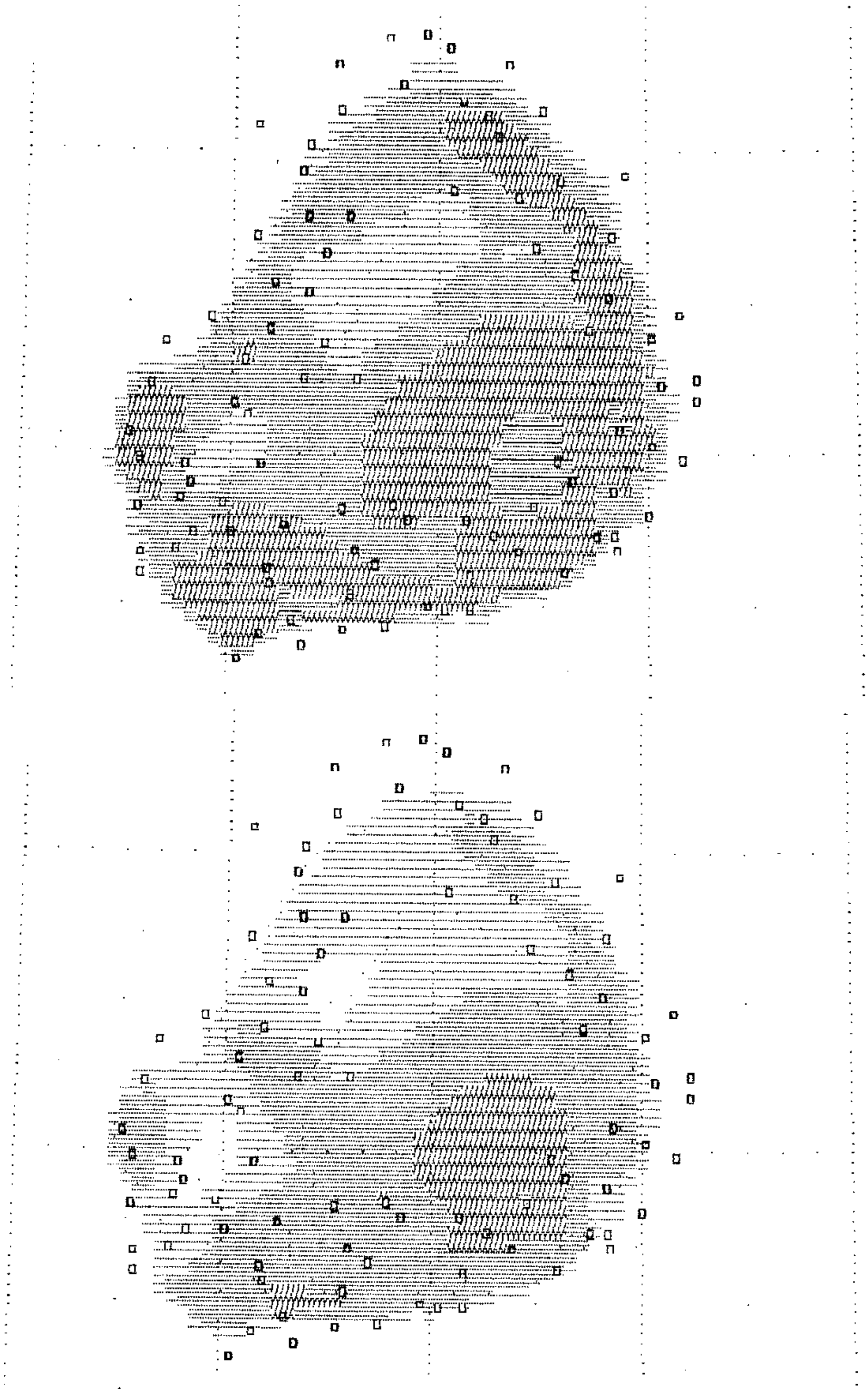


Fig.3. The spatial pattern for cod stock density and abundance in 1985

