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A STUDY OF THE ZOOPLANKTON OF LOWER CHESAPEAKE BAY

NSF-RANN

Annual Report 1972

By

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INTRODUCTION

Studies of zooplankton are necessary to any broader investigation of aquatic ecosystems. In estuaries such as the Chesapeake Bay, zooplankton function as both detritus feeders and primary consumers of phytoplankton. Some of them, including chaetognaths, medusae and large copepods, are members of a higher trophic level. The diversity of zooplankton, especially in neritic areas, contributes to the complexities of such studies.

The present project was intiated wholly as a result of the interest of the National Science Foundation in Chesapeake Bay and the establishment of the Chesapeake Research Consortium. The design of the research was planned to integrate with ongoing phytoplankton and plankton physiology studies at VIMS, although it was deemed necessary to cover a much wider study area than that of the other programs. No comprehensive study of the zooplankton of Chesapeake Bay has been carried out since the 1920's. Much of that work (Cowles, 1930) is in error and taxonomically obsolete.

Initial goals of the project were to quantitatively describe the zooplankton in the lower, or Virginia, region of Chesapeake Bay, to analyze these data for diversity and community structure, and to report the results in terms useful to a general model of the Bay ecosystem. To be included in these analyses were all components of the zooplankton, including the microzooplankton. Together with the phytoplankton and plankton physiology programs, we could therefore contribute data on the following components of ecosystems,

1. Inorganic substances
2. Organic compounds
3. Climate regimes (temp., S‰, etc.)
4. Autotrophs
5. Phagotrophs (macro-consumers)
6. Saprotrophs (heterotrophic organisms)

and on the following processes (Odum, 1972).

1. Food chains
2. Diversity patterns
3. Nutrient cycles

Although considerable retrenching has been necessitated by a shyness in funding, the specific objectives of the zooplankton aspects of this research project remain:

1. A complete inventory of species
2. A description of the horizontal and seasonal distribution of biomass
3. Relation of species occurrence and abundance to hydrography
4. A definition of zooplankton communities and dominant species
5. A description of zooplankton succession within the lower Bay
6. Calculation of diversity indices and correlation of diversity with environmental parameters
7. Description and quantification of the biochemistry of dominant zooplankters and
8. Life cycle studies of dominant zooplankters.

SAMPLING PLAN

Approximately 700 nm^2 of Lower Chesapeake Bay are being sampled for zooplankton. The study area extends from latitude 37°40'N to the mouth of the bay. The area has been gridded into one-square-mile stations and divided into eight strata (Figs. 1-10). These strata were preselected on the basis of depth, thereby separating channels from shoaler areas, and with a view to separating the higher salinity eastern half of the bay from the western half.

Stations within strata are consecutively numbered. Those to be sampled in any given month are selected from a table of random numbers. From three to five stations in each stratum have been sampled monthly since August 1971, except for unavoidable misses due to either weather conditions, vessel breakdowns or lack of vessel time. All sampling has been conducted during daylight hours from the 55-ft R/V Pathfinder and is completed each month within three or four consecutive days.

Shipboard Observations and Procedures

Tidal stage, sky conditions, wind direction and velocity, air temperature, time of day, ships position, depth of water, and depth of Secchi disk visibility are recorded at each station. A submersible pump (Little Giant) with 1/2 inch hose is then lowered to an even number of meters below the surface, but safely off the bottom (maximum 14 meters). Pumped water is directed through a system of filters consisting of a 202 micron screen that serves to exclude the larger zooplankton, a 35 micron screen that traps microzooplankton, and a plastic 55 gallon drum that collects the filtrate.

Water samples for salinity and dissolved oxygen are taken at 2 meter intervals during this pumping operation. Water temperature is also recorded at each 2 meter interval. Beginning in April 1972, samples have been taken at 6 and 0 meters for analysis of the nutrients nitrite, nitrate and orthophosphate. These are preserved with mercuric chloride and kept on ice.

Material collected on the 202 micron filter is discarded; that on the 35 micron filter is preserved in 5% formalin, and an aliquot of the filtrate is preserved in Lugol's iodine solution. The vessel is then placed underway for towed net collections.

Towed nets include 8 inch Bongo nets and 5 inch Clarke-Bumpus samplers. Both samplers are metered, the former with a General Oceanics flowmeter attached to a 2 foot Braincon depressor, the latter with its incorporated Veeder meter. These meters are periodically calibrated at Langley Field, Virginia.[1] Nets used are constructed of 202 Nitex.

Bongo nets are towed obliquely, from depth to the surface. Depending on depth, tows vary from 4 to 8 minutes. Collected plankton in the paired nets is kept separate, that from one net preserved in 5% formalin; the other collection is rinsed in distilled water, placed in a plastic bag and frozen over dry ice.

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[1] High Performance Craft Powering Branch, Naval Ship Research and Development Center, Langley Field, Virginia.

A Clarke-Bumpus sampler is lowered to a specified depth, towed horizontally and retrieved after 5 minutes. Collected zooplankton is preserved in 5% formalin.

Laboratory Procedures

Physical, chemical and meteorological data are entered on IBM forms for storage and retrieval.

Preserved Bongo samples of zooplankton are being sorted for taxonomic aspects of the project. An initial split (1/2) of this sample is scanned for rare forms, successive splits for more abundant groups. The final aliquot is one that will provide from 200-500 of the most abundant zooplankter (usually copepods). Sorted groups such as copepods, cladocerans, decapod larvae, chaetognaths, polychaetes, mysids, hydromedusae, fish eggs and fish larvae are counted and placed in separate vials for identification. One-half of the initial split is stored for future reference.

The frozen Bongo sample (replicate of the above) is used for chemical analyses. It is initially lyophilized and dry weight is recorded. The dried material is then used for analyses of protein, carbohydrates, total lipids, ash, chitin and fatty acids.

The final filtrate from pumped samples is aliquoted and replicates are vacuum filtered through a 0.45 micron Millipore filter. These filters are washed in distilled water to remove salt, dried, then clear-mounted with Permount on 1"x3" glass slides.

Remaining preserved samples are being stored until funding is adequate to allow further analyses.

PRELIMINARY RESULTS AND PROGRESS

Hydrography of the Lower Bay

Hydrographic data collected during these cruises are not intended to provide a definitive view of the hydrography of the area. A complete physical survey of the area would require many vessels employed over closely-controlled time periods. Rather, these data are collected only for future correlation with occurrence and abundance of zooplankton species.

Zooplankton cruises have occupied from one to four consecutive days each month from August 1971 through May 1972. Plots of resulting hydrographic data are therefore not perfectly synoptic and isolines have been drawn without adjustment for included tidal excursions.

Temperature (Figs. 11-30)

Water temperatures were recorded at intervals of two meters from the surface to the greatest depth of pumping (maximum 14 meters). Figures 11-30show the horizontal distribution of temperatures recorded at the surface and at 6 meters. Horizontal variation in surface temperatures was slight, as might be expected for relatively short sampling periods of three to four days. In summer months coolest temperatures were found at the bay mouth and along the eastern half of the bay. Surface temperatures were quite uniform over the sampling area in October, November and December, then showed the reverse of summer patterns in January-March. Temperatures were again uniform in April. May observations showed the summer condition of cooler water at the bay mouth and warmer water up-bay. Temperature patterns at 6 meters were similar.

The vertical distribution of temperatures varied seasonally. The water column was thermally stratified in August and September, unstratified in October through March, then stratified again in April and May. During the winter months of instability, numerous instances were observed of warmer water underlying cold surface layers. When the water column was stratified, surface temperatures at a given station often exceeded those at 10 meters depth by 2-3°C. Mean temperatures within sampling areas are given in Table 1 for the selected depths of 0 and 6 meters. Temperatures in Areas B and C are often moderated by the influence of the ocean. Although Area A is also located toward the mouth of Chesapeake Bay, it is in the path of outflowing, low salinity Chesapeake waters.

Salinity (Figs. 31-50)

Water samples were taken at 2 meter depth intervals at each station for salinity determinations. Results fit the well-known and classical picture of a northern hemisphere estuary, with low salinity water flowing to the right-hand, or western, side of the bay. Therefore, at any given latitude, salinity generally increases from west to east as one traverses the bay.

The selected study area is largely the polyhaline (> 18‰) region of Chesapeake Bay. Area G is more often mesohaline in nature and other areas may, in times of heavy runoff, be freshened below a salinity of 18‰. An example of this may be seen in the

Table 1. Mean water temperature at 0 and 6 meters depth, lower Chesapeake Bay, August 1971-May 1972.

Month	Depth(m)	A	B	C	D	E	F	G	H
		Sampling Area							
Aug	0	25.2	25.1	25.4	26.2	25.7	25.3	25.8	25.6
	6	24.6	23.5	23.7	26.0	25.2	24.5	25.7	25.1
Sept	0	25.2	24.6	24.7	25.0	25.4	24.1	24.0	24.1
	6	24.4	24.2	23.1	24.5	24.5	24.2	24.1	24.4
Oct	0	19.7	20.0	19.7	19.6	19.7	19.6	19.5	19.5
	6	19.6	20.0	19.7	19.7	19.6	19.6	19.5	19.5
Nov	0	14.1	14.3	14.9	14.2	14.5	14.7	---	14.6
	6	14.3	14.3	14.9	14.6	14.5	14.7	---	14.8
Dec	0	---	---	---	8.4	8.5	---	8.5	8.6
	6	---	---	---	8.4	8.6	---	8.6	8.5
Jan	0	4.1	5.3	4.8	4.7	4.7	5.5	4.9	4.8
	6	5.1	5.4	5.0	4.9	4.8	5.2	4.9	4.9
Feb	0	5.4	5.6	5.6	5.7	5.3	4.5	4.2	4.4
	6	5.4	5.6	5.6	5.7	5.6	4.5	4.2	4.4
Mar	0	6.5	7.2	6.9	7.0	6.7	6.3	5.9	6.3
	6	6.6	7.2	6.8	6.8	6.7	6.2	5.7	6.1
Apr	0	9.2	9.5	9.3	8.9	9.1	9.5	9.3	8.9
	6	8.9	8.9	8.7	8.8	8.8	9.0	8.8	8.8
May	0	16.8	17.2	16.2	16.8	16.8	19.2	19.2	18.0
	6	16.4	16.1	15.4	16.4	15.9	16.3	17.1	16.9

salinity distribution for April 1972 (Fig. 47) when most of the study area was mesohaline.

Table 2 lists the mean salinity within sampling areas at the selected depths of 0 and 6 meters.

Dissolved Oxygen and Other Parameters

Measurements of dissolved oxygen were also obtained from each 2-meter depth interval, but since oxygen never appeared to be limiting, data are not included in this report. They are, however, available for recall from the VIMS data storage system. Values as low as 3 to 4 mg/liter were observed at 8-10 m depth in the upper portion of the study area in August, and values near 4 mg/liter were again evident in September over a wider area. All waters appeared to be well oxygenated during the remainder of the year.

Other parameters measured at each station but not included in this report are water transparency as measured by a Secchi disc and meteorological factors recorded at each station.

Nutrients and Phytoplankton

Measurements of nitrite nitrogen, nitrate nitrogen and orthophosphate were initiated on these cruises in April 1972. Samples have been obtained at each station from just below the surface and at a depth of six meters. They are collected in acid-rinsed polyethylene bottles, preserved in mercuric chloride then transported to the laboratory on ice for filtration and analysis. Results for the months of April and May 1972 are shown in Figures 51-62.

Table 2. Mean salinity at 0 and 6 meters depth, lower Chesapeake Bay, August 1971-May 1972.

		Sampling Area							
Month	Depth	A	B	C	D	E	F	G	H
Aug	0	23.71	23.42	22.15	18.49	18.95	18.46	16.14	17.26
	6	25.12	27.28	25.41	19.98	23.00	23.52	16.85	19.86
Sept	0	23.32	24.72	25.03	20.50	21.95	22.45	18,07	20.88
	6	24.77	25.96	28.18	22.52	24.91	22.64	18.18	21.35
Oct	0	21.26	23.89	23.22	18.92	19.72	21.02	17.14	18.97
	6	21.29	26.16	24.37	18.83	20.51	23.80	17.41	21.75
Nov	0	21.73	26.39	24.11	17.84	19.98	19.68	---	21.83
	6	22.60	27.68	26.07	17.90	22.84	23.25	---	22.49
Dec	0	---	---	---	19.98	20.95	---	16.48	20.60
	6	---	---	---	20.00	21.42	---	18.16	21.34
Jan	0	20.61	22.77	21.64	19.30	19.63	19.30	17.23	17.92
	6	24.02	22.99	24.56	19.62	19.91	20.77	17.44	18.61
Feb	0	22.40	21.74	21.84	19.44	18.76	18.56	15.43	18.51
	6	22.86	24.79	24.27	22.74	21.83	22.29	17.47	21.19
Mar	0	22.49	26.31	25.91	16.92	16.93	19.35	14.16	18.31
	6	25.01	28.69	27.13	17.55	18.76	21.28	15.29	19.78
Apr	0	18.37	15.68	17.72	16.97	16.89	13.56	12.91	18.12
	6	22.55	21.10	23.07	17.30	21.00	18.15	14.32	19.01
May	0	18.96	22.13	22.60	15.57	16.56	16.47	11.90	14.73
	6	19.11	22.35	23.30	16.41	18.99	21.72	13.36	17.57

Nitrites are at their highest level (> 1 μg-at/liter) in the upper central portion of the study area. In April, concentrations were also relatively high along the eastern side of the bay. Nitrates were found in concentrations >12 μg-at/liter in the upper portion of the study area in both months. Concentrations generally decreased seaward. Orthophosphate concentrations were highest in mid-Bay and channel stations.

No direct studies of phytoplankton from these cruises have yet been initiated. However, aliquots of the final filtrate obtained from our pumping and filtering procedure have routinely been vacuum filtered through 0.45 micron Millipore filters. These filters are dried and clear-mounted on 1"x3" glass slides and stored for future analysis. Most of the material collected on these filters (having previously passed through a 35 micron screen) is phytoplankton. These slides will provide quantitative reference material.

Zooplankton

Analyses of collected zooplankton samples have been limited to the 8 inch bongo samples. Pumped zooplankton (35-202 micron fraction) and Clarke-Bumpus samples are stored in 5% formalin. Since bongo samplers were towed in a stepped oblique manner, the collected zooplankton represents a composite of the populations present throughout the water column.

Large scyphozoans and ctenophores that tend to disintegrate in formalin are counted and discarded before preservation; these counts are recorded on plankton log sheets. The remainder of the sample is preserved and returned to the laboratory for analysis. Prior to splitting and sorting of samples, settled volumes of zooplankton are routinely obtained by the use of Imhoff cones. These results will be included below with other biomass estimates.

Preliminary Sorting and Estimation of Numbers

The major task of any zooplankton survey is the sorting of forms prior to identification. This study has been no exception. Preliminary sorting of successively smaller aliquots insures against an investigator missing many rare forms and yet reduces the collection to a manageable number of organisms within vials of higher taxonomic groups. The taxonomic groups, some broader than others, into which we have been sorting these collections include: copepods, cladocerans, barnacle larvae, copepod nauplii, decapod larvae, polychaetes, fish eggs and larvae, pelecypods, gastropods, stomatopods, mysids, chaetognaths, hydromedusae, medusae, ctenophores, flatworms, forams, isopods, amphipods, cumaceans, ostracods and tunicates. At the time of writing this report (June 13, 1972), a total of 227 of the bongo samples have been so sorted. The various sorted groups are stored in separate vials for eventual identification to species, and an initial one-half split of the total sample is stored in the event that a specialist on any particular group needs recourse to the original sample.

Counts of both groups and species are to be entered on IBM cards, using a format being designed at VIMS (Richard Swartz, personal communication). Since these counts will be relative to the volume of water sampled, as based on meter revolutions and calibration, the counts of only a few selected groups are presented in this report. These are presented as numbers per minute of tow (bongo samples) in Table 3. Our bongo net tows sample approximately 2.25 cubic meters of water each minute. Therefore, numbers presented in Table 3 should be divided by 2.25 to yield an approximation of density of organisms per cubic meter. More exact calculations will be forthcoming.

Biomass Estimates

A minute of towing is again used as the basic unit of measurement in estimates of biomass (Table 4). Presently available estimates are those of settled volume, in milliliters of zooplankton per minute of tow with an eight-inch bongo net, and dry weight in milligrams per minute of tow. Both estimates are presented as monthly means within each of the eight sampling areas, A-H.

Biomass decreased rapidly from unitial sampling in August to November 1971. It remained low through January 1972, increased somewhat in February and March, then decreased again in April and May.

Chemical Analyses

An integral part of the zooplankton program since its initiations, chemical analyses of frozen zooplankton samples have been conducted in cooperation with the Plankton Physiology program (P. L. Zubkoff). Those analyses already available are presented in Table 3, along with counts of copepods, cladocerans and chaetognaths. These include ash weight, total protein and total lipid. Analyses of fatty acids

Table 3. Numbers of copepods, cladocerans and chaetognaths captured per minute of tow with an 8-inch bongo net, and chemical measurements made on frozen replicates (total zooplankton), lower Chesapeake Bay, August 1971-May 1972.

		Numbers Captured Per Minute			Percent of Dry Weight		
Month	Station Number	Copepods	Clodocerans	Chaetognaths	Ash	Protein	Total Lipids
Aug 71	A30	5,610	109,000	14	19.4	51.0	4.6
	A69	16,900	12,000	32	9.6	26.5	5.0
	A83	7,170	39,100	121	24.3	41.4	4.3
	B03	55,700	547,000	1	17.5	34.0	7.3
	B16	17,600	254,000	6	17.8	30.3	5.8
	B36	15,800	113,000	5	15.3	44.3	3.8
	B68	6,140	181,000	102	19.9	30.0	6.3
	B79	11,500	121,000	154	34.7	30.6	6.0
	C03	13,000	89,700	19	17.0	38.8	3.8
	C13	9,140	33,100	0	7.3	37.3	4.7
	C33	6,350	141,000	6	21.5	35.6	4.9
	D24	18,400	14,200	1	12.3	40.1	9.1
	D25	60,000	22,900	11	12.0	34.6	6.7
	D38	94,700	46,600	17	12.6	29.8	9.9
	E03	25,700	29,000	56	25.5	36.6	4.9
	E25	62,900	103,000	69	18.6	32.7	5.9
	E75	18,600	76,800	0	17.4	40.0	3.5
	F08	69,600	142,000	14	36.7	28.8	6.0
	F22	34,800	96,500	99	16.5	36.0	5.9
	F31	73,300	328,000	51	16.9	18.7	6.9
	G37	73,700	83,600	19	15.9	38.8	5.3
	G40	42,600	57,300	1	12.6	36.1	7.5
	G71	85,600	20,300	0	13.3	38.6	6.3
	G107	20,200	7,470	< 1	8.0	41.4	4.7
	G120	40,500	92,200	0	12.3	44.0	6.1
	H36	27,000	21,700	14	15.7	41.0	6.2
	H49	25,800	33,300	3	10.4	43.4	7.1
	H64	69,900	115,000	53	--	--	--
	H95	38,500	54,300	90	12.6	20.9	11.5
	H103	276,000	292,000	128	9.6	43.8	6.5
Sept 71	A70	12,500	533	725	11.5	61.5	3.8
	A74	2,070	650	278	29.0	44.7	3.1
	B13	1,710	1,780	70	21.8	47.1	3.6
	B31	7,710	13,200	784	15.3	55.2	4.0
	B44	4,020	1,340	472	--	48.0	3.1

Table 3. (Cont)

		Numbers Captured Per Minute			Percent of Dry Weight		
Month	Station Number	Copepods	Clodocerans	Chaetognaths	Ash	Protein	Total Lipids
Sept (Cont)	B68	5,480	4,990	270	12.6	46.2	4.2
	C33	3,350	44	173	--	41.9	4.3
	C38	9,110	1,380	1,070	--	47.2	5.2
	D01	156,000	2	39	12.0	48.0	4.0
	D08	46,200	5	352	19.0	46.9	4.0
	E56	32,000	1,040	94	--	48.8	6.0
	F08	12,000	1,010	243	11.8	62.5	3.8
	F11	17,300	165	499	12.4	60.3	1.9
	F39	13,000	896	192	13.7	37.2	5.3
	G56	38,100	66	192	--	58.3	4.4
	G81	29,500	13	37	14.4	52.4	2.8
	G96	22,800	< 1	137	8.7	38.6	4.6
	G126	47,600	0	64	--	68.0?	2.2
	G139	29,900	797	34	10.0	59.5	3.3
	H21	11,400	50	107	9.9	54.8	5.5
	H27	65,700	32	98	11.3	67.7	2.9
	H33	28,500	30	314	12.1	58.1	4.8
	H59	26,100	250	144	--	57.6	4.7
	H61	53,000	312	160	--	54.9	5.5
Oct 71	A11	23,900	0	25		54.1	5.9
	A22	10,900	0	28		41.9	4.7
	A90	1,600	0	3		40.1	4.9
	B20	9,370	0	37		37.9	9.5
	B43	7,090	< 1	35		43.3	4.6
	B46	14,100	0	25		28.8	6.3
	B66	7,620	0	9		16.2	5.3
	B71	9,730	0	14		42.3	4.5
	C06	13,700	0	85		49.1	5.2
	C16	14,100	0	94		52.4	4.4
	C28	7,900	0	91		38.5	4.8
	D19	13,200	2	20		57.7	4.8
	D43	6,510	22	12		41.5	6.3
	D45	3,290	13	6		53.1	4.2
	E36	9,920	0	22		55.5	5.8
	E68	9,760	1	37		41.6	4.0
	E80	17,200	0	67		29.8	6.6
	F10	11,700	0	26		40.2	4.5
	F13	10,000	4	46		62.6	4.9
	F41	8,700	0	112		33.3	4.4
	G12	564	8	< 1		18.3	3.5
	G70	3,670	92	< 1		24.2	6.1
	G102	225	4	0		11.9	1.7

Table 3. (Cont)