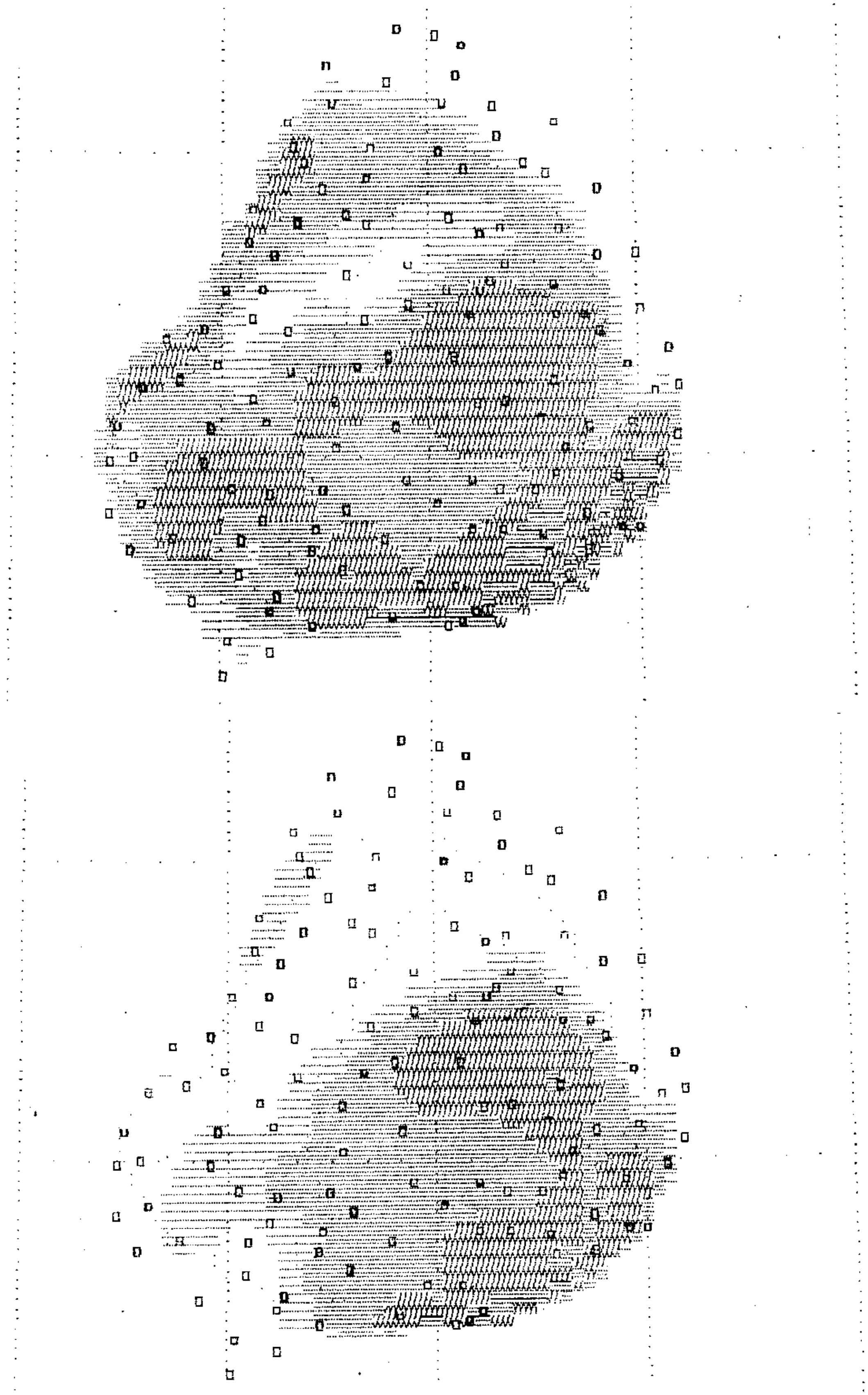


Fig.4. The spatial pattern for cod stock density and abundance in 1986

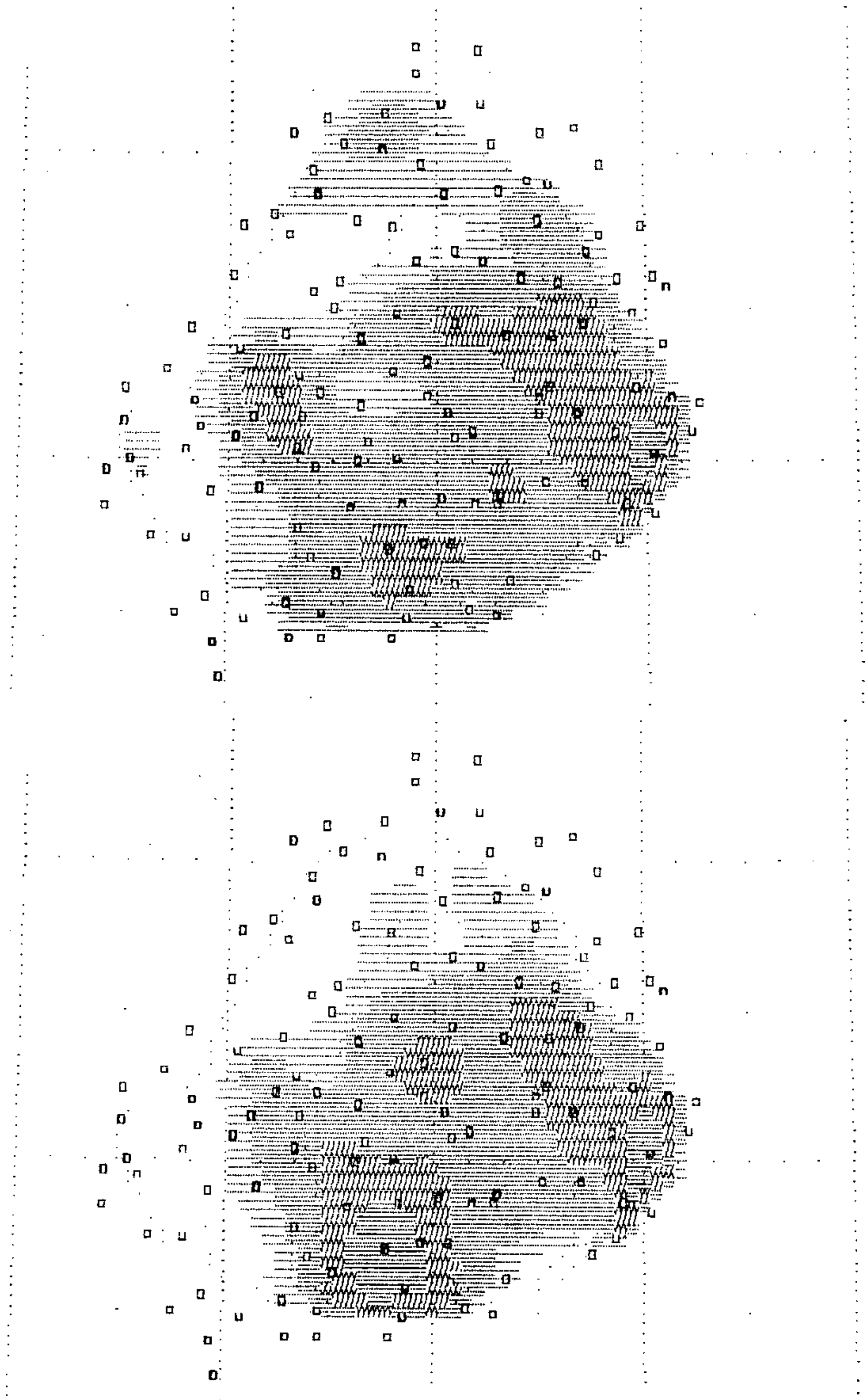


Fig.5. The spatial pattern for cod stock density and abundance in 1987

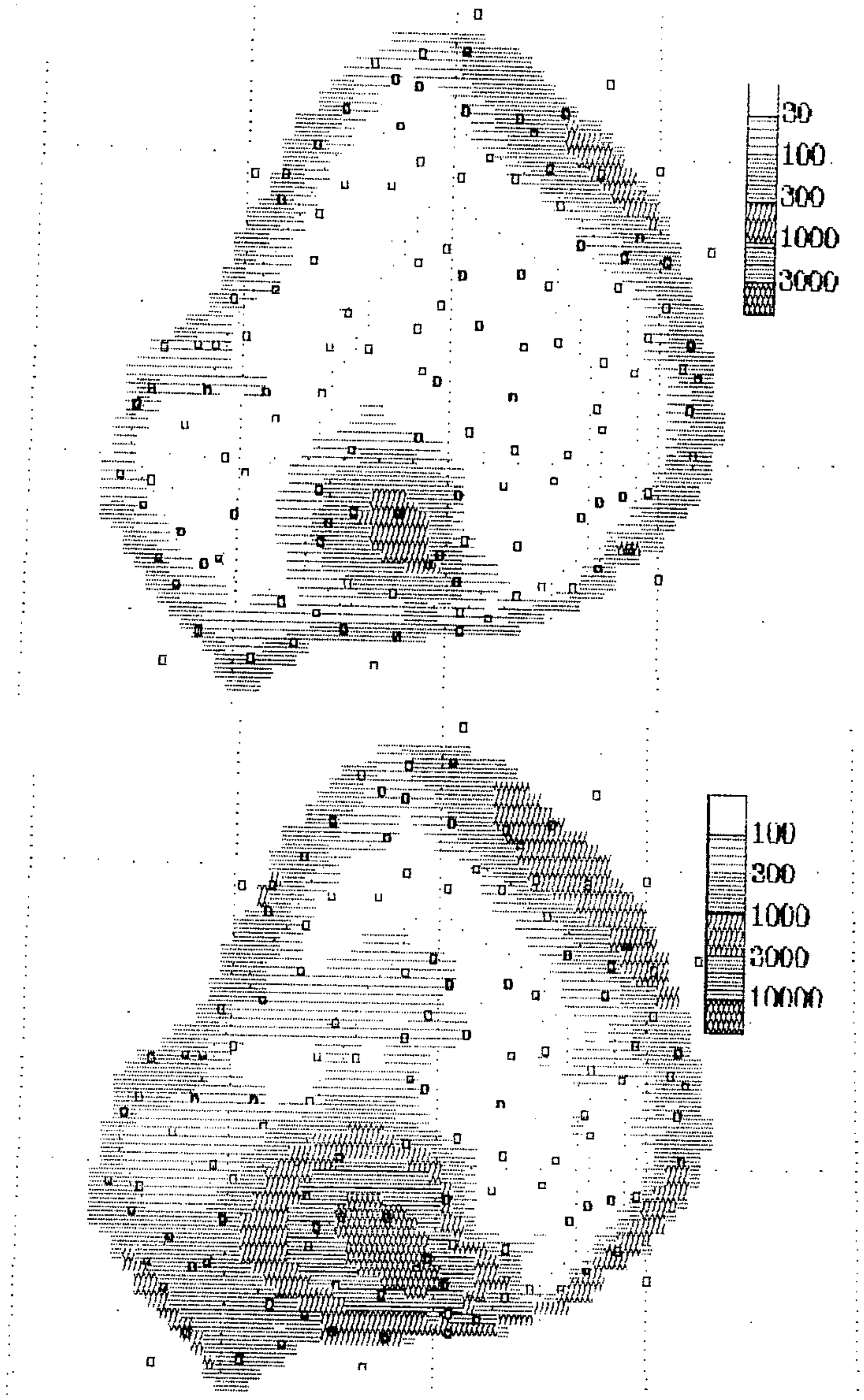


Fig.6. The spatial pattern for redfish stock density and abundance in 1983. Legend - kg per tow for biomass and number per tow for abundance