		Numbers Captured Per Minute			Percent of Dry Weight		
Month	Station Number	Copepods	Clodocerans	Chaetognaths	Ash	Protein	Total Lipids
Oct (Cont)	G145	8,920	2	6		16.7	2.1
	G156	3,630	14	0		41.8	5.6
	H36	4,120	38	<1		57.5	6.5
	H41	2,720	16	1		45.6	5.7
	H57	2,340	29	7		--	5.7
	H75	3,730	23	9		30.7	4.4
	H106	11,500	<1	51		34.7	5.9
Nov 71	A31	768	6	5		--	--
	A46	2,050	0	28		42.7	4.6
	A49	600	1	15		37.5	7.7
	B26	5,420	2	13		32.7	7.3
	B51	1,820	0	5		35.5	5.6
	B63	5,470	0	6		31.7	6.5
	C12	3,350	3	34		35.3	6.3
	C18	2,740	<1	5		41.6	5.8
	D04	7,680	212	3		--	--
	E20	1,860	117	0		--	--
	E49	5,890	13	2		39.5	5.8
	E62	2,920	133	3		--	--
	F17	3,330	7	<1		33.2	6.0
	F19	3,480	47	<1		45.5	6.7
	F33	893	10	<1		--	--
	H79	4,200	23	<1		32.7	7.6
	H89	7,090	4	<1		24.5	5.5
Dec 71	D03	1,180	259	0		12.7	3.7
	D07	7,740	48	0		--	--
	D11	1,240	72	0		6.7	2.4
	E04	69	81	0		--	--
	E34	300	71	0		--	--
	G91	14,400	108	0		9.8	2.8
	G104	2,560	883	0		15.1	3.3
	H105	198	82	0		--	--
Jan 72	A14	955	7	0	--	21.0	9.3
	A22	1,190	104	0	70.1	9.0	2.1
	A56	1,760	77	0	67.6	8.8	3.1
	B17	4,090	137	<1	24.2	22.8	7.8
	B27	986	128	0	64.7	12.8	2.0
	B29	1,920	166	<1	41.2	34.4	4.7
	B39	2,190	35	0	57.3	27.8	3.1

Table 3. (Cont)

		Numbers Captured Per Minute			Percent of Dry Weight		
	Station						Total
Month	Number	Copepods	Clodocerans	Chaetognaths	Ash	Protein	Lipids
Jan (Cont)	B49	389	135	0	75.8	10.0	1.7
	C01	1,030	230	0	54.7	24.0	6.5
	C21	1,980	74	0	24.4	27.0	5.3
	C30	2,840	5	0	55.3	19.5	2.8
	D23	1,940	19	0	70.2	11.3	2.0
	D37	1,270	51	0	65.7	13.4	3.4
	D52	1,370	28	0	28.2	7.5	1.9
	E04	3,480	183	0	34.7	36.6	5.8
	E41	1,120	786	0	--	19.0	--
	E58	2,730	299	0	68.8	13.4	2.2
	F03	4,030	195	0	22.0	17.7	5.2
	F17	2,060	131	0	65.3	20.0	3.1
	F25	2,560	129	0	28.3	21.0	7.2
	G115	6,910	776	0	33.2	22.4	4.6
	G131	3,790	437	0	46.0	25.2	6.8
	G147	2,670	149	0	41.1	26.4	2.8
	H37	14,100	1,600	0	51.2	29.2	8.1
	H53	5,920	422	0	61.1	11.8	3.5
	H72	7,620	864	0	61.1	19.5	4.5
	H80	14,200	2,460	0	51.5	15.5	4.0
Feb 72	A22	69,800	304	0	18.9	30.0	14.9
	A72	8,530	64	0	--	44.3	6.4
	A91	1,980	0	0	11.3	30.6	7.4
	B02	91,600	1,060	0	11.3	37.5	7.8
	B17	48,900	213	0	10.0	37.0	6.6
	G56	7,810	21	0	80.1	8.6	2.3
	B69	6,400	18	0	31.4	34.8	10.0
	C03	24,600	151	<1	8.6	50.1	9.3
	C21	5,540	26	<1	8.3	49.5	9.1
	C37	2,230	22	0	--	48.3	6.8
	D16	21,800	730	0	24.5	27.8	10.8
	D24	19,300	208	0	11.5	37.0	9.5
	D26	16,100	232	0	25.8	22.0	10.3
	E24	27,100	224	0	24.5	31.6	11.6
	E48	29,700	346	0	11.0	40.0	10.9
	E54	40,400	168	0	14.8	37.6	4.8
	F15	32,100	41	0	9.2	42.2	12.3
	F21	41,700	91	0	15.9	38.7	8.7
	F27	13,500	59	0	10.1	38.8	12.3
	G64	5,400	200	0	13.7	32.2	10.3
	G88	?	?	?	11.3	41.0	13.3

Table 3. (Cont)

		Numbers Captured Per Minute			Percent of Dry Weight		
Month	Station Number	Copepods	Clodocerans	Chaetognaths	Ash	Protein	Total Lipids
Feb (Cont)	G156	15,500	667	0	16.6	34.2	11.2
	G162	15,800	88	0	14.7	31.0	9.9
	H13	17,200	50	0	25.8	26.1	10.2
	H54	38,100	75	0	25.4	32.3	7.3
	H85	29,200	252	0	13.9	38.8	12.1
Mar 72	A05	95,700	6	0		37.8	11.5
	A45	80,900	3	0		22.9	9.6
	A56	3,850	0	0		21.3	3.3
	B07	1,880	0	0		39.1	8.4
	B51	28,200	0	0		25.7	4.3
	B52	28,100	5	0		27.8	7.8
	B62	33,600	< 1	0		23.9	4.5
	B72	5,980	0	0		25.9	6.4
	C05	74,600	0	0		41.3	9.9
	C26	770	< 1	0		--	--
	C28	2,600	0	0		--	--
	D40	26,000	3	0		20.7	4.9
	D45	39,800	< 1	0		33.1	8.0
	D59	63,800	4	0		39.3	8.5
	E02	31,100	11	0		38.5	8.6
	E52	90,500	26	0		38.4	6.5
	E71	50,600	5	0		30.5	6.3
	F05	88,200	0	0		36.5	5.4
	F28	76,500	< 1	0		30.9	7.1
	F35	169,000	2	0		33.8	8.0
	G61	47,400	2	0		39.1	10.3
	G83	24,800	29	0		42.9	11.9
	G109	81,100	16	0		32.6	6.8
	H05	34,000	0	0		39.0	7.4
	H71	61,700	0	0		39.5	4.0
	H88	37,400	0	0		23.8	5.0
	'A'	62,200	0	0		32.1	9.2
	'E'	27,600	2	0		44.3	10.9
Apr 72	A36	24,200	8	< 1			
	A47	3,350	2	< 1			
	A64	6,140	0	5			
	B02	3,050	0	0			
	B11	1,950	0	0			
	B21	6,660	< 1	0			
	C07	2,850	11	0			
	C11	5,590	3	0			

Table 3. (Cont)

		Numbers Captured Per Minute			Percent of Dry Weight		
Month	Station Number	Copepods	Clodocerans	Chaetognaths	Ash	Protein	Total Lipids
Apr (Cont)	C17	9,280	< 1	2			
	D28	39,900	0	0			
	D34	31,600	8	0			
	D54	31,200	0	0			
	E18	23,200	11	< 1			
	E34	15,200	3	0			
	E67	41,000	0	0			
	F35	8,990	3	0			
	G14	14,600	8	0			
	G21	8,340	1	0			
	G130	5,550	112	0			
	H18	9,890	0	0			
	H88	6,400	160	0			
	H89	6,180	0	1			
	'A'	140,000	0	0		31.8	5.2
	'E'	14,700	0	0		21.3	4.3
May 72	A08	13,200	13,200	0			
	A62	29,800	25,500	0			
	A83	21,800	14,800	0			
	B05	13,000	14,100	1			
	B10						
	B81						
	C14	22,000	10,000	0			
	C24						
	C36	21,800	7,550	7			
	D07						
	D22	3,990	3,170	0			
	D46	2,300	3,170	0			
	E07	1,420	1,300	0			
	E43	32,600	1,320	1			
	E63	10,300	6,400	0			
	F15						
	F22	10,400	7,680	2			
	F32	8,530	9,040	5			
	G30						
	G63						
	G144						
	H08	608	224	0			
	H43						
	H102						
	'A'						
	'E'						

Table 4. Measurements of zooplankton biomass in lower Chesapeake Bay, August 1971-May 1972. Settled volume (24 hours) in ml per minute of sampling, and dry weight in milligrams per minute.

		Sampling Area							
Month		A	B	C	D	E	F	G	H
Aug 71	ml/min	16.1	32.2	30.0	14.2	27.1	29.7	15.2	22.9
	dry wt/min	199	547	383	276	462	568	388	507
Sept 71	ml/min	5.9	6.0	3.0	18.0	12.8	7.9	9.6	10.1
	dry wt/min	90	136	36	398	276	107	197	143
Oct 71	ml/min	3.4	5.1	6.1	2.5	7.2	5.3	2.3	4.0
	dry wt/min	22	66	93	37	99	101	49	37
Nov 71	ml/min	0.6	1.7	1.5	0.9	1.5	1.0	---	2.0
	dry wt/min	11	27	30	10	16	20	---	51
Dec 71	ml/min	---	---	---	0.70	0.25	---	4.10	0.38
	dry wt/min	---	---	---	26	3	---	420	3
Jan 72	ml/min	2.68	1.67	1.35	1.65	1.71	1.37	4.81	2.83
	dry wt/min	109	125	71	217	82	99	205	203
Feb 72	ml/min	7.50	7.92	2.45	5.58	7.28	12.14	5.52	10.80
	dry wt/min	175	328	49	164	325	425	234	444
Mar 72	ml/min	4.87	9.03	5.63	9.09	12.36	14.41	13.73	20.70
	dry wt/min	138	193	124	220	577	684	507	512
Apr 72	ml/min	1.46	1.90	2.06	7.17	3.66	1.88	5.20	5.08
	dry wt/min	not complete							
May 72	ml/min	6.11	6.25	7.22	3.25	6.90	4.65	2.99	5.34
	dry wt/min	not complete							

have also been conducted on over 20 samples (see Zubkoff, this report) Freeze-dried samples are being stored for other analyses, including carbohydrates, amino acids, chitin and DNA. Measurements of DNA will provide a third estimate of biomass.

The goal of these cooperative studies with the Plankton Physiology program is to chemically characterize the dominant zooplankters, and to eventually be able to accurately predict, from chemical analyses of a mixed plankton sample, the taxonomic composition of that sample.

DISCUSSION OF INITIAL RESULTS

Ten months of an anticipated 24 month sampling period have been completed prior to this report. The collection and storage of hydrographic data associated with zooplankton collections has been orderly due to an already well-organized system of computer operations (Data Processing, Oceanography Departments, VIMS). Comparable systems for handling biological data are still being developed. The results reported in the present report are limited, in part, by this difference in development of machine operation. A more important, and less easily solved, limitation is the slow and tedious, but necessary, sorting of zooplankton samples.

A "mini-sorting center" has been organized to handle incoming zooplankton samples. Skills and techniques have been developed to the point where the sorting of bongo samples has been brought up to date. Gradually, inroads are being made on specific identification of sorted groups. As sorting becomes more rapid, the amount of time available for other aspects of the study increases. Presently, the Zooplankton Program is able to sort bongo samples, estimate settled volumes, prepare finished slides of < 35 micron plankton and perform some limited species identifications between monthly sampling cruises. In cooperation with the Plankton Physiology group, we can also keep up to date with dry weight, ash weight, protein and total lipid analyses.

Hydrographically, the past year has not been a "typical" one, reinforcing our anticipated need for more than one calendar year of sampling. The winter was quite mild, followed by a spring that was cool, protracted and accompanied by heavy precipitation. Water temperatures decreased from about 25 C in August and September to 4-5 C in January and February. They remained low until the May cruise. Heavy spring runoff was evident in the low salinities recorded in April and May.

Copepods and cladocerans are the most numerous organisms in the Chesapeake Bay zooplankton. As such, the numbers captured per minute of tow may be expected to closely parallel total zooplankton biomass. This was especially true for the copepods, less so for cladocerans. Numbers of cladocerans fluctuated much more widely than did those for copepods. Cladocerans were dominant in August, outnumbering copepods in 23 of the 30 samples, decreased dramatically in September, increased somewhat in winter months, were scarce again in March and April, and increased significantly in May. These seasonal fluctuations will become clear only after completion of specific identification. Several species of three genera are involved.

Chaetognaths reached a peak of abundance in September. Catches were heavily predominated by the inshore species *Sagitta tenuis*. Other warm water species were *S. enflata* and *S. hispida*. The cold water *S. elegans* appeared sporadically in winter and spring months.

Seasonal changes in protein and lipid content of zooplankton are evident but cannot be interpreted until additional information is available on the species composition of samples.

PLANS FOR FURTHER RESEARCH

Despite the absence of an anticipated and planned-for expansion of the plankton program in the second year of RANN operations, we intend to continue with our planned two-year sampling program. This will be possible only with the continued contribution by VIMS of the costs associated with vessel use, and of unbudgeted in-house services such as drafting, library costs, Xeroxing costs, publication and computer costs.

Lacking under the present budget, in addition to the above items, are the funds needed for the hiring of professional-level zooplanktologists. A shortage of professionals in the study will, at best, greatly prolong the wait for final results.

During the ensuing twelve months, monthly sampling will continue, bongo samples will be routinely sorted, specific identifications will be provided for copepods, cladocerans and chaetognaths (plus other groups if time allows), computer phases of the zooplankton operation will be put into operation and chemical analyses will continue and be added to.

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Odum, E. P. 1972. Ecosystem theory in relation to man. In: Ecosystem Structure and Function (ed. J. A. Wiens). Oregon State Univ. Press, pp. 11-24.

Personnel in Zooplankton Program

August 1971-May 1972

George C. Grant, Ph.D. - principal investigator

Fred Jacobs, grad. assistant

September 1971-May 1972

Burton Bryan, grad. assistant

Douglas Wood, grad. assistant

September 1971-January 1972

Paul A. Sandifer, Ph.D. (1972)

January-May 1972

John E. Olney, Laboratory Specialist

April-May 1972

Linda McEachran, Laboratory Technician

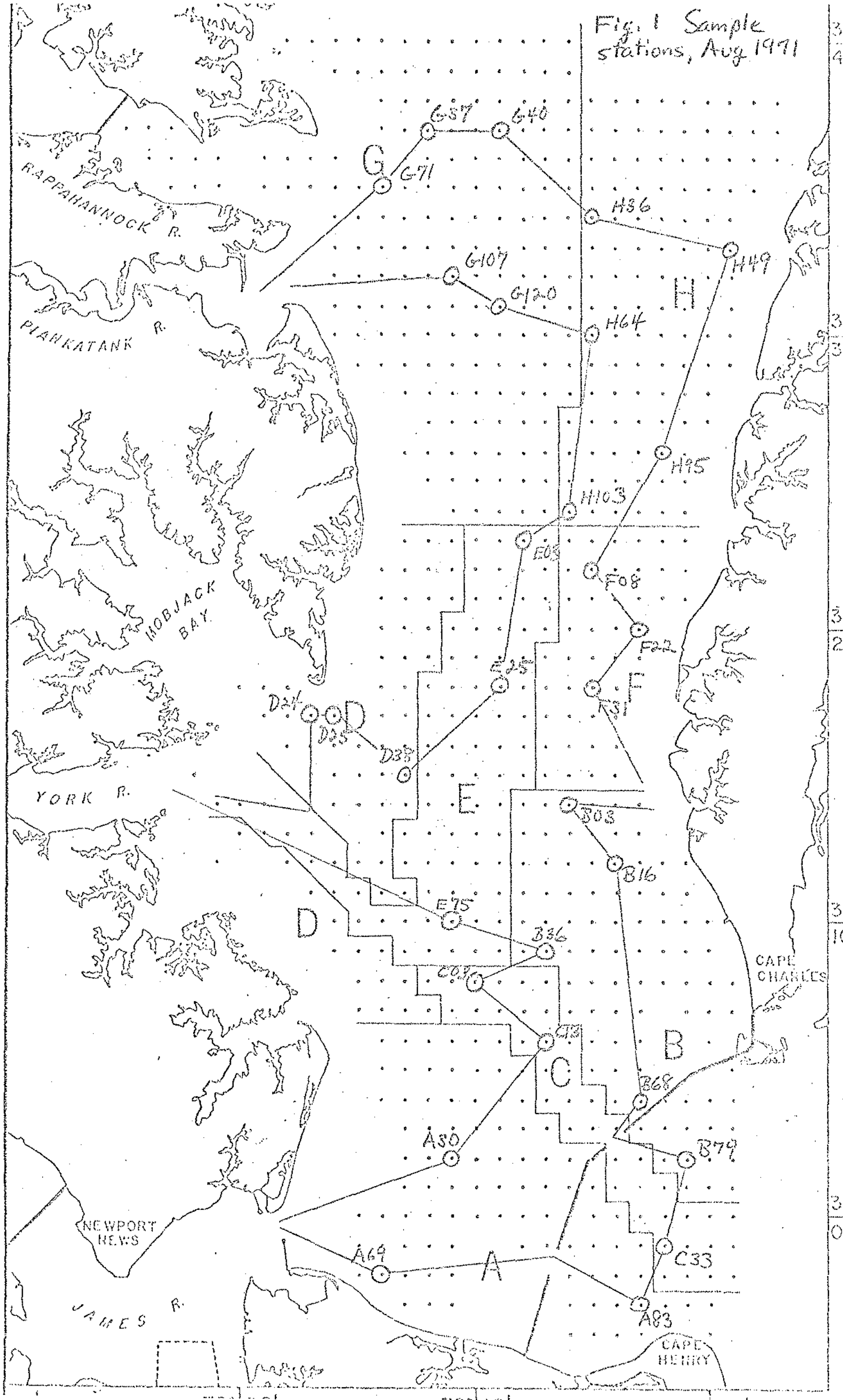
Fig. 1 Sample stations, Aug 1971
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
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G71
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H64
H95
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E08
F08
F22
F
F31
E25
D24
D25
D
D38
E
B03
B16
E75
D
B36
C02
C13
C
B
B68
A80
B79
C33
A69
A
A83

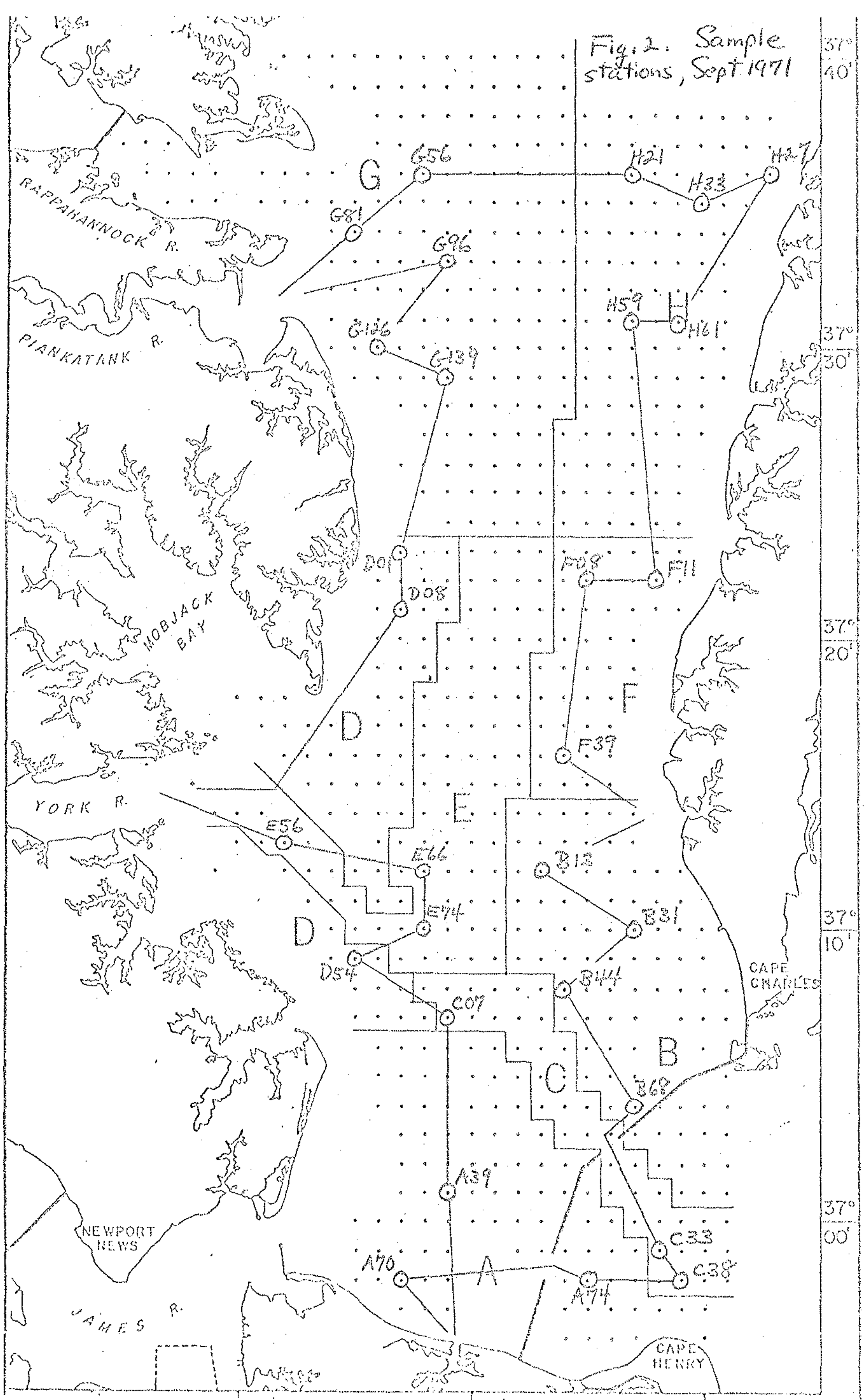
Fig. 2. Sample stations, Sept 1971
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D08
F08
F11
F39
E56
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B31
B44
C07
B68
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A70
A74
C33
C38

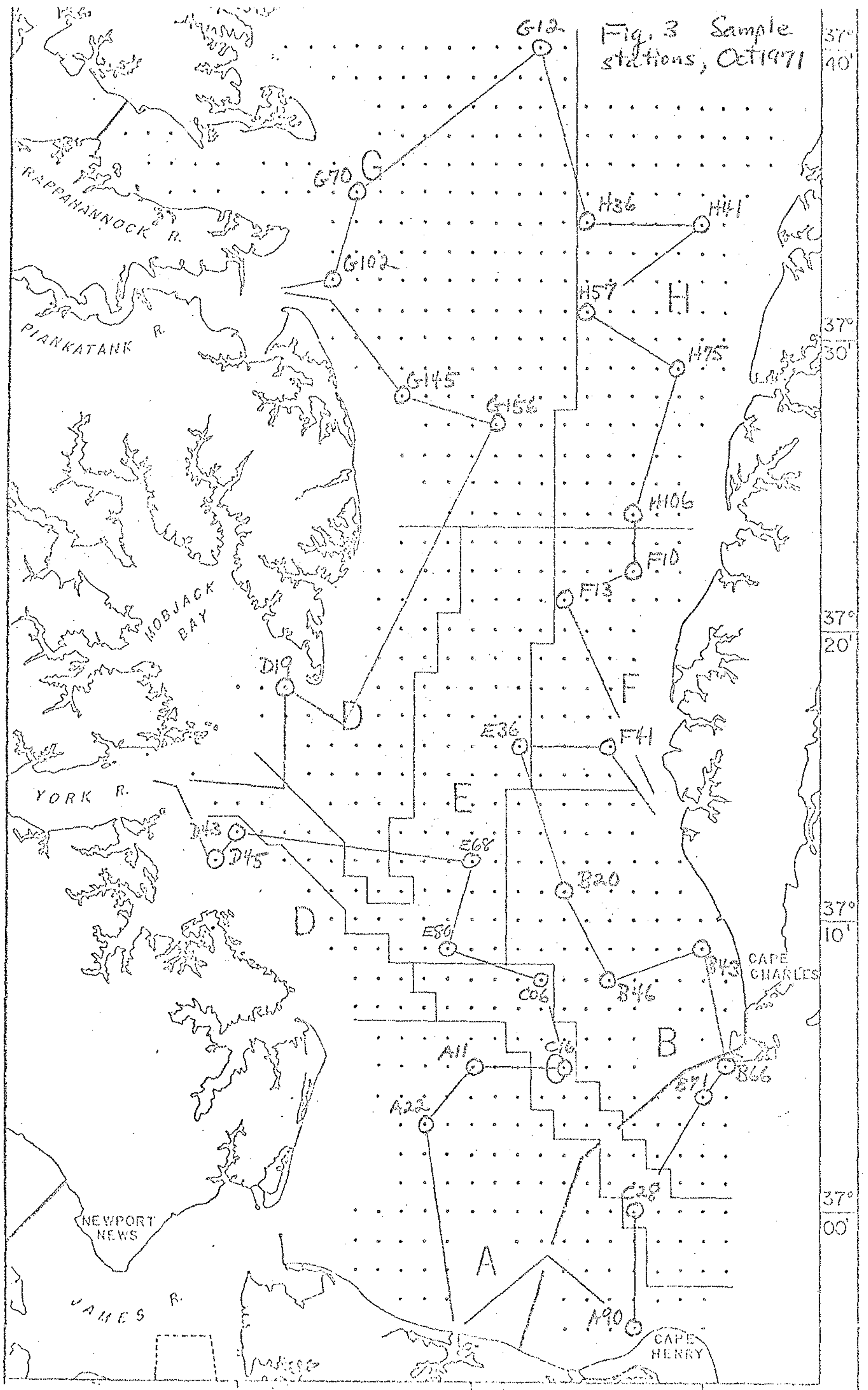

Fig. 3 Sample stations, Oct 1971

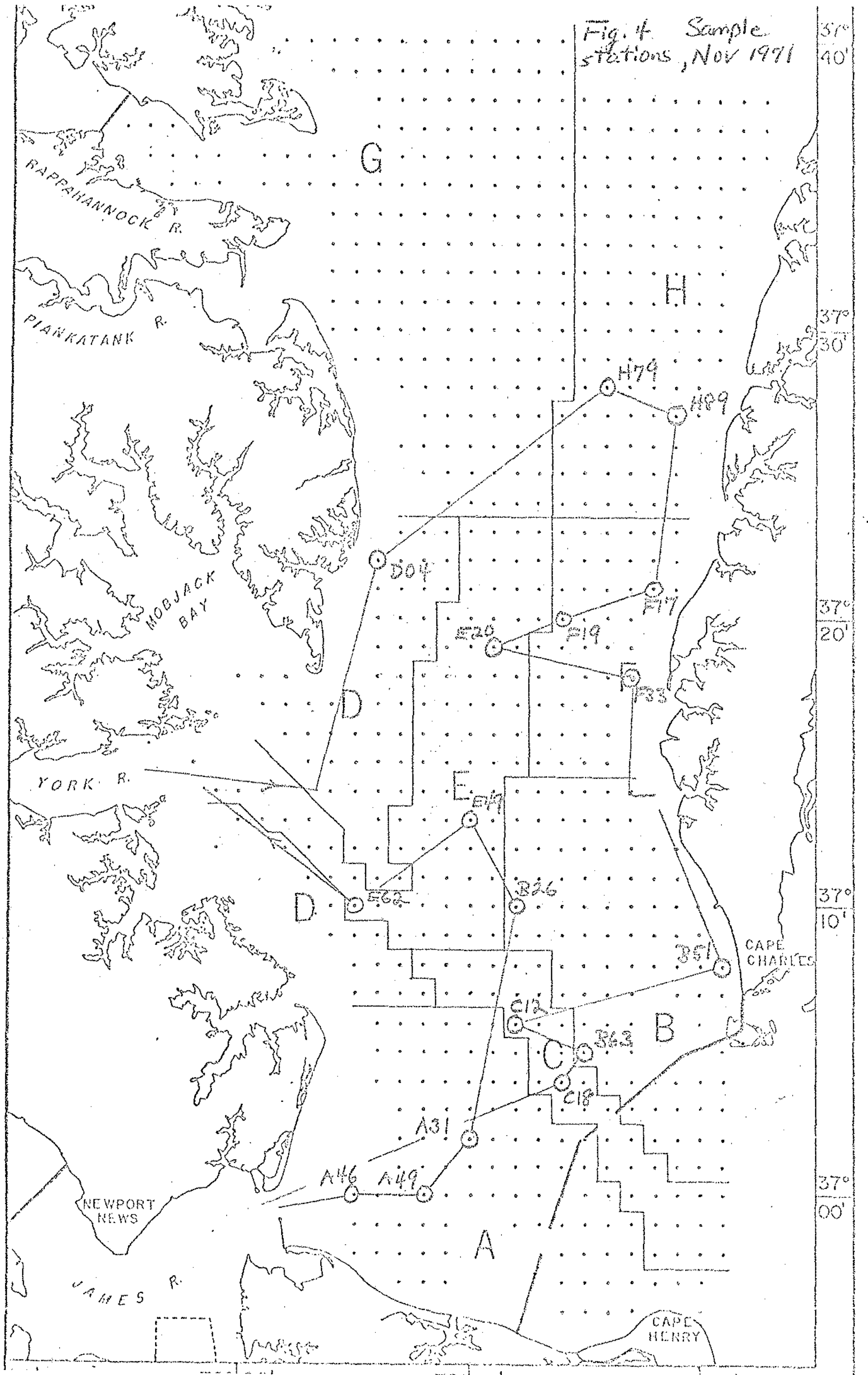
Fig. 4 Sample stations, Nov 1971
37° 40'
37° 30'
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PIANKATANK R.
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NEWPORT NEWS
CAPE CHARLES
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A46
A49
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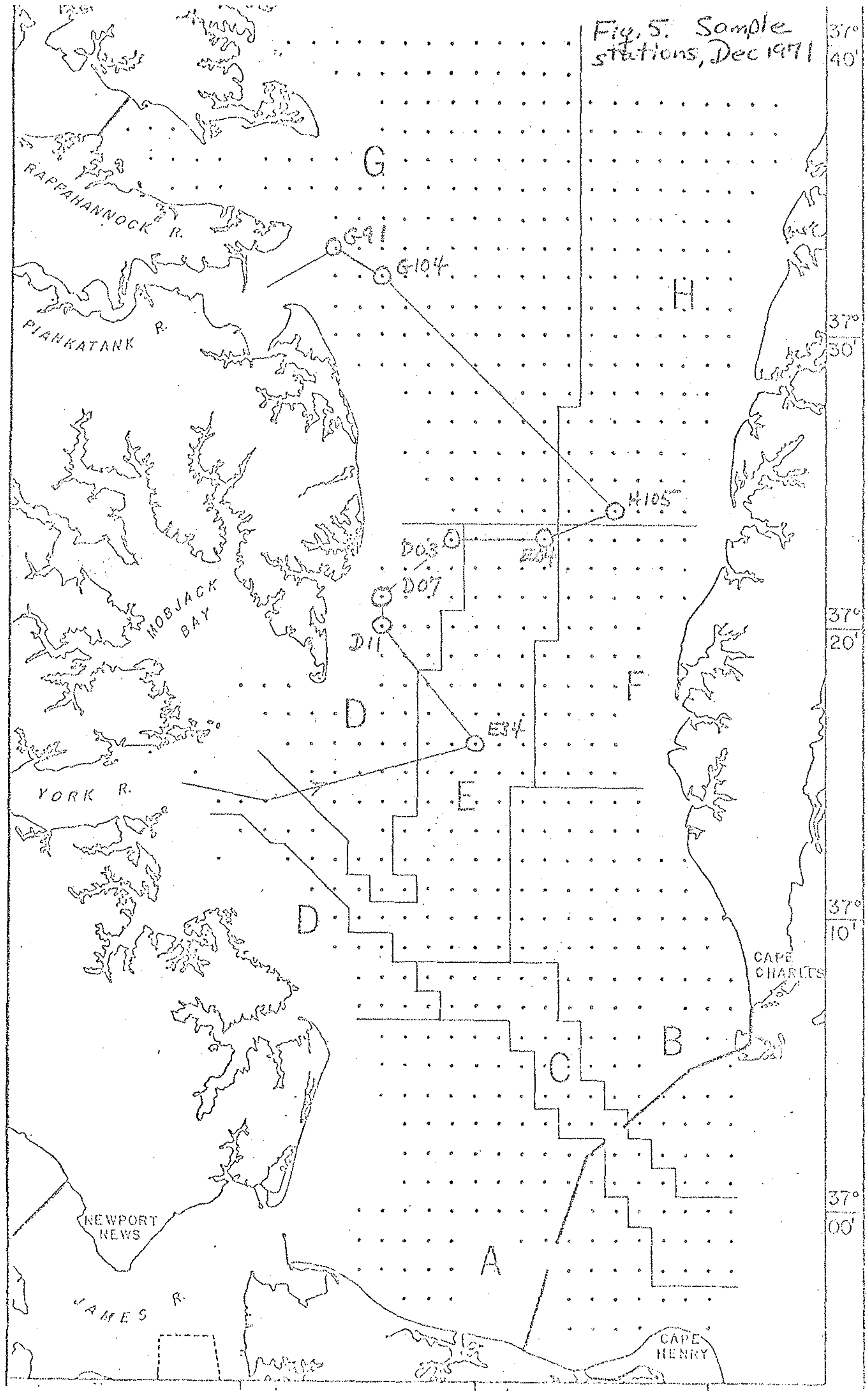
Fig. 5. Sample stations, Dec 1971



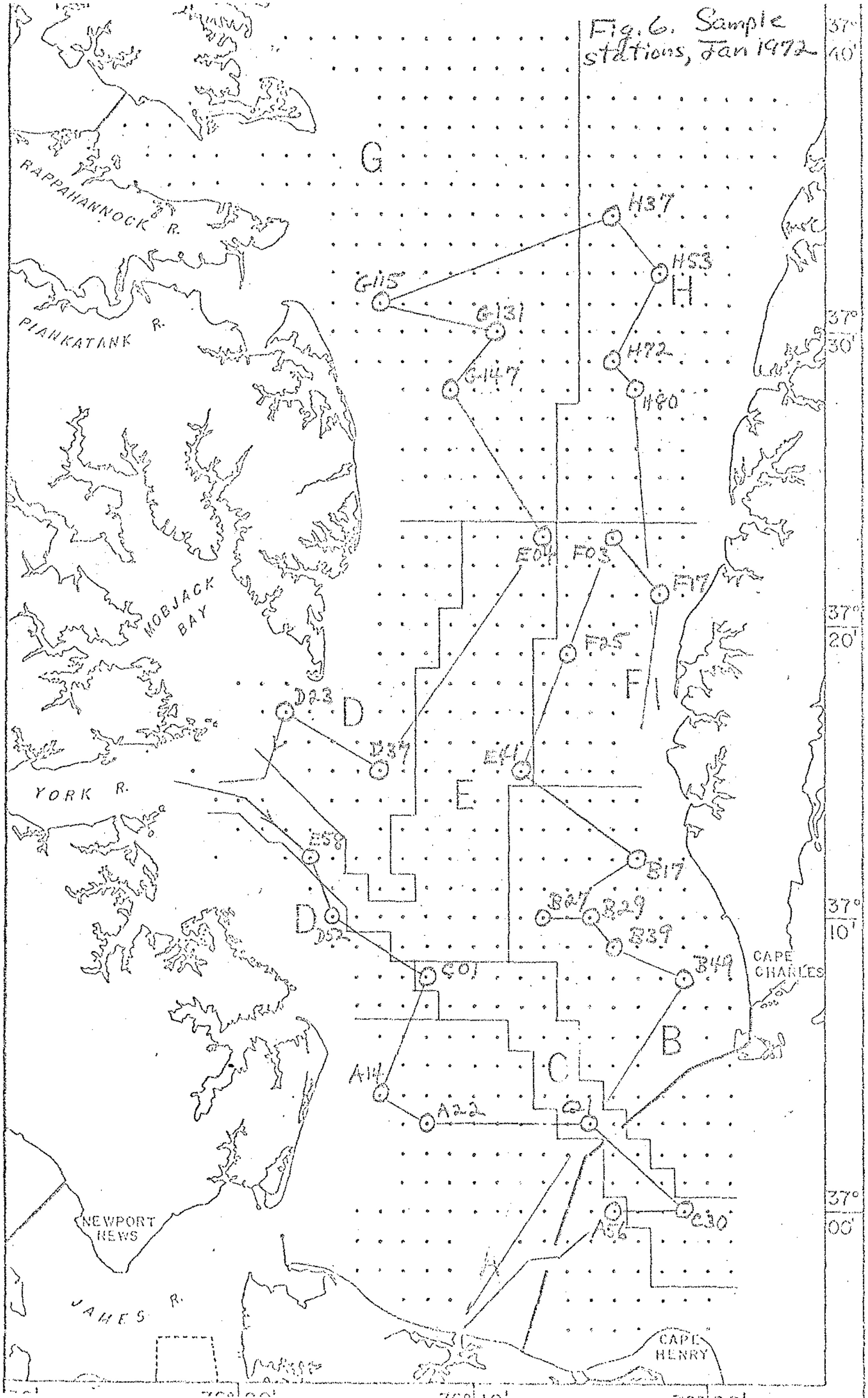


Fig. 6. Sample stations, Jan 1972

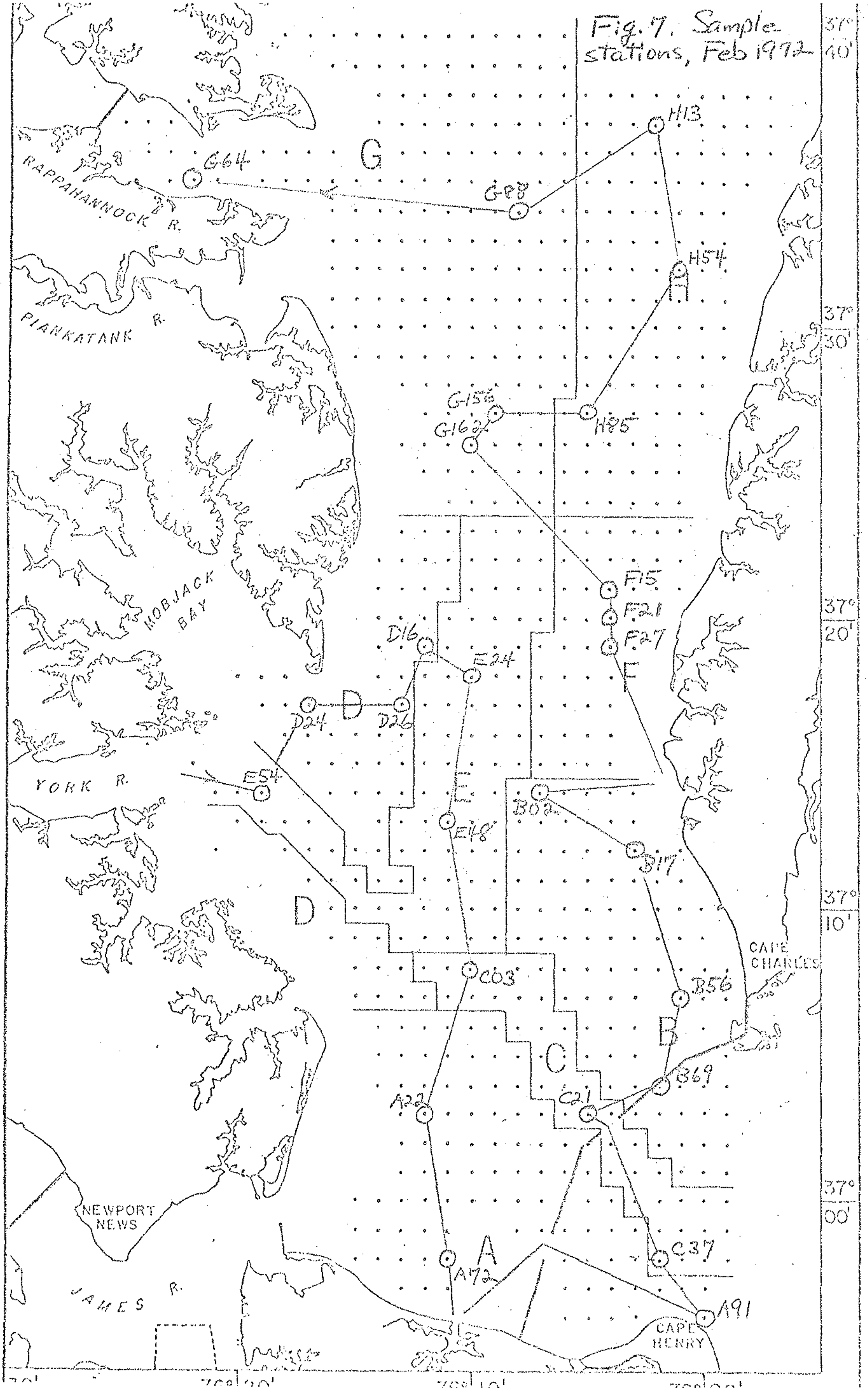


Fig. 7. Sample stations, Feb 1972

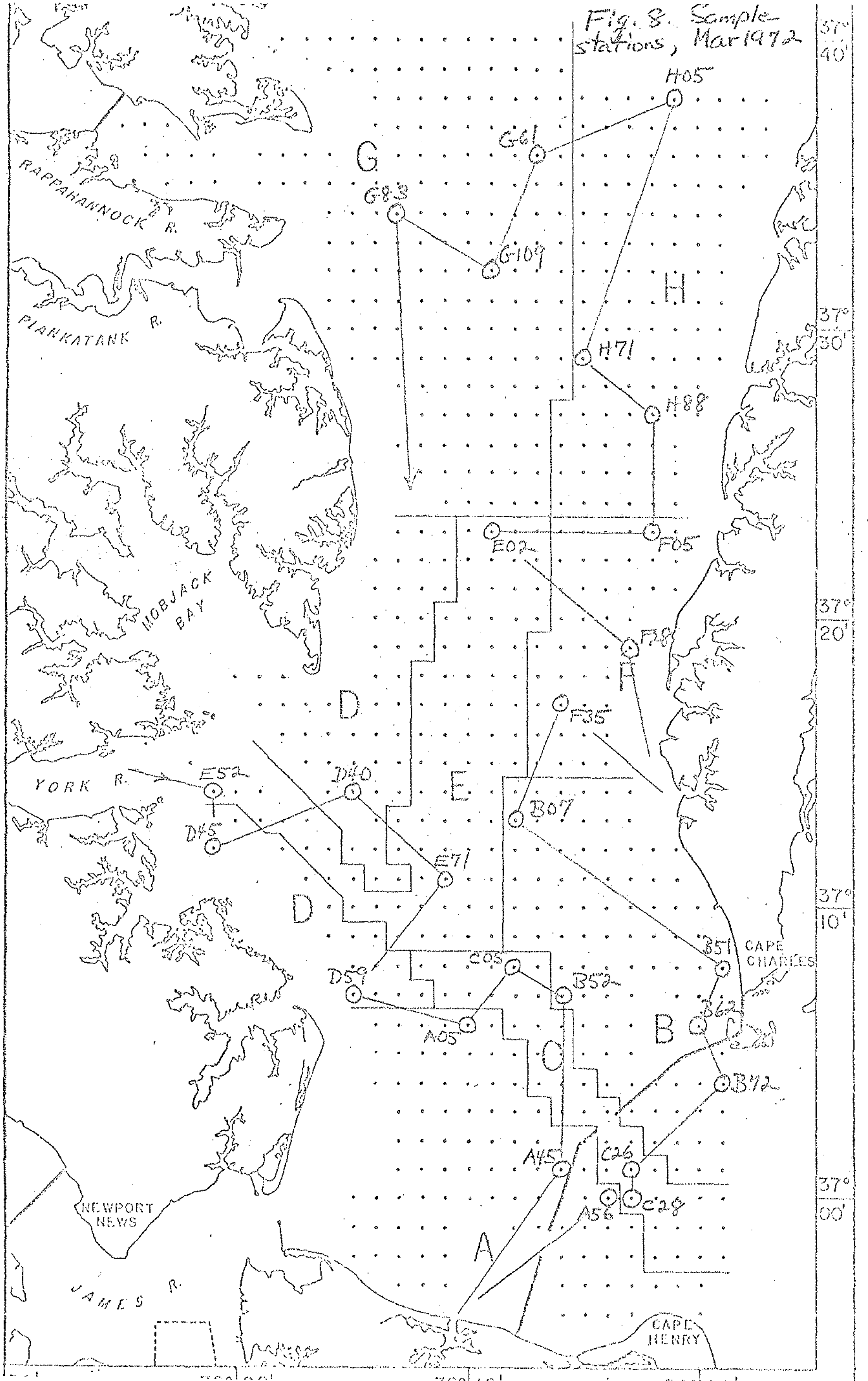


Fig. 8. Sample stations, Mar 1972
37° 40'
37° 30'
37° 20'
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RAPPAHANNOCK R.
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F35
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A56
C28