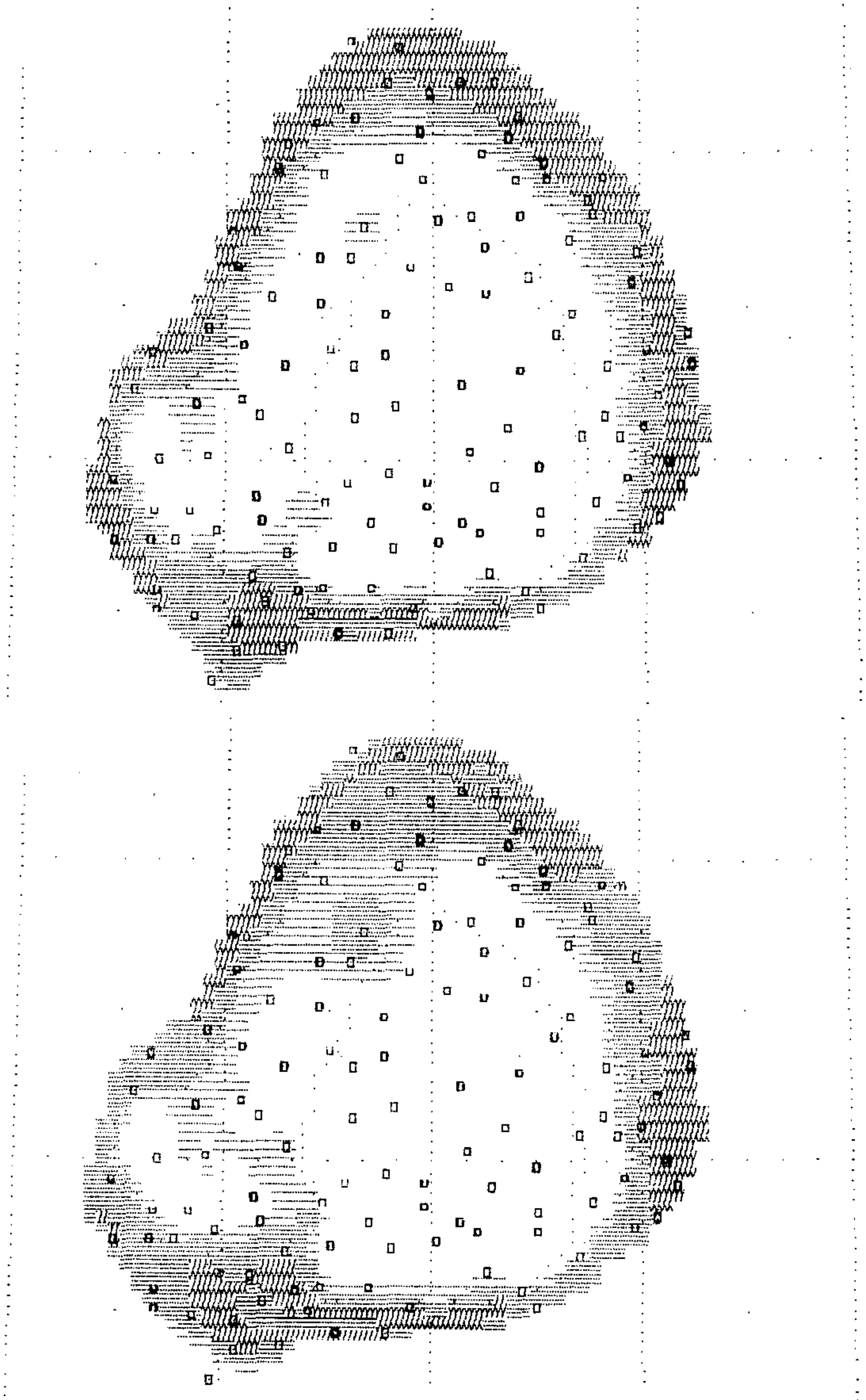


Fig.7. The spatial pattern for redfish stock density and abundance in 1984.

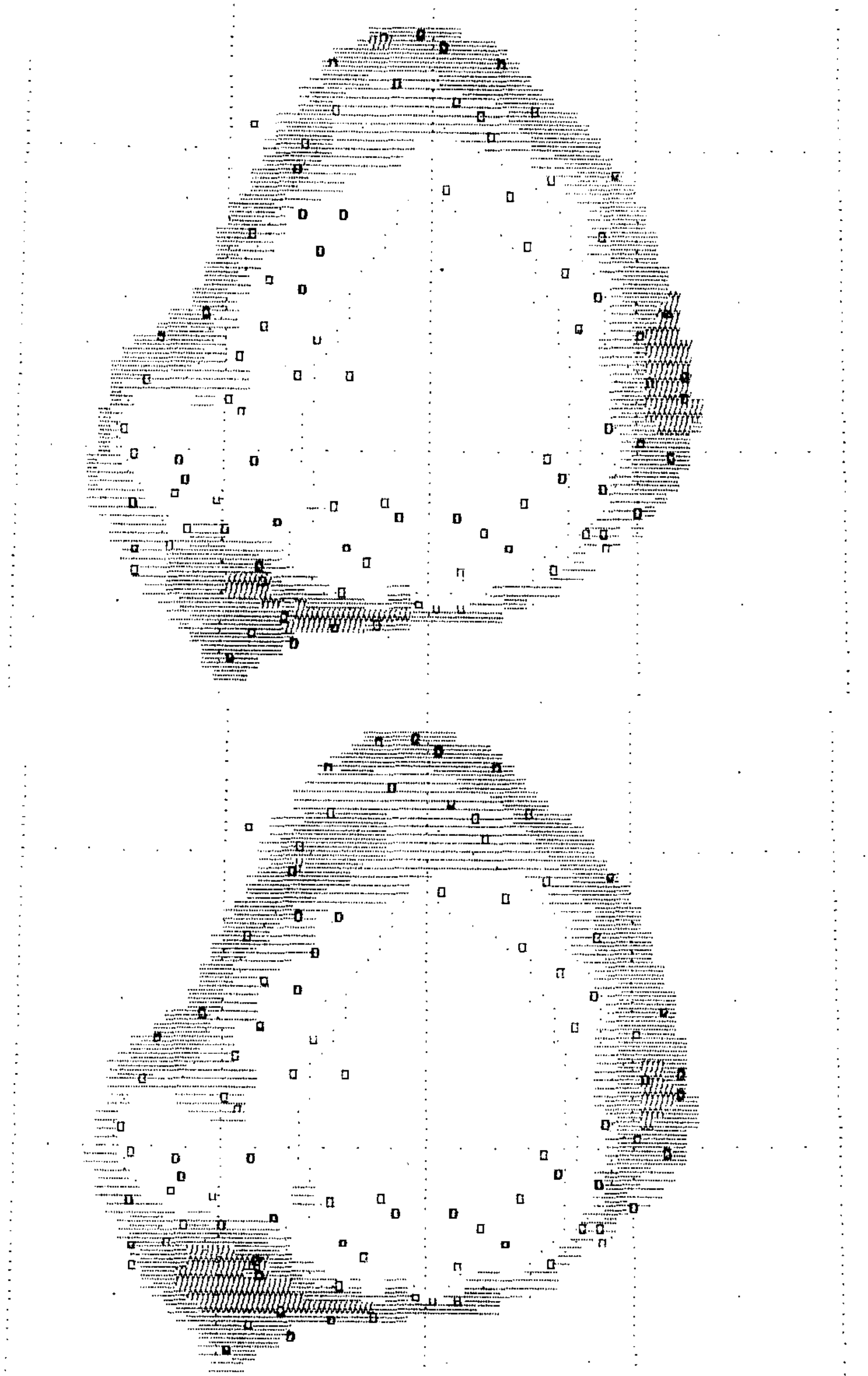


Fig.8. The spatial pattern for redfish stock density and abundance in 1985.