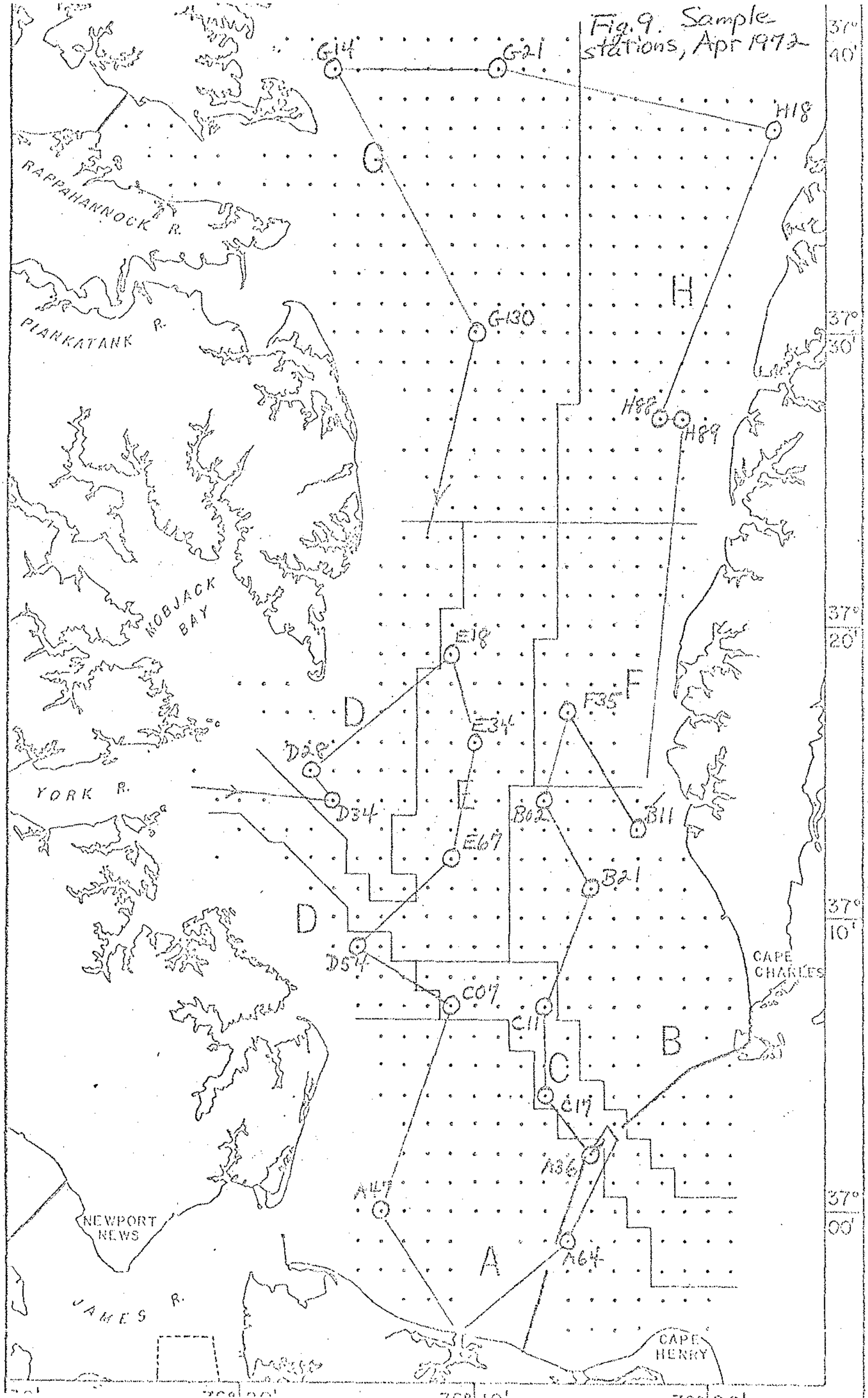

Fig. 9. Sample stations, Apr 1972

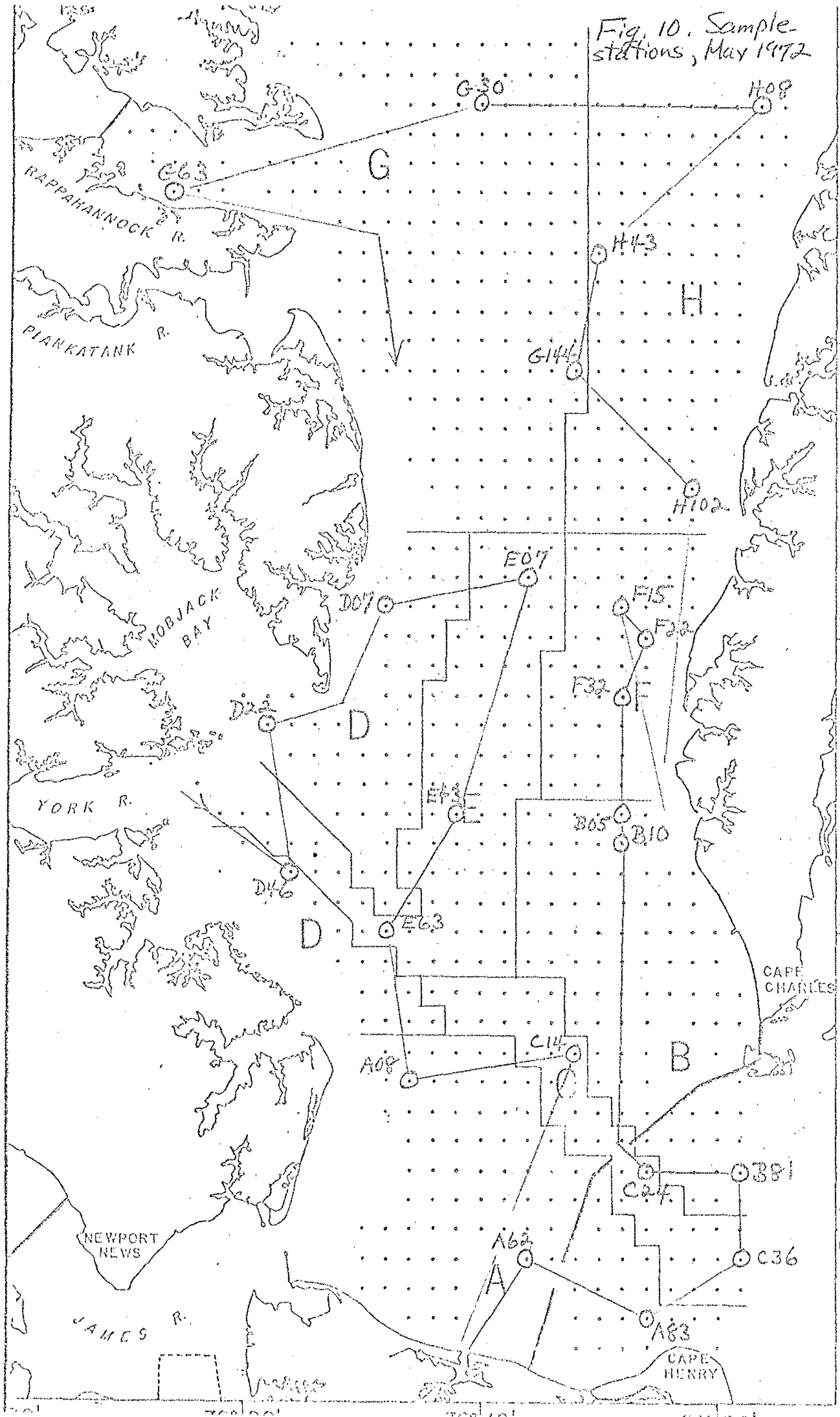

Fig. 10. Sample stations, May 1972

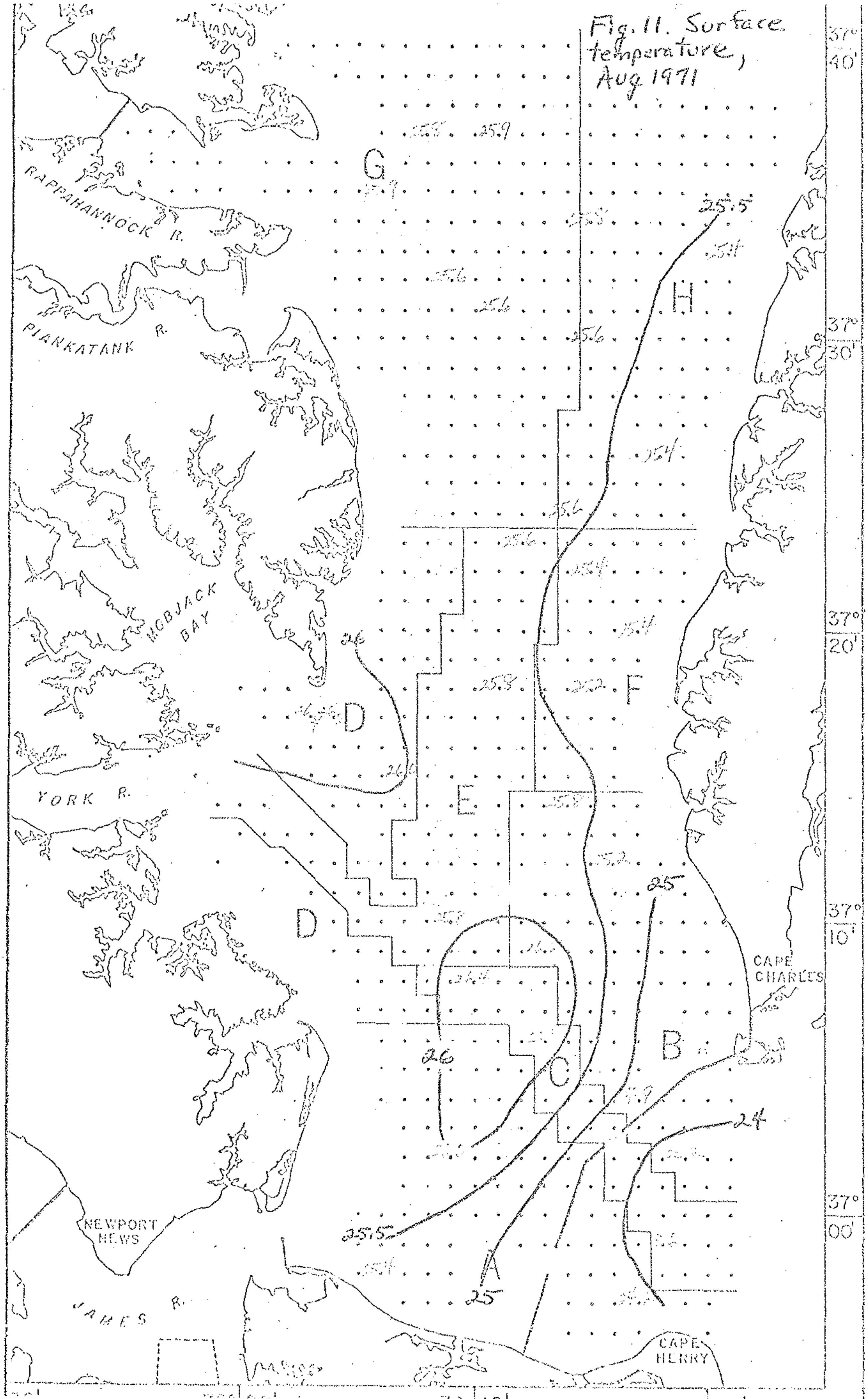

Fig. 11. Surface temperature, Aug 1971

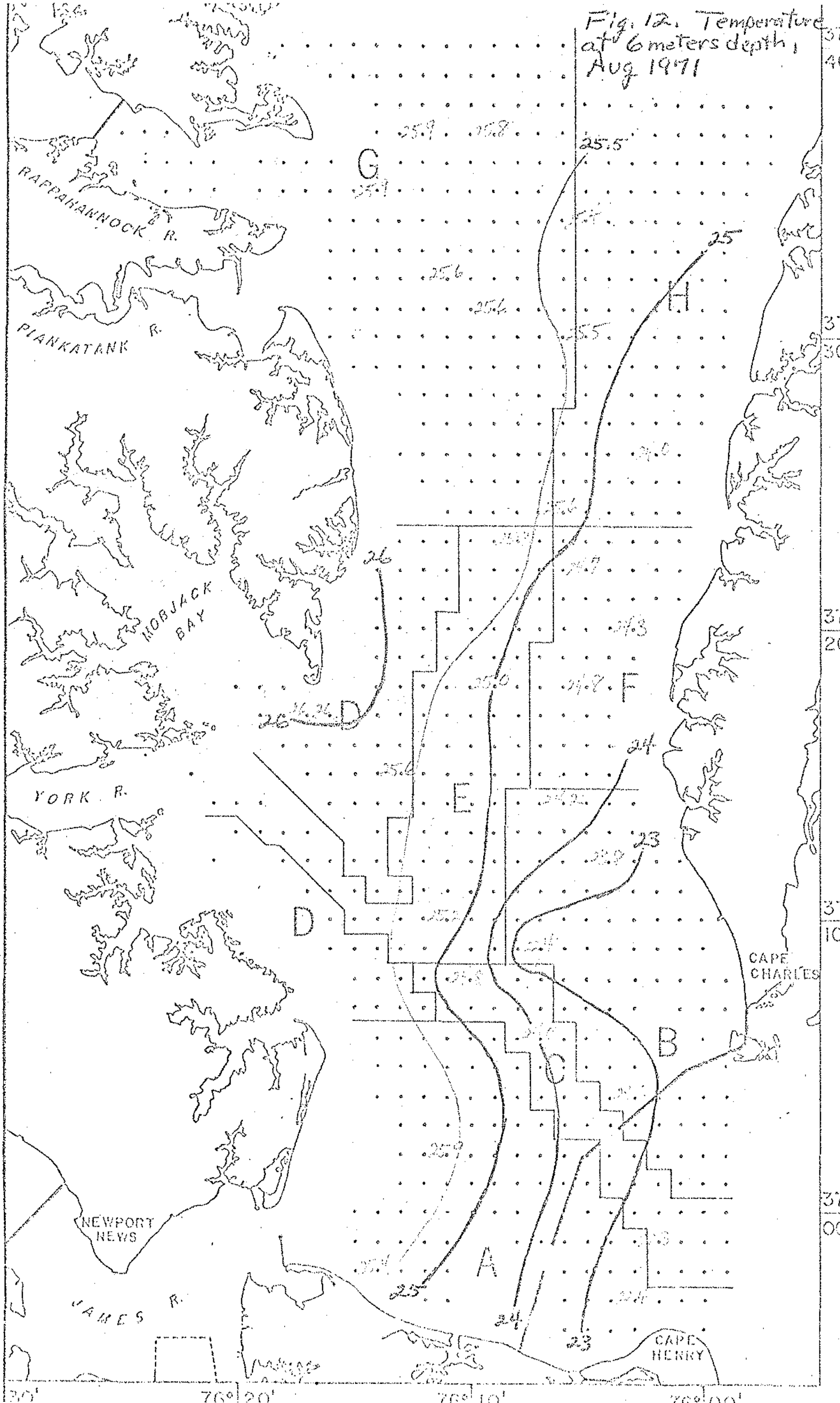

Fig. 12. Temperature at 6 meters depth, Aug 1971

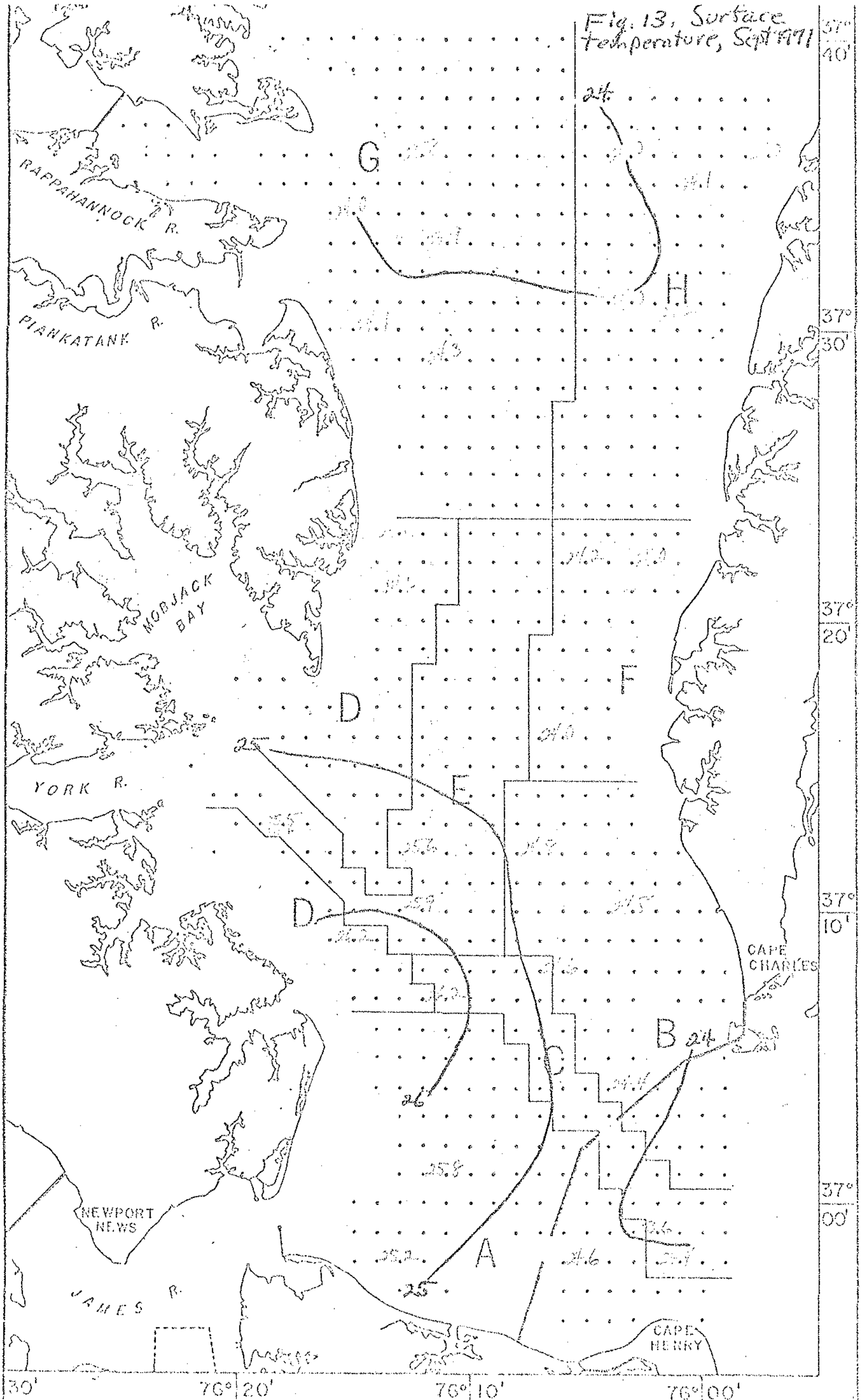

Fig. 13, Surface Temperature, Sept 1971

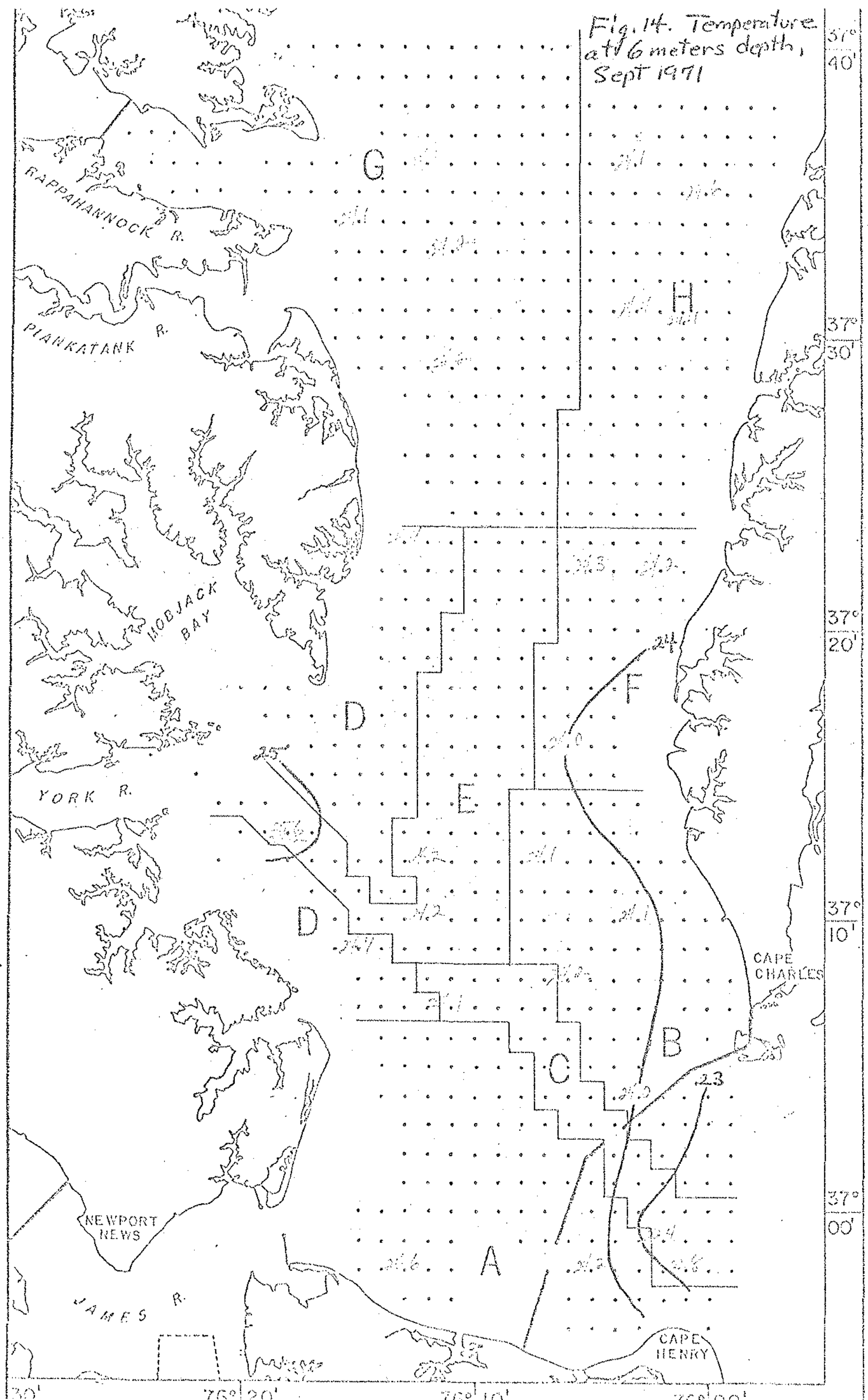

Fig. 14. Temperature at 6 meters depth, Sept 1971

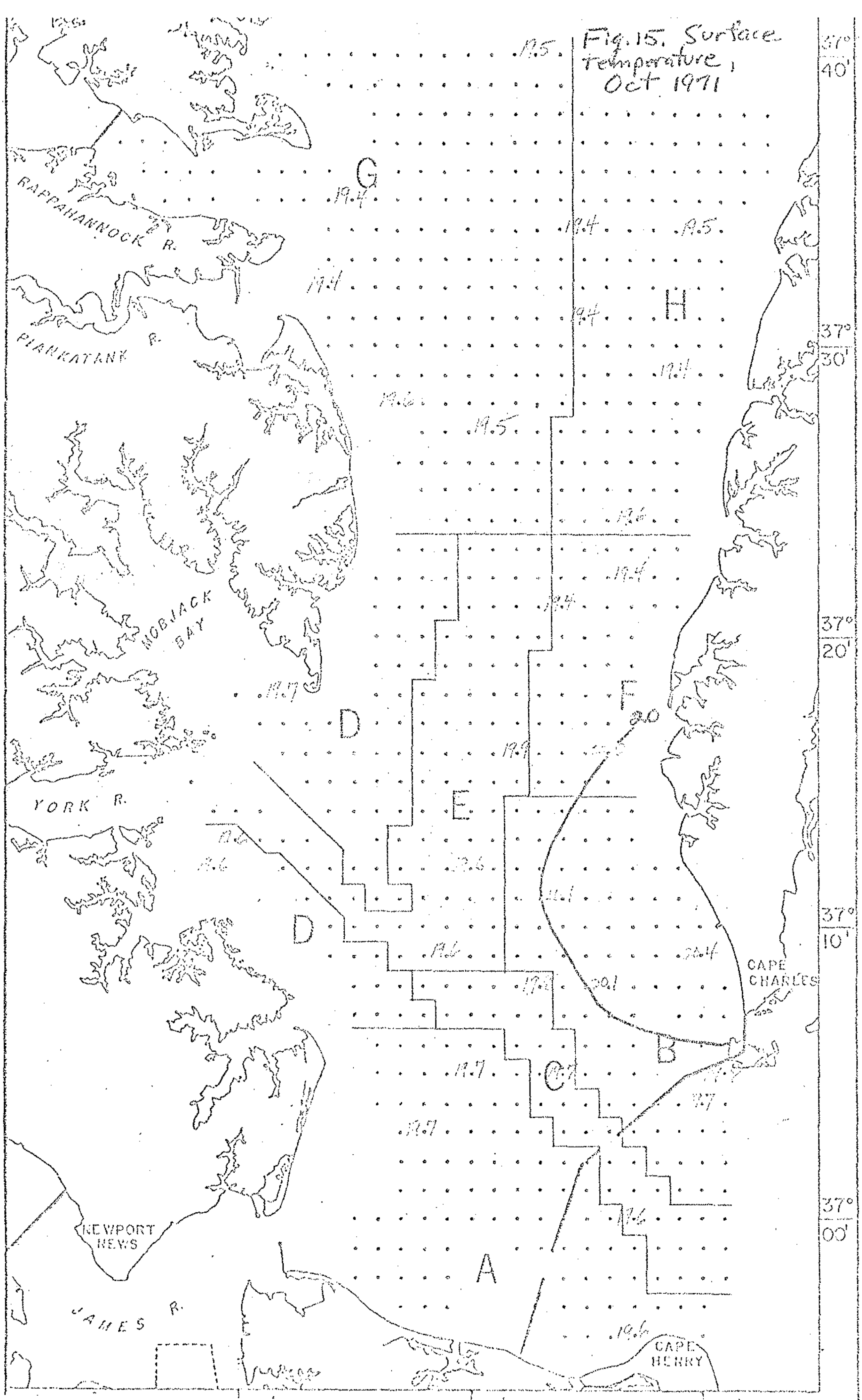

Fig. 15. Surface temperature, Oct 1971

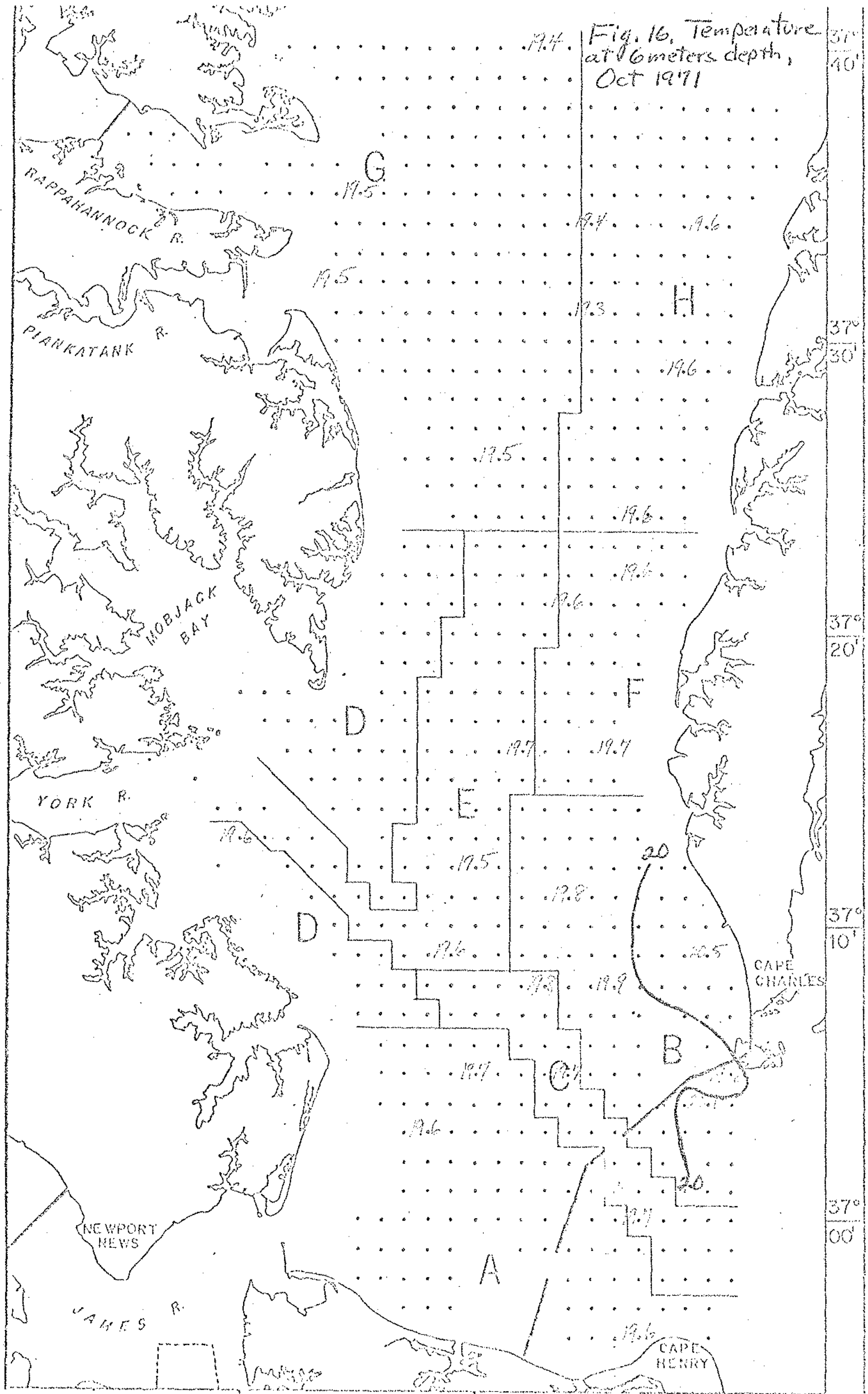

Fig. 16. Temperature at 6 meters depth, Oct 1971

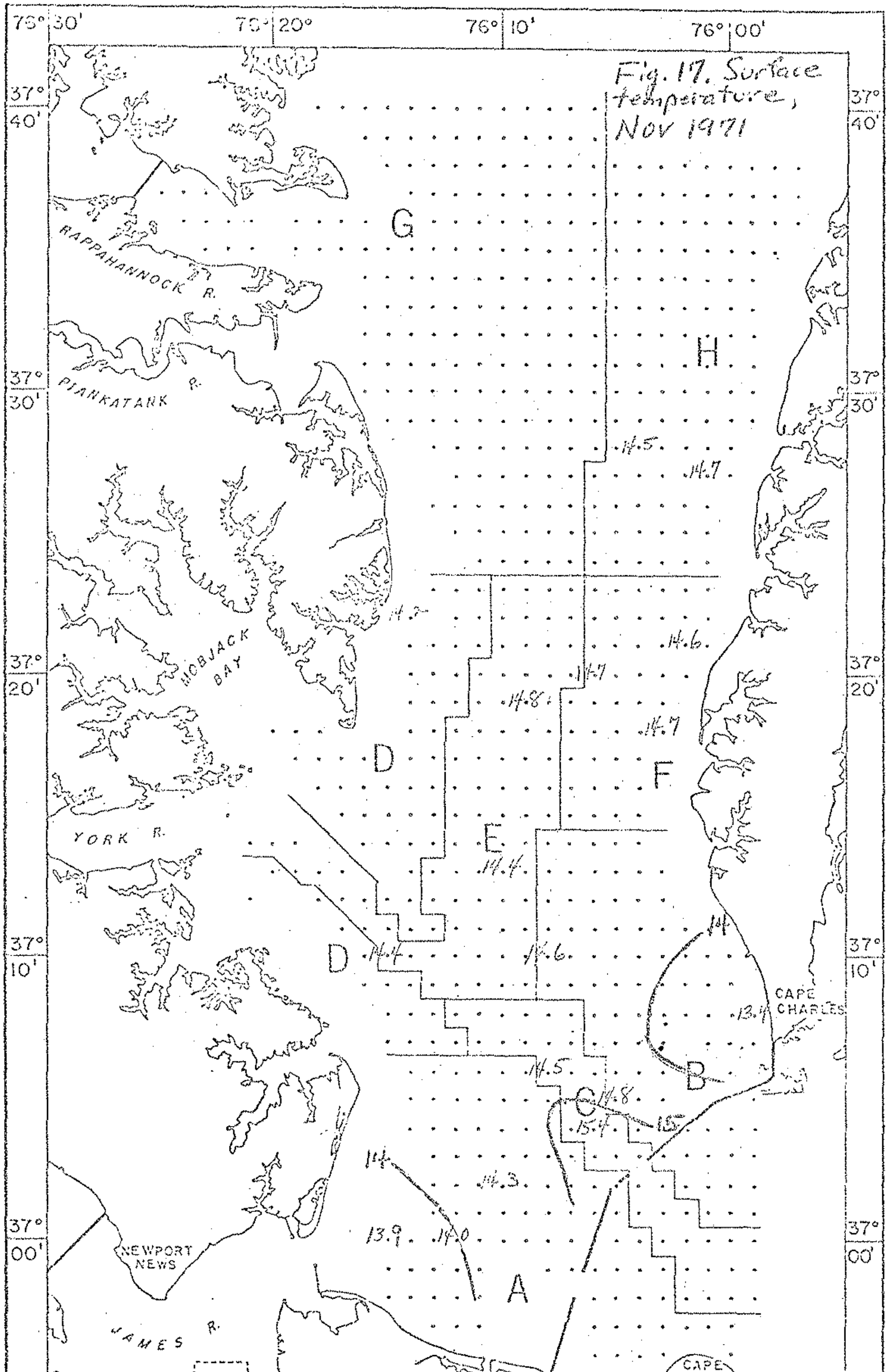
Fig. 17. Surface temperature, Nov 1971
76° 30'
76° 20'
76° 10'
76° 00'
37° 40'
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37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
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JAMES R.
NEWPORT NEWS
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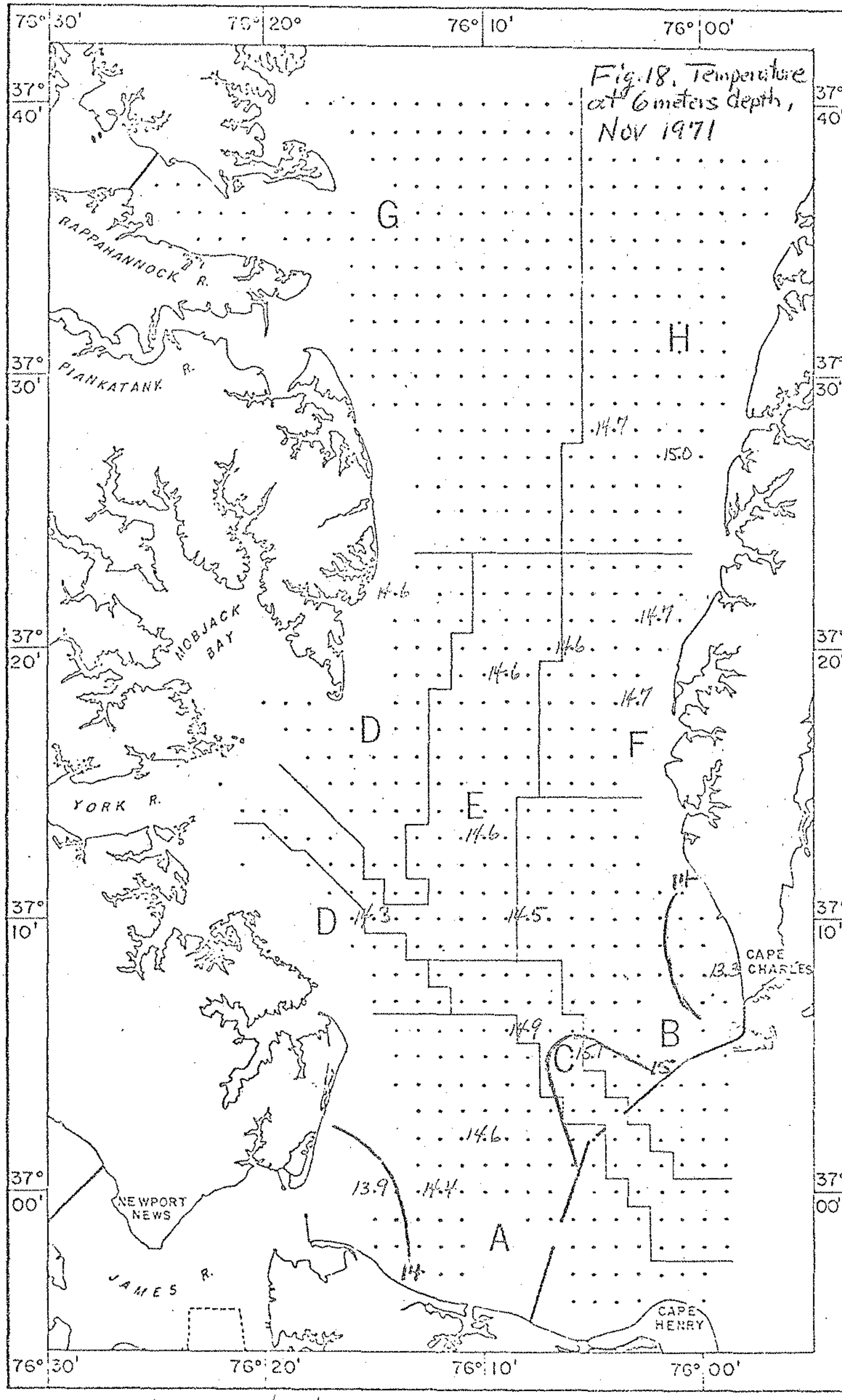

Temp at 6m, Nov 71

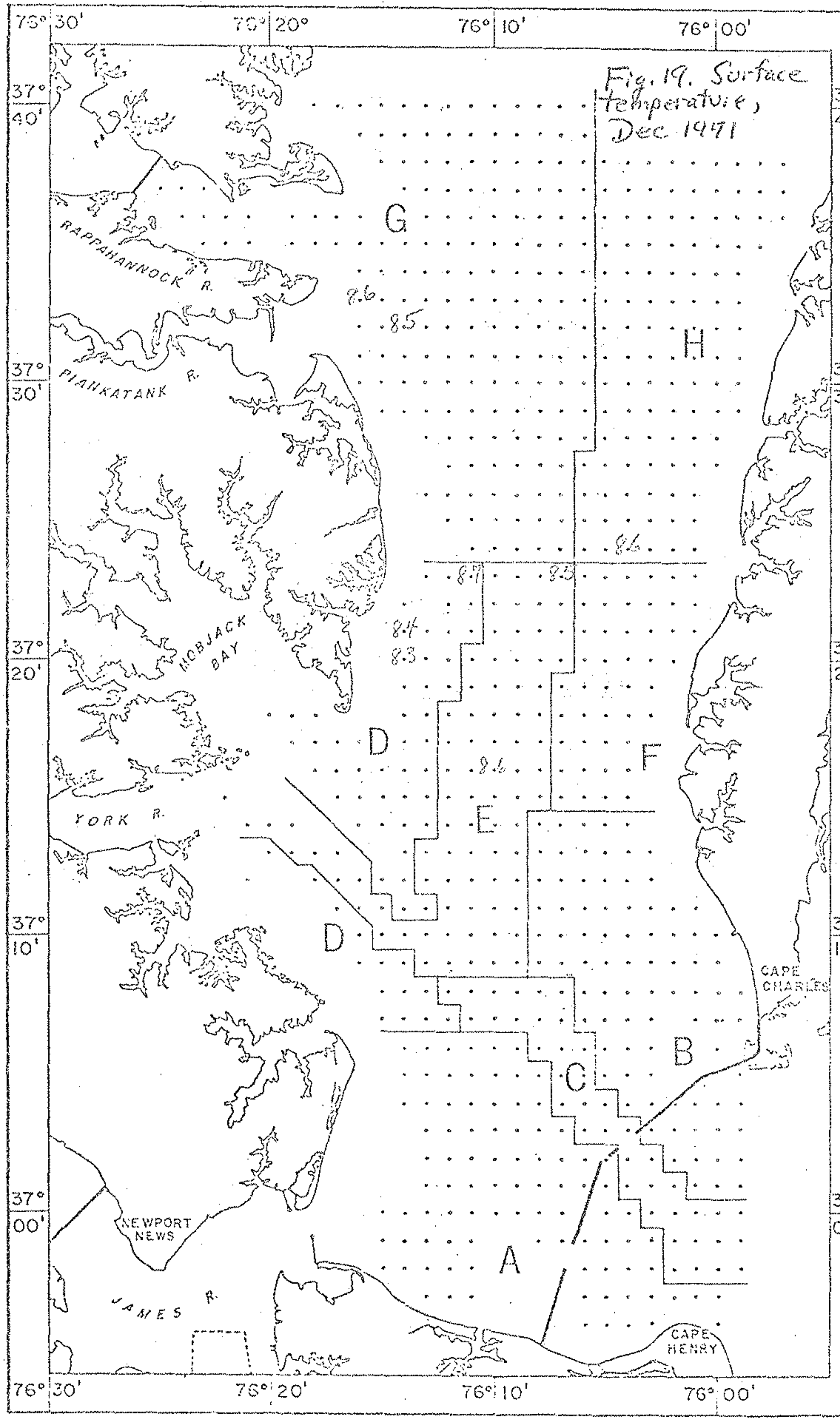

Fig. 19. Surface temperature, Dec 1971
76° 30'
76° 20'
76° 10'
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37° 40'
37° 30'
37° 20'
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RAPPAHANNOCK R.
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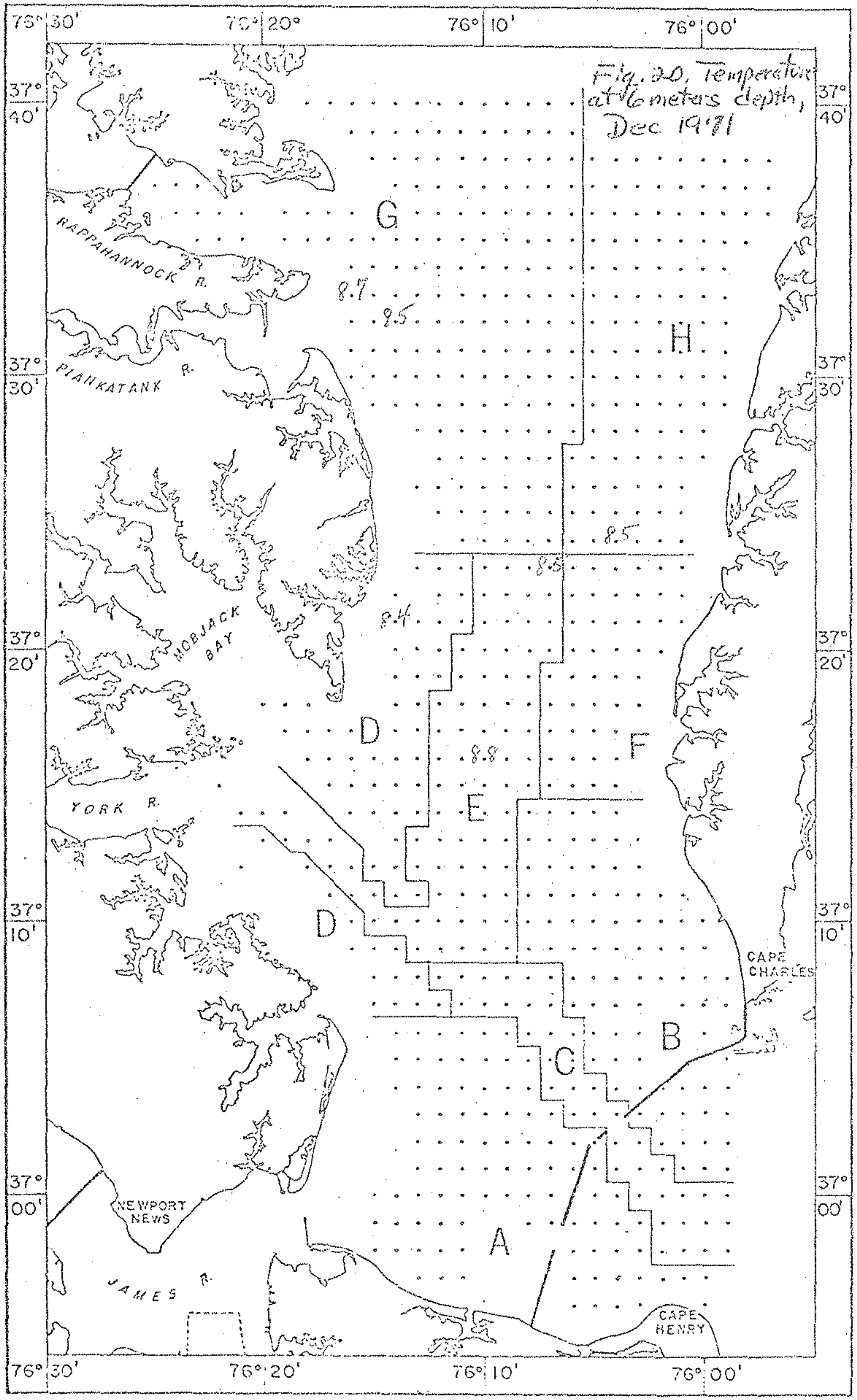
Fig. 20, Temperature at 6 meters depth, Dec 1971
76° 30'
76° 20'
76° 10'
76° 00'
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
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CAPE HENRY
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8.4
8.8