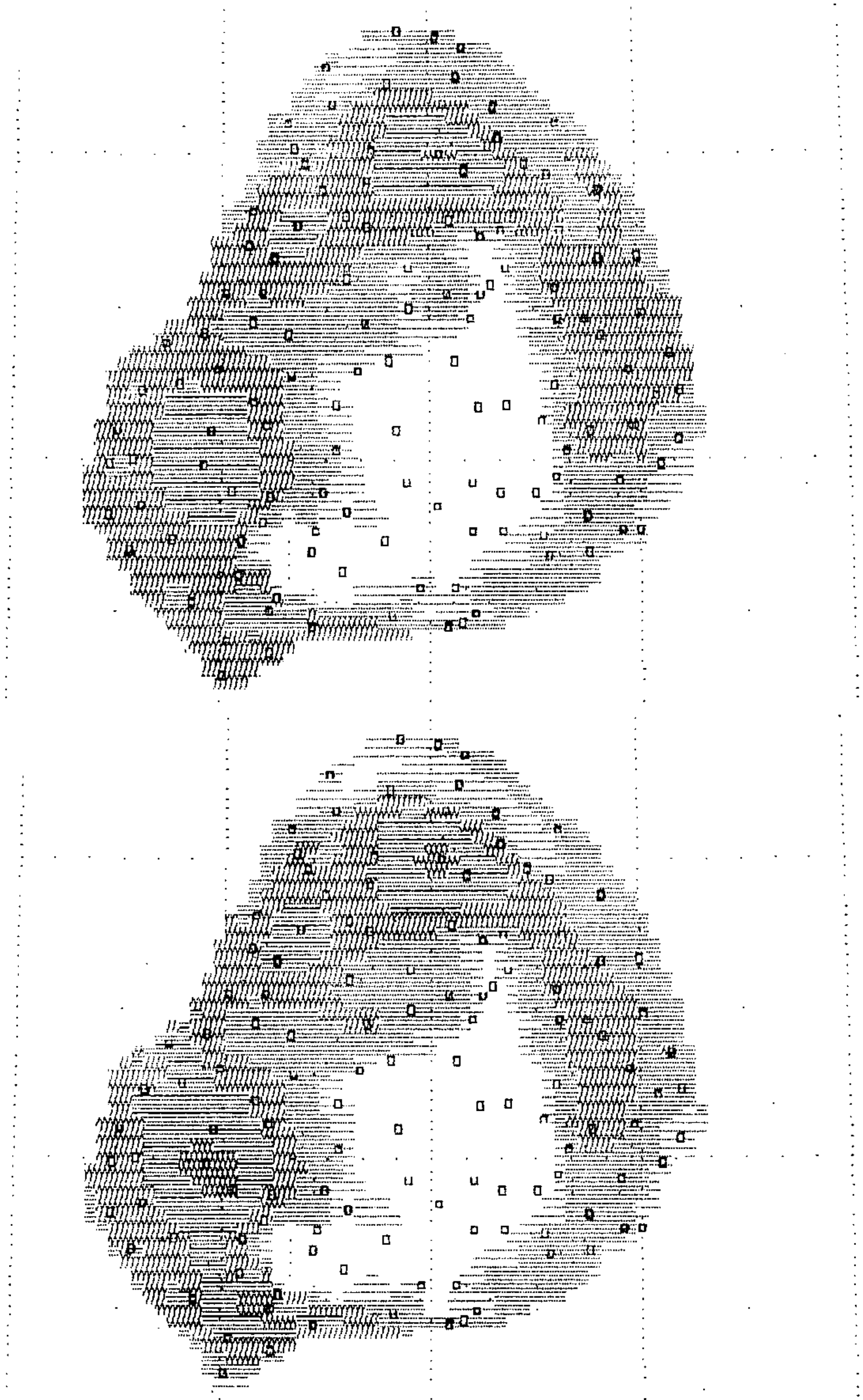


Fig.9. The spatial pattern for redfish stock density and abundance in 1986.