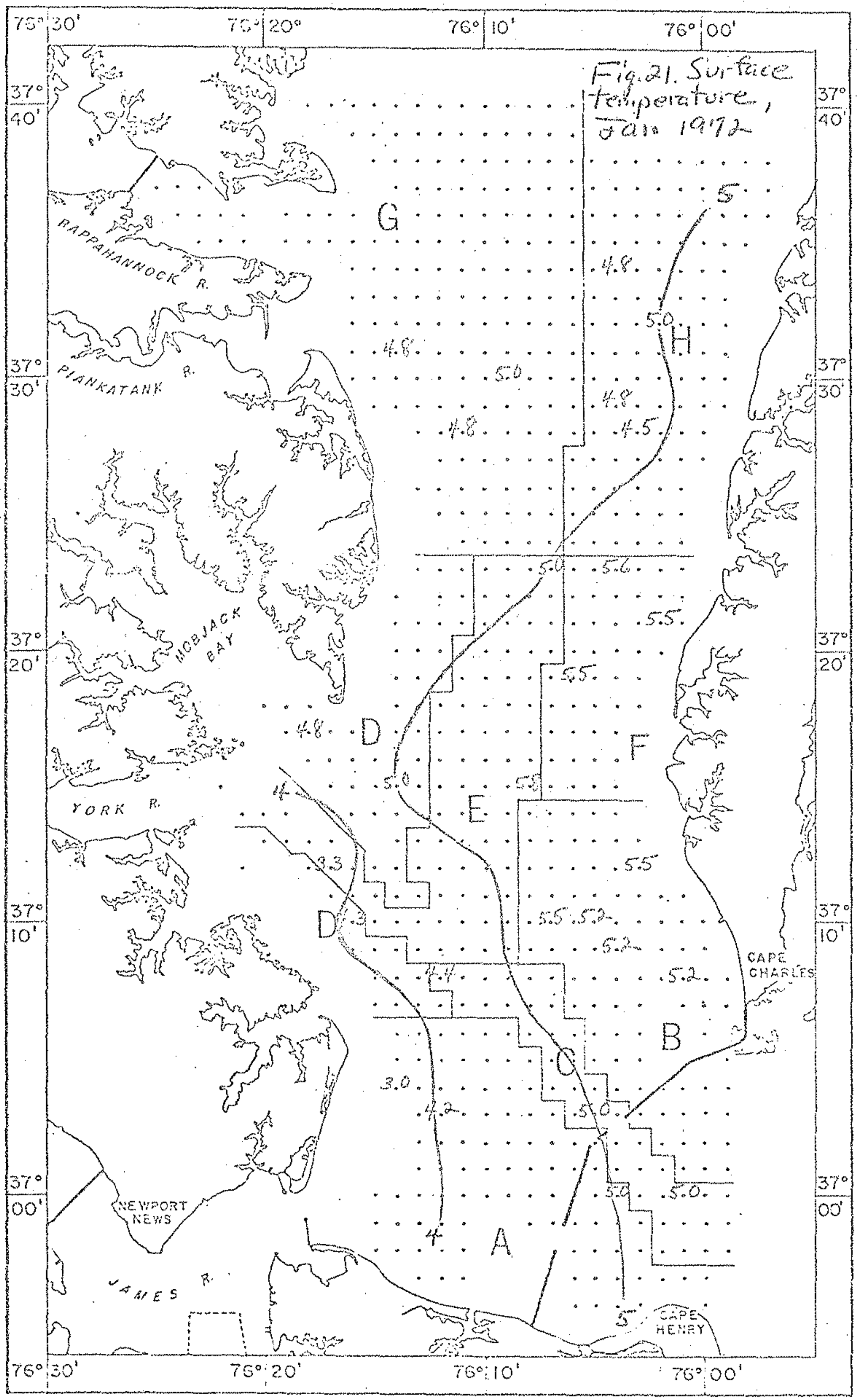


Fig. 21. Surface temperature, Jan 1972

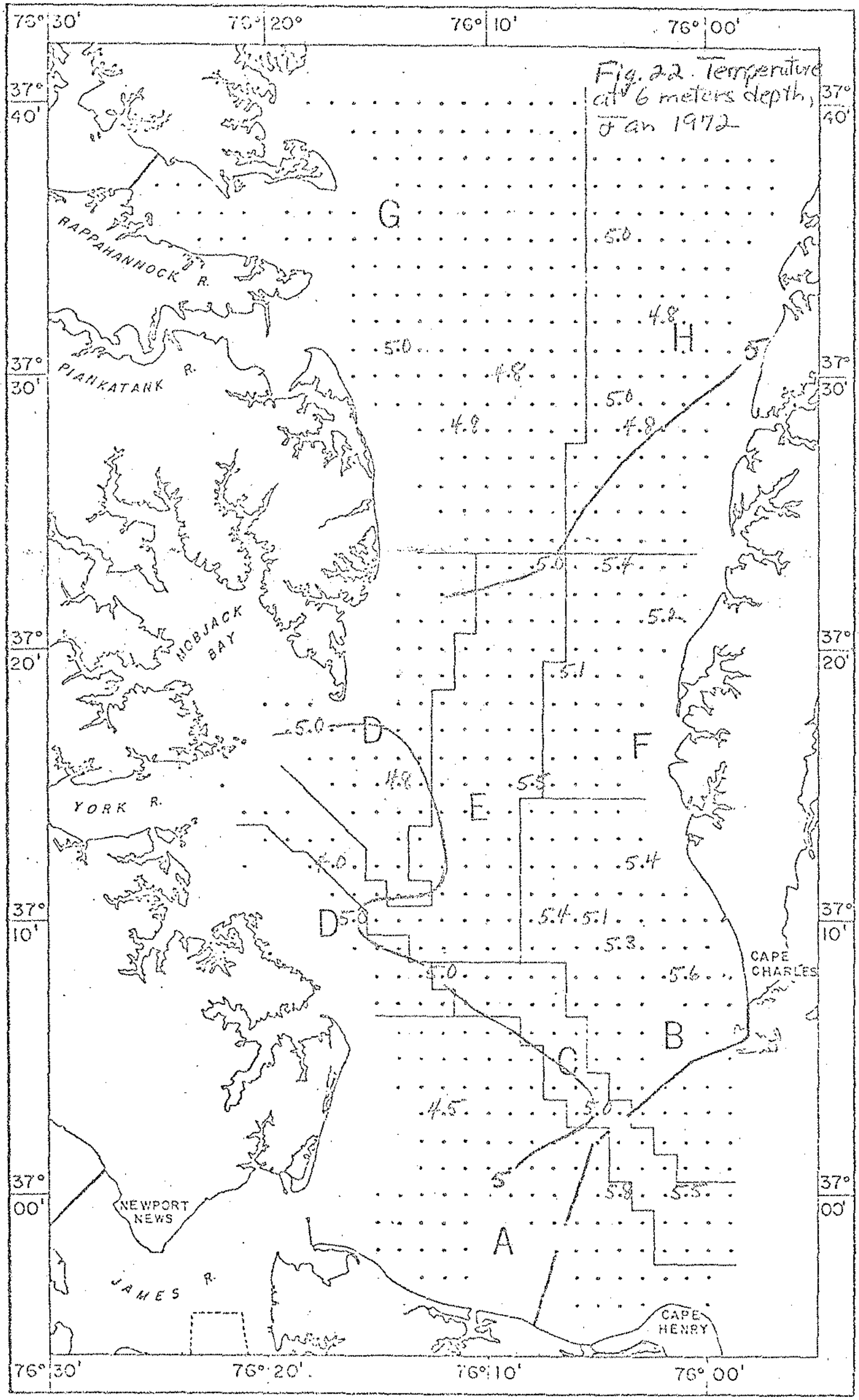


Fig. 22. Temperature at 6 meters depth, Jan 1972

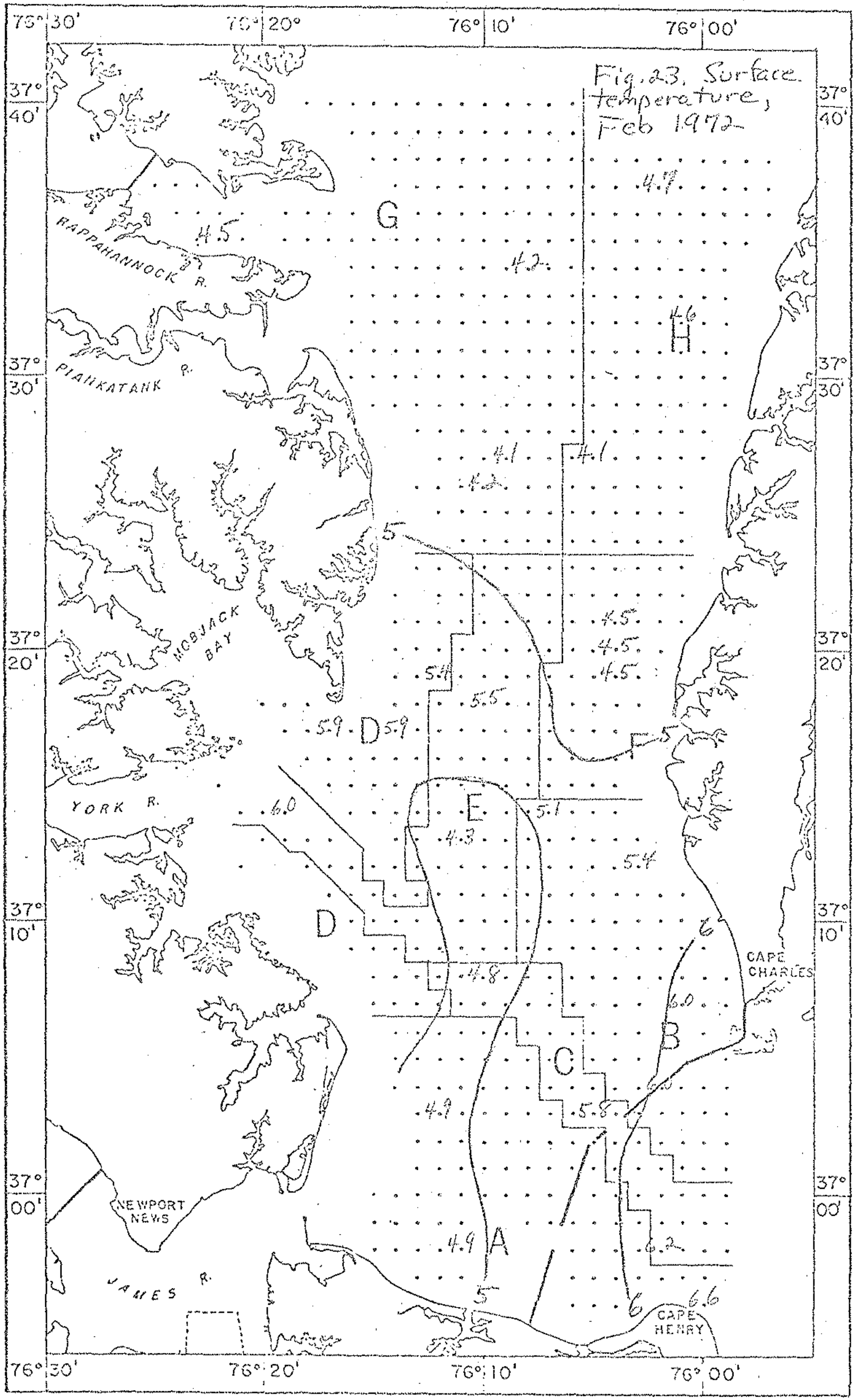


Fig. 23. Surface temperature, Feb 1972
76° 30'
76° 20'
76° 10'
76° 00'
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
C
B
A
4.5
4.2
4.7
4.6
4.1
5
5.4
5.5
5.9
6.0
4.3
5.1
4.8
4.9
5.8
6.2
6.6
6

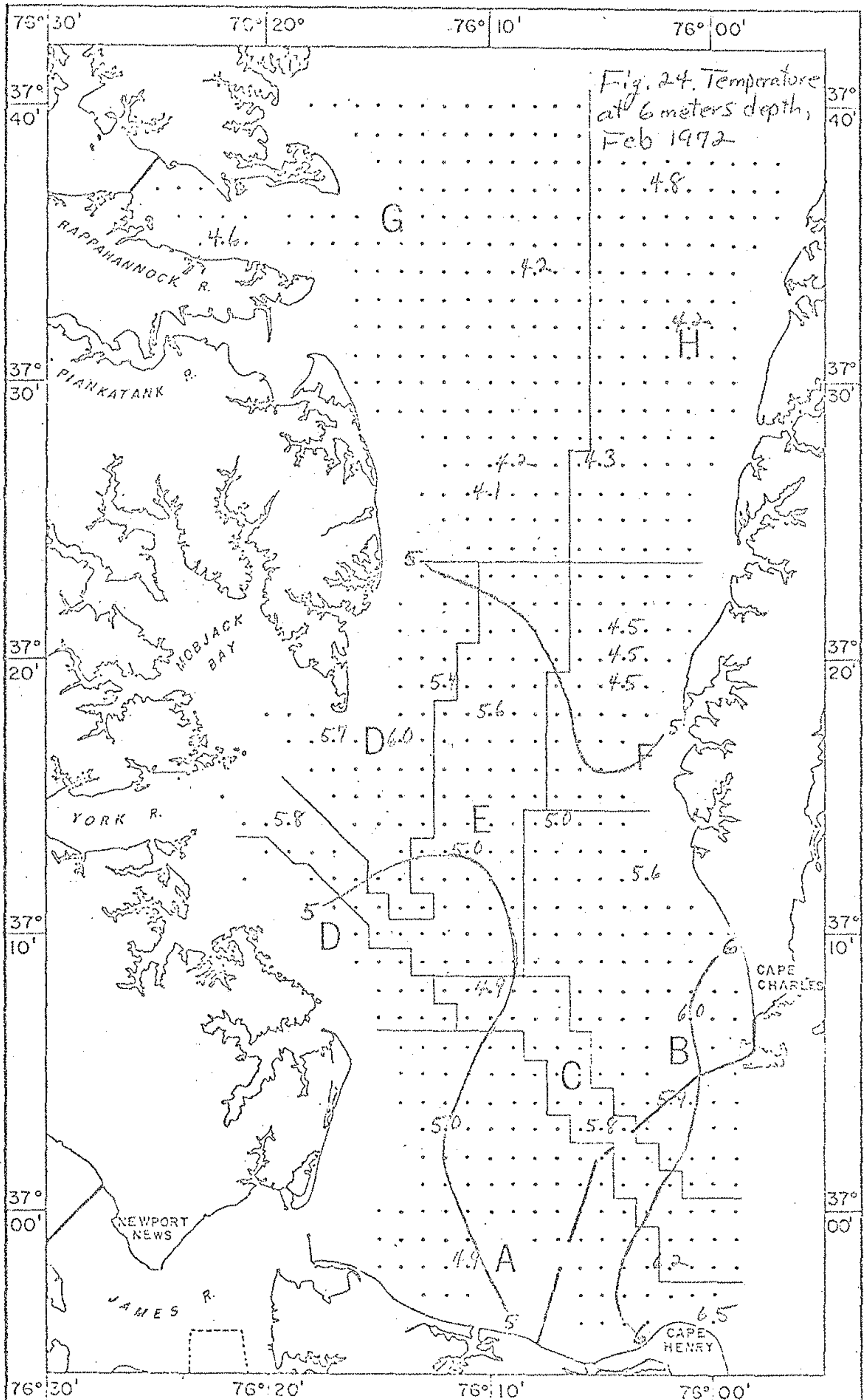


Fig. 24. Temperature at 6 meters depth, Feb 1972
76° 30'
76° 20'
76° 10'
76° 00'
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
F
C
B
A
4.6
4.8
4.2
4.2
4.3
4.2
4.1
4.5
4.5
4.5
5.4
5.6
5.7
6.0
5.8
5.0
5.0
5.6
4.9
6.0
5.4
5.8
5.0
4.9
6.2
6.5
5
6

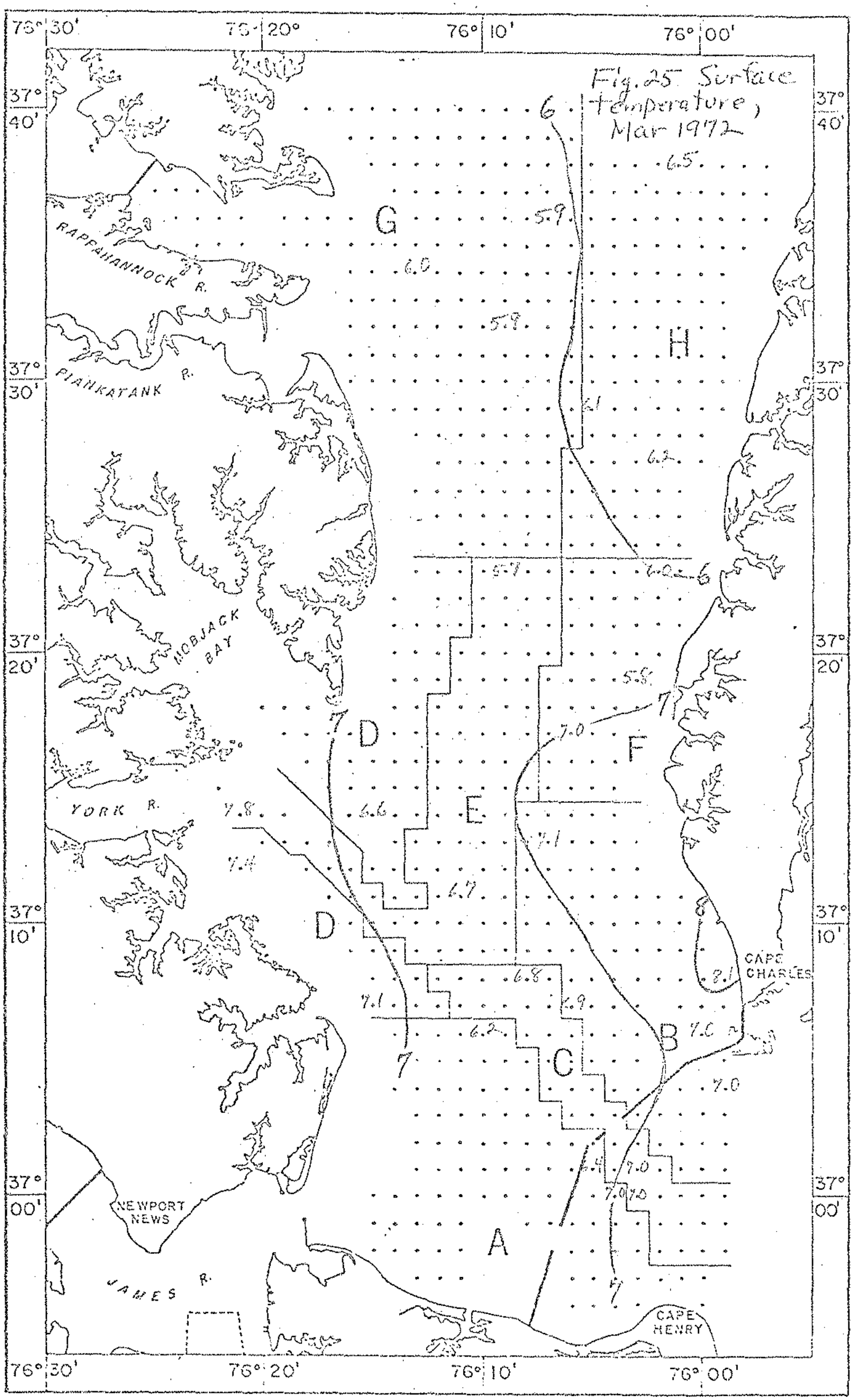


Fig. 25 Surface temperature, Mar 1972
76° 30'
76° 20°
76° 10'
76° 00'
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
F
D
C
B
A

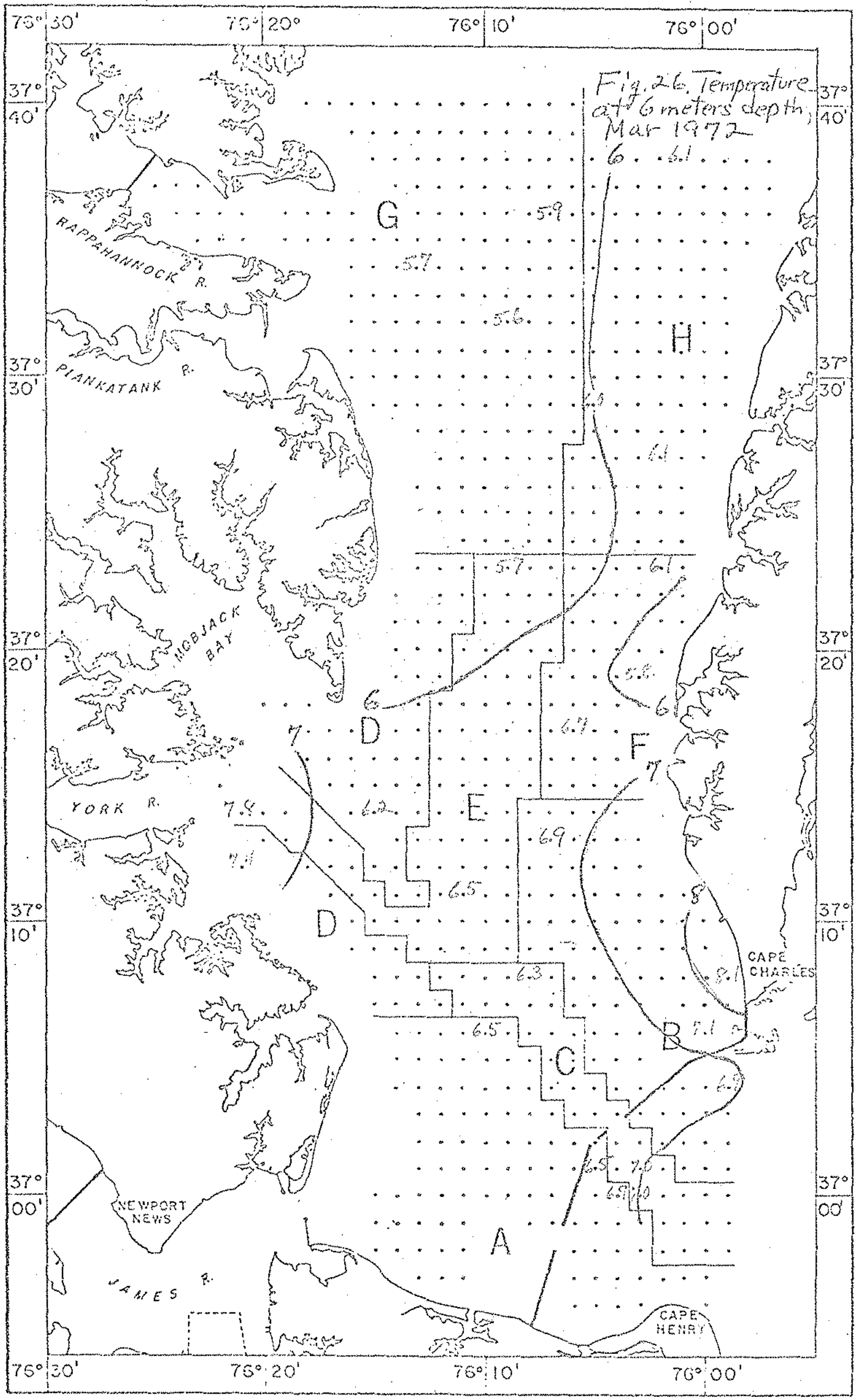


Fig. 26. Temperature at 6 meters depth, Mar 1972

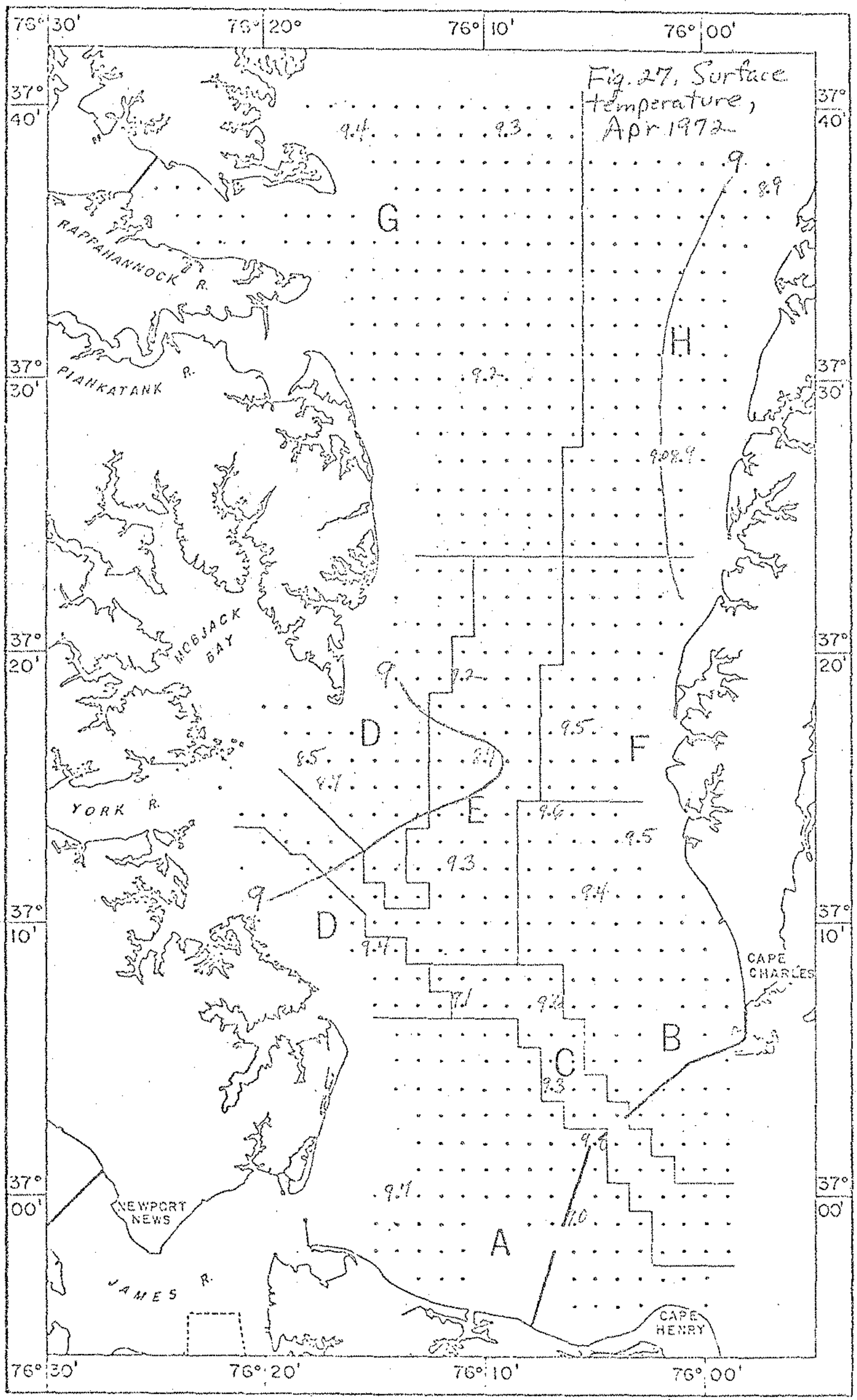


Fig. 27, Surface temperature, Apr 1972
76° 30'
76° 20'
76° 10'
76° 00'
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
A
B
C
D
E
F
G
H
9.4
9.3
9.2
9
8.9
9.5
9.6
9.4
9.3
9.1
9.5
11.0