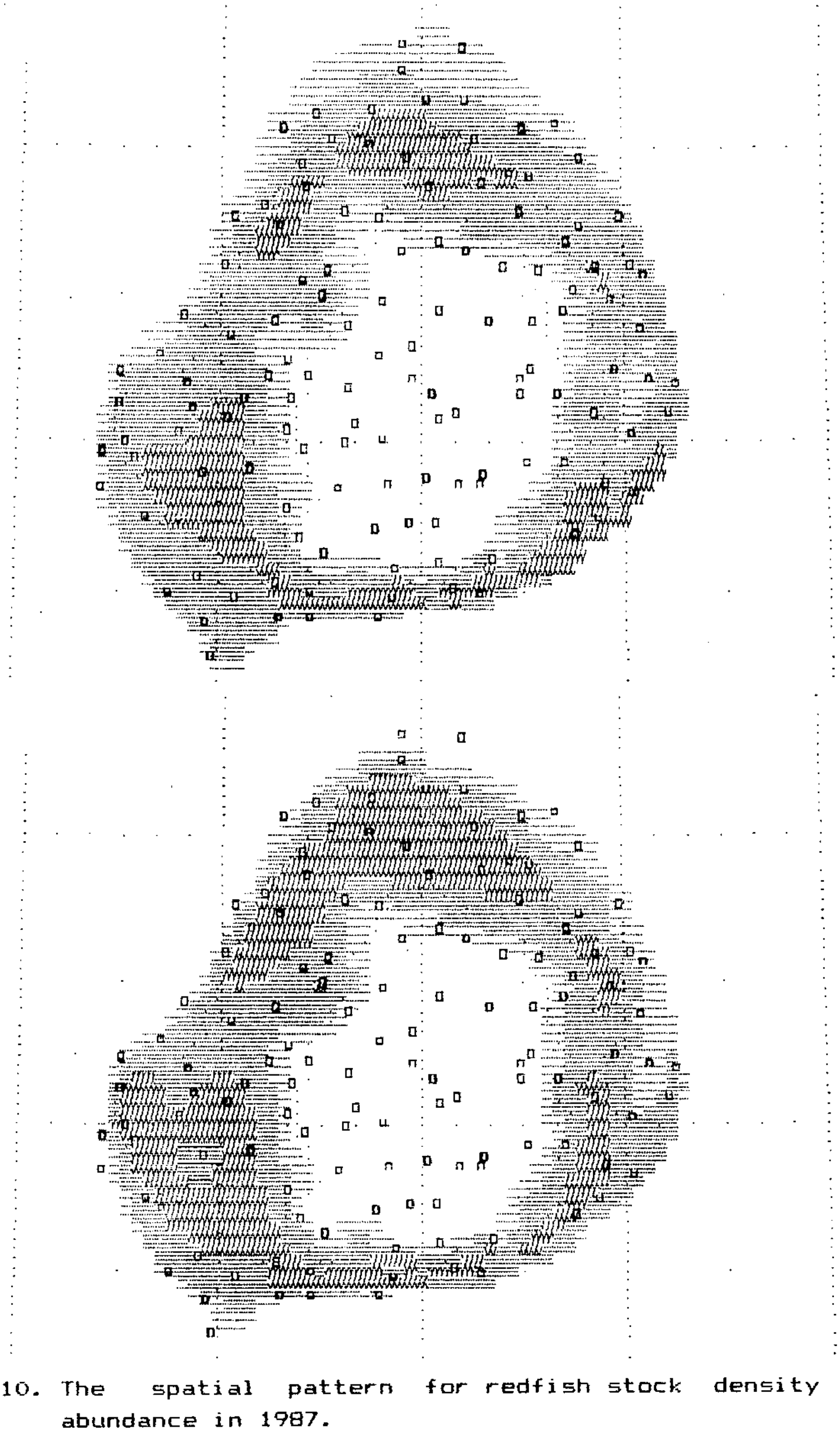


Fig.10. The spatial pattern for redfish stock density and abundance in 1987.