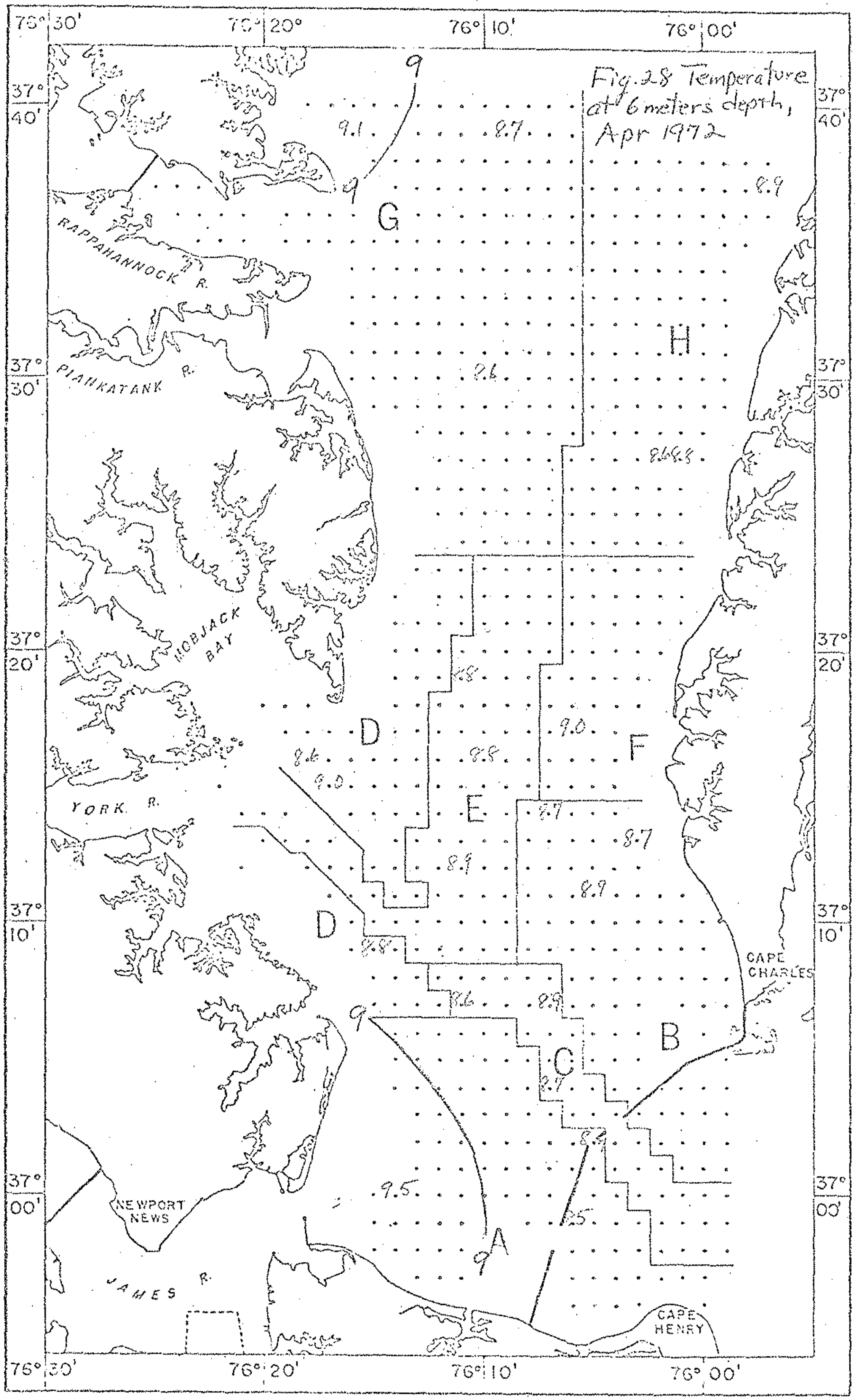


Fig. 28 Temperature at 6 meters depth, Apr 1972

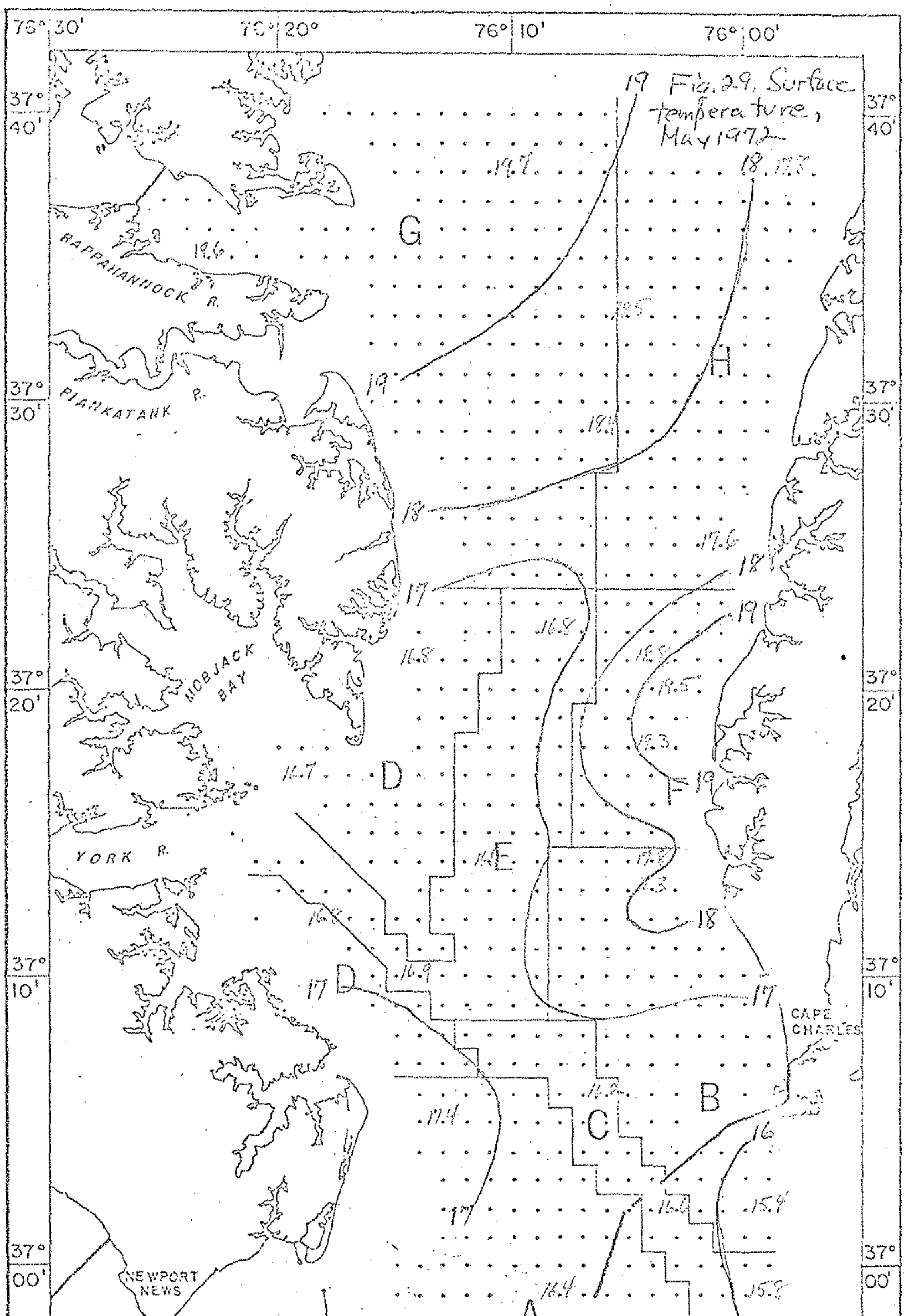


Fig. 29. Surface temperature, May 1972

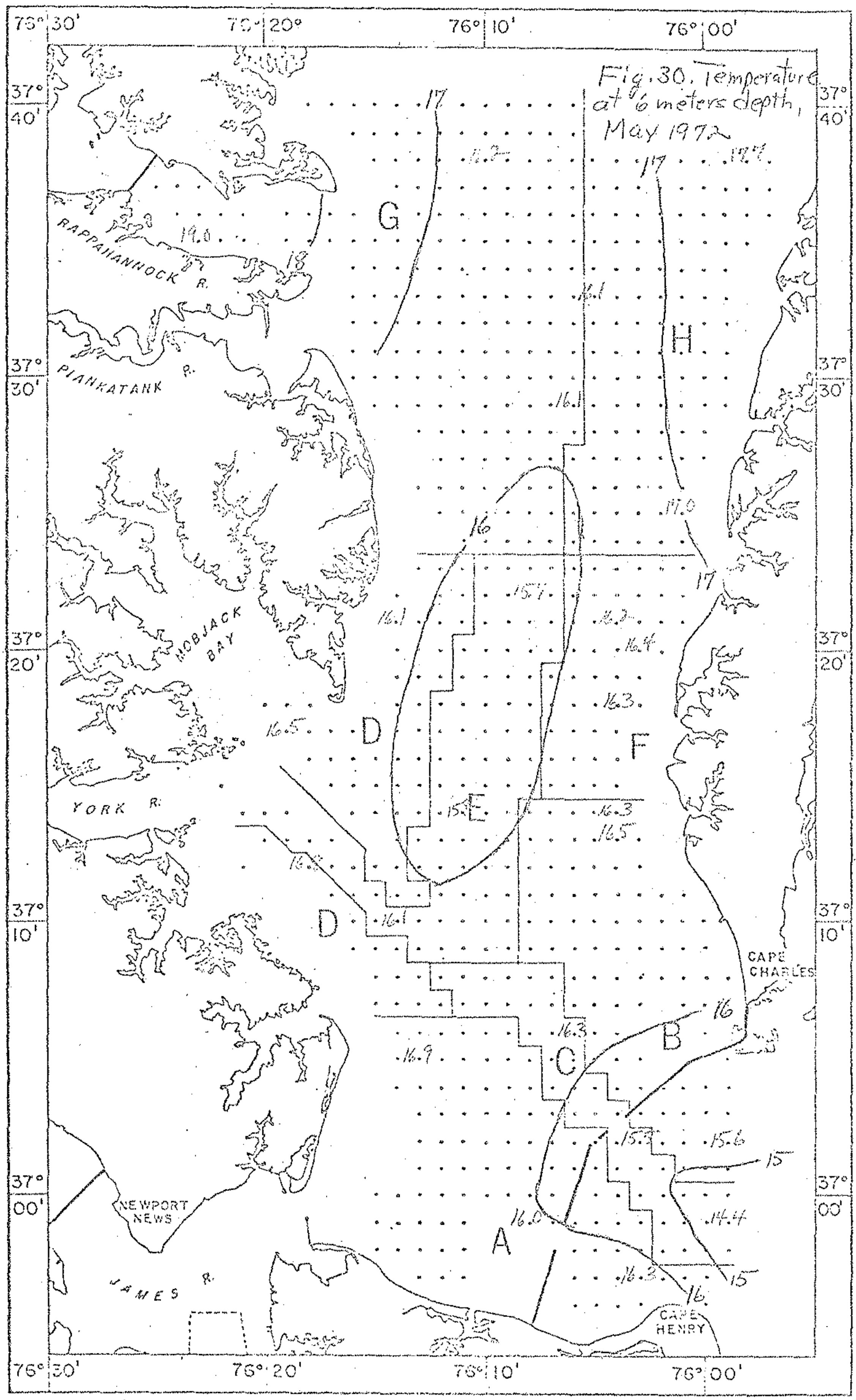


Fig. 30. Temperature at 6 meters depth, May 1972

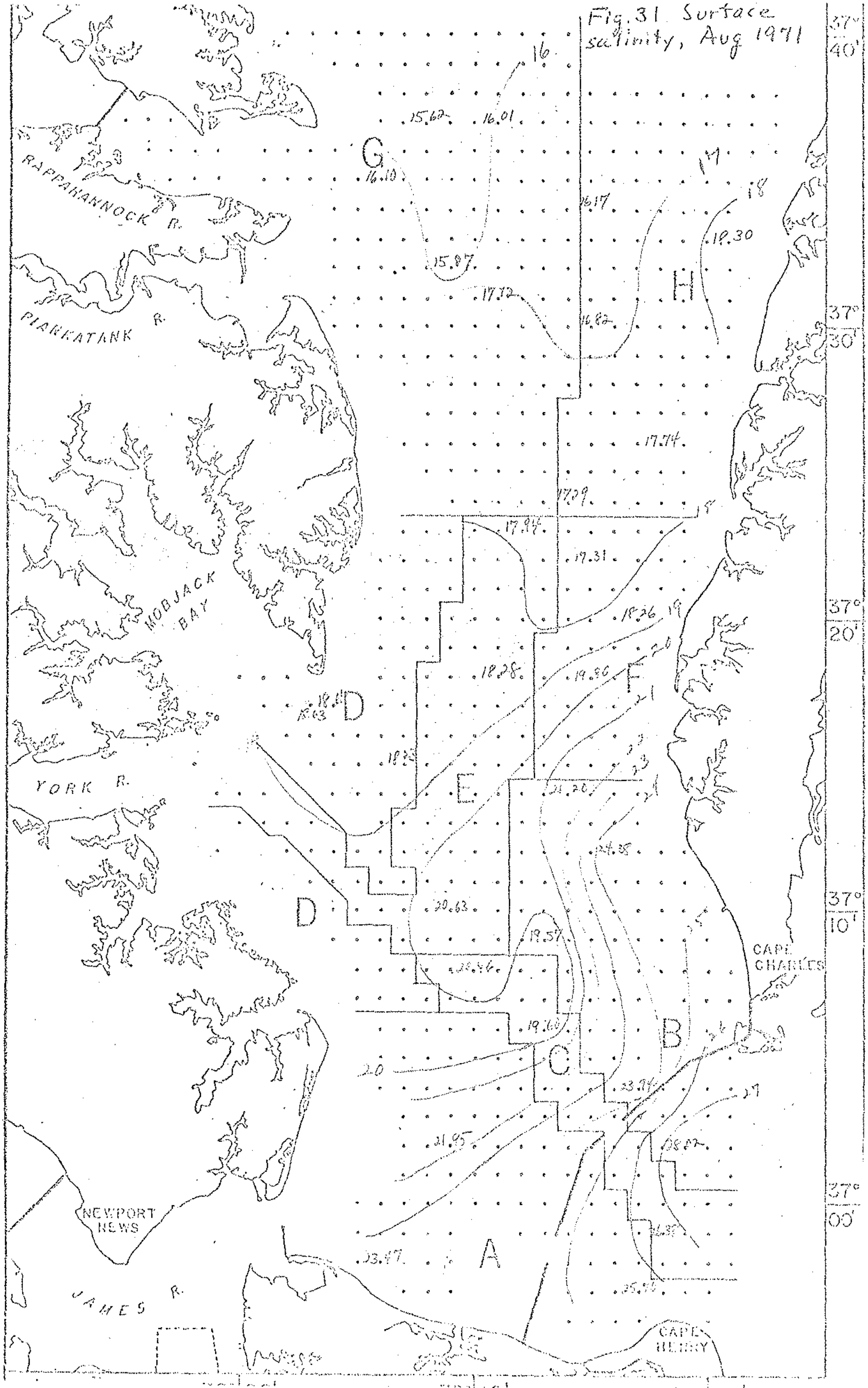


Fig. 31 Surface salinity, Aug 1971

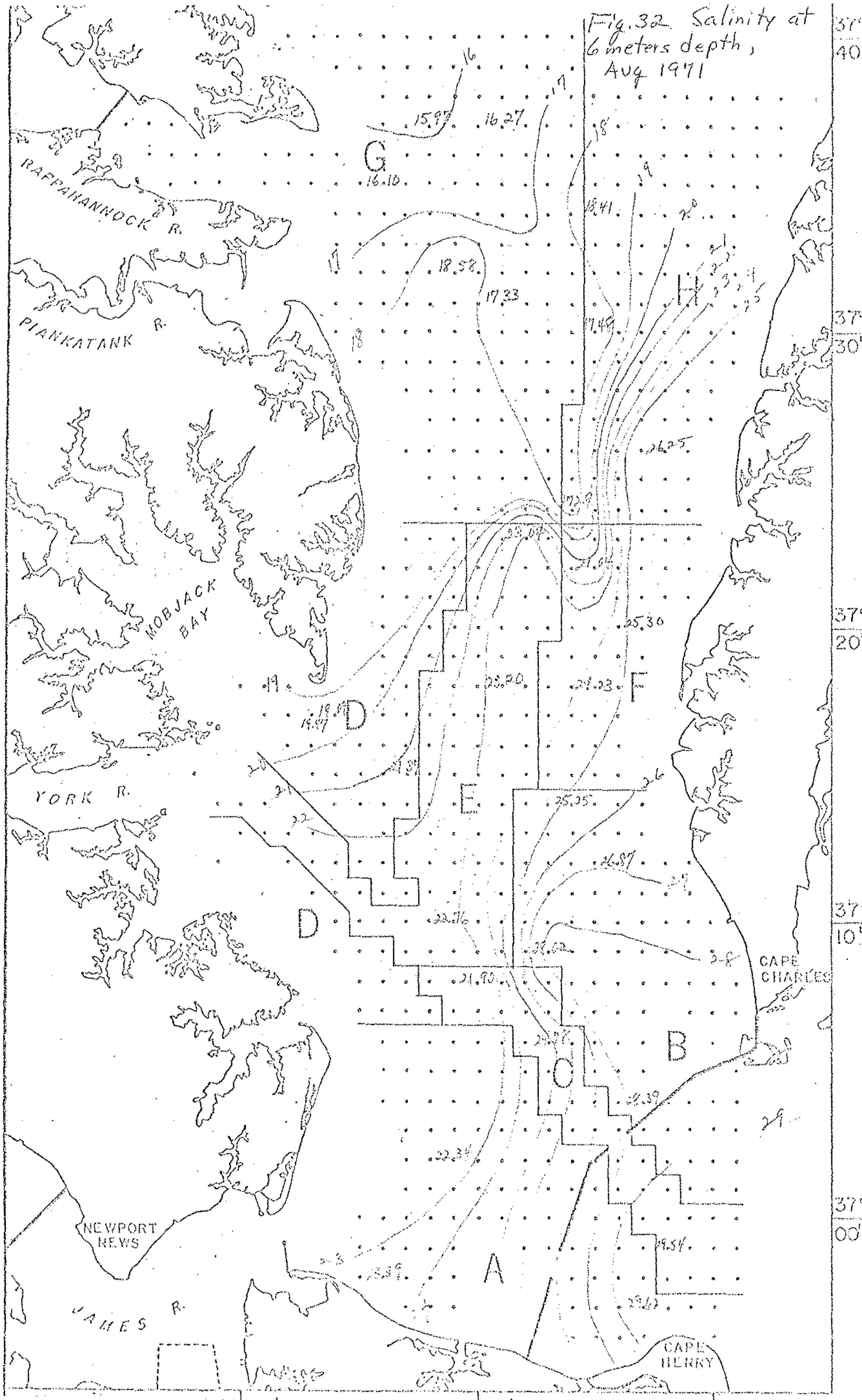


Fig. 32 Salinity at 6 meters depth, Aug 1971

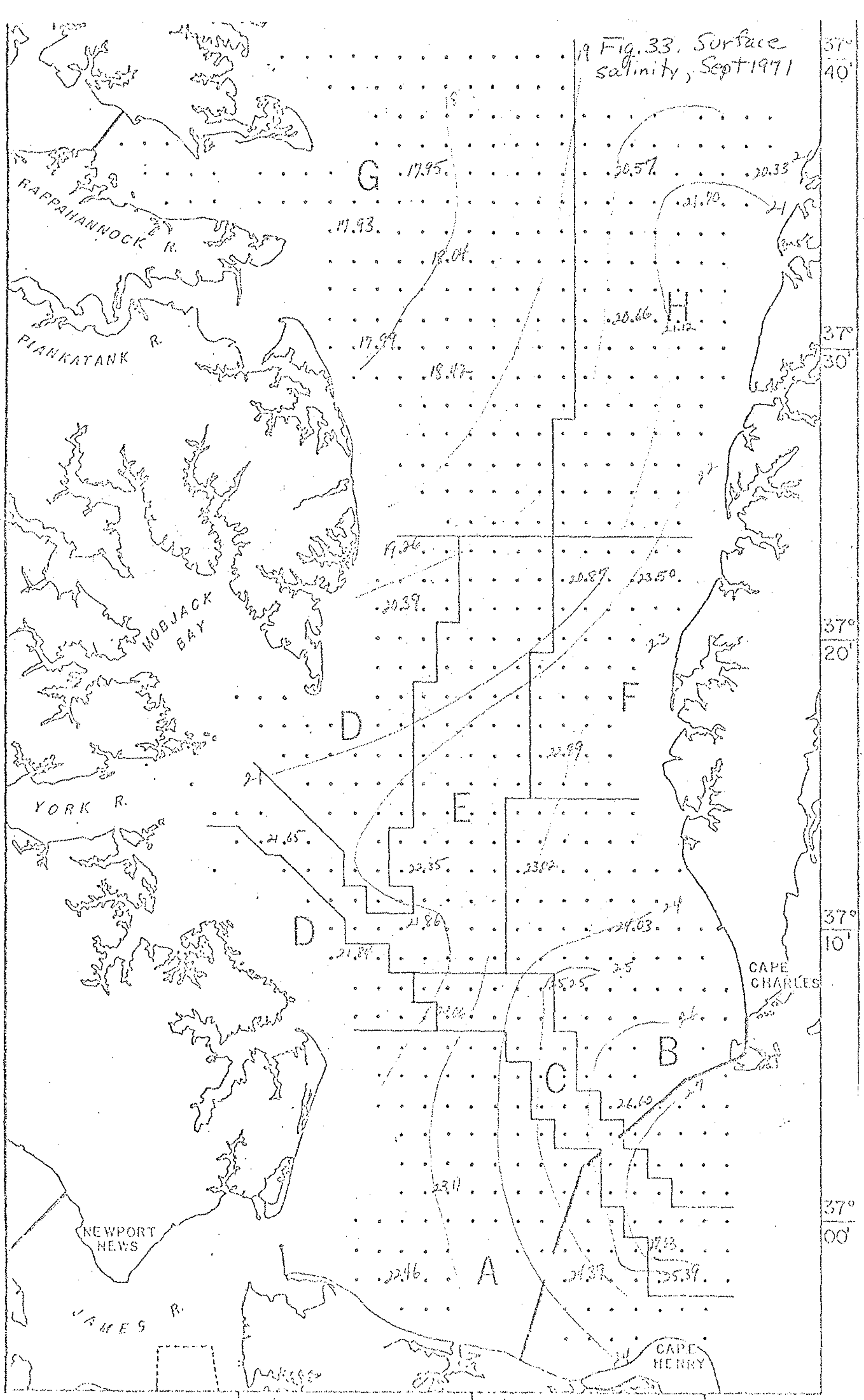


Fig. 33. Surface salinity, Sept 1971

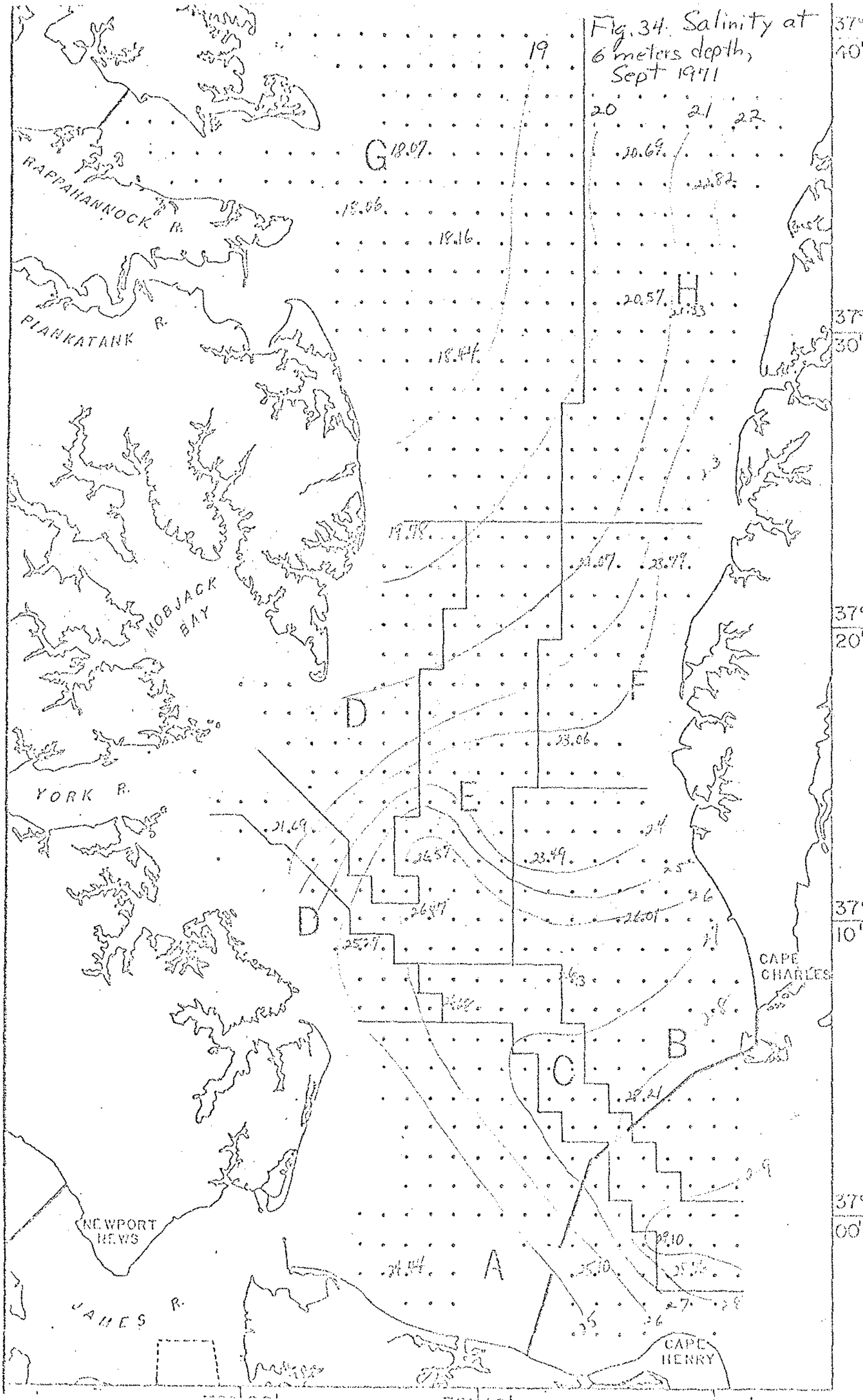


Fig. 34. Salinity at 6 meters depth, Sept 1971

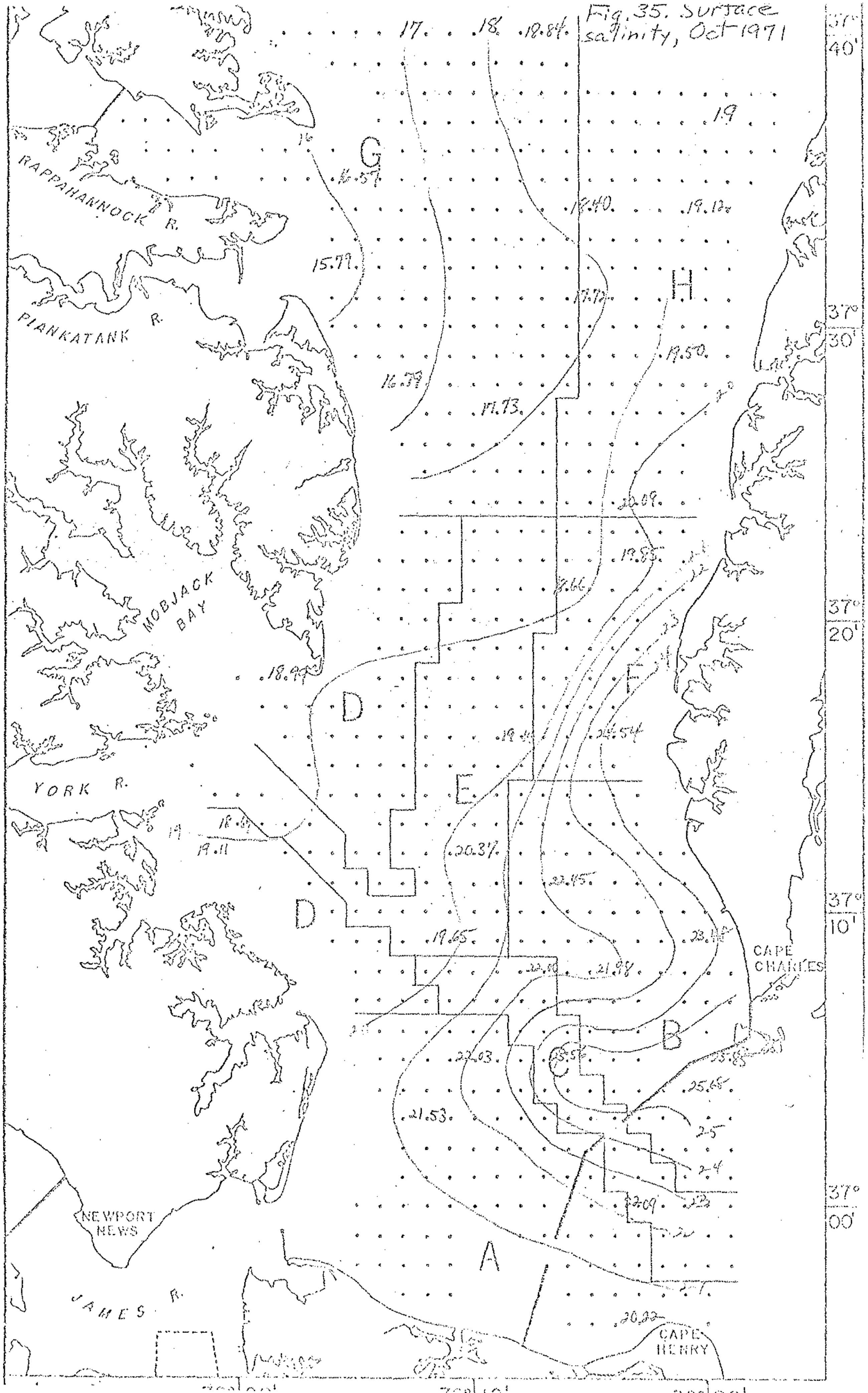


Fig. 35. Surface salinity, Oct 1971

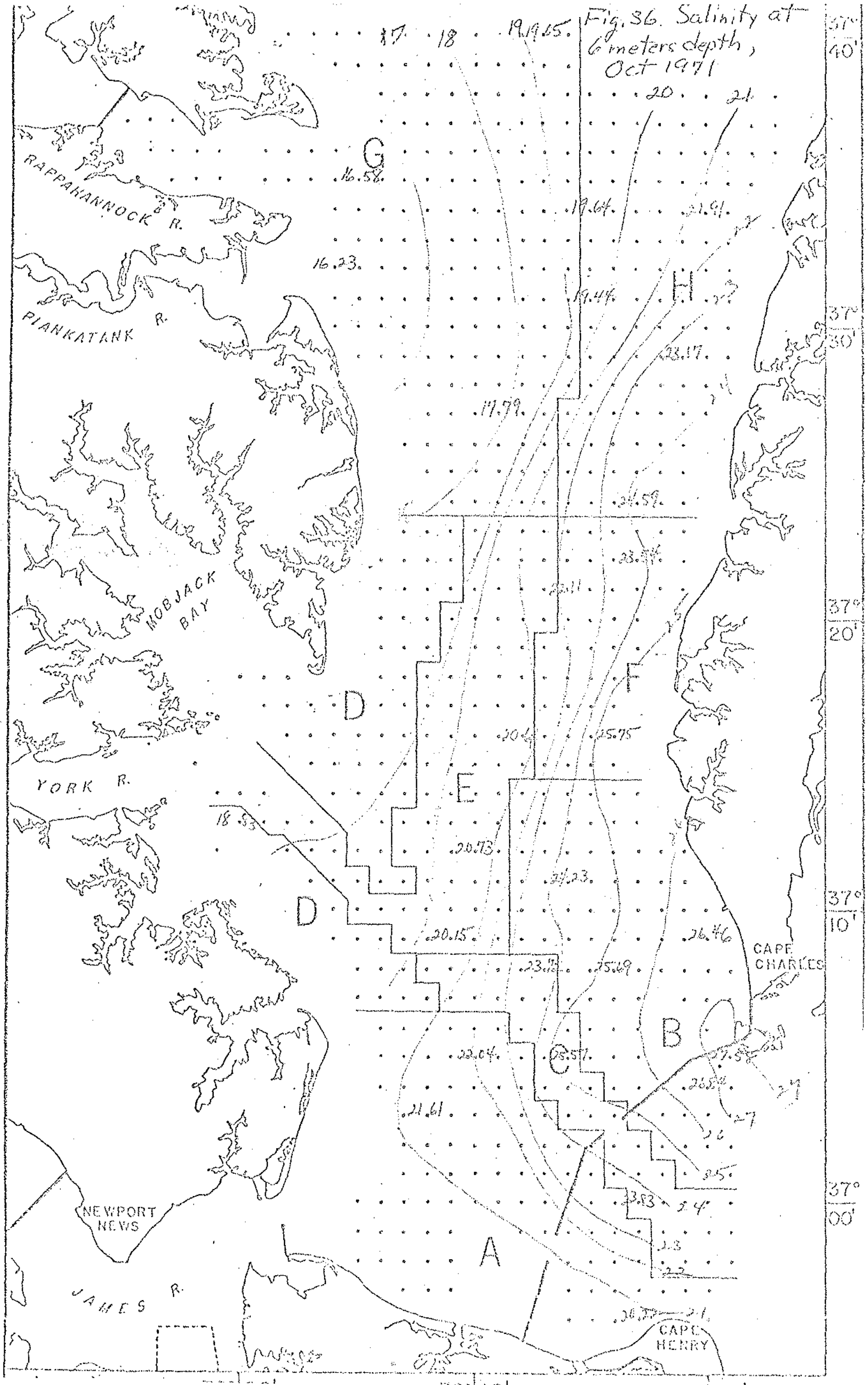


Fig. 36. Salinity at 6 meters depth, Oct 1971

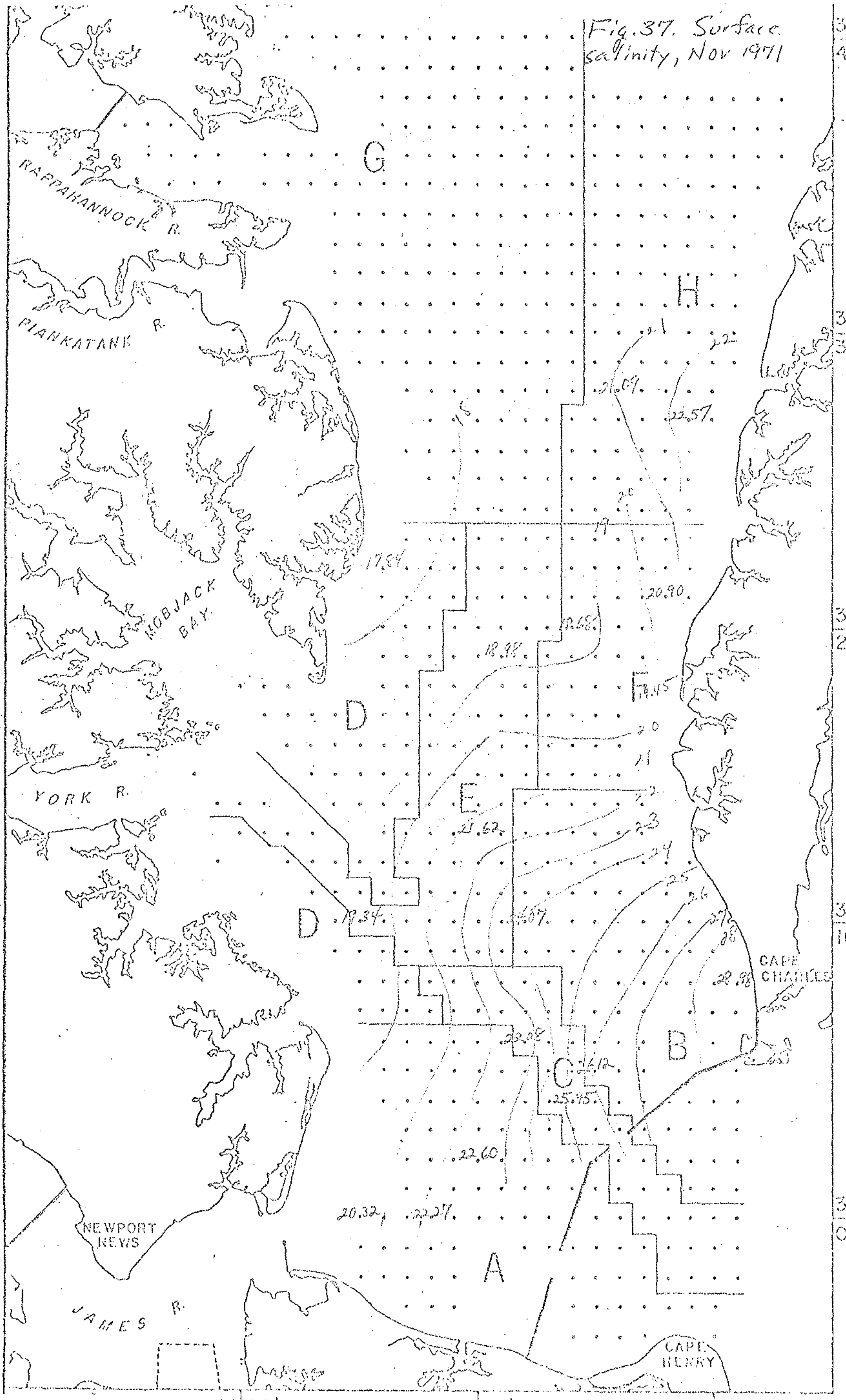


Fig. 37. Surface salinity, Nov 1971

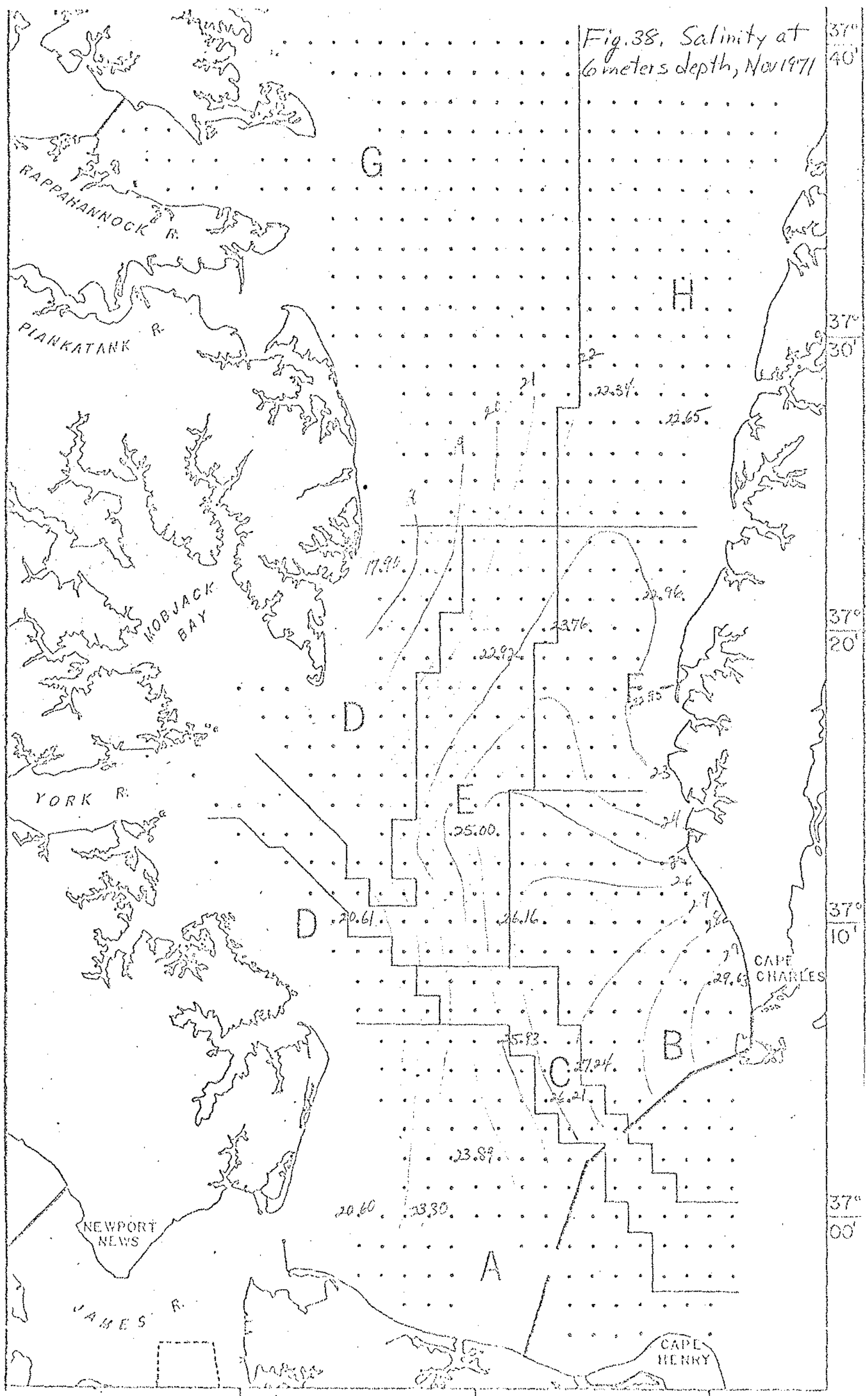


Fig. 38. Salinity at 6 meters depth, Nov 1971
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
F
D
C
B
A
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
22.34
22.65
17.95
22.96
23.76
22.92
22.85
25.00
20.61
26.16
29.63
25.93
27.24
26.21
23.89
20.60
23.30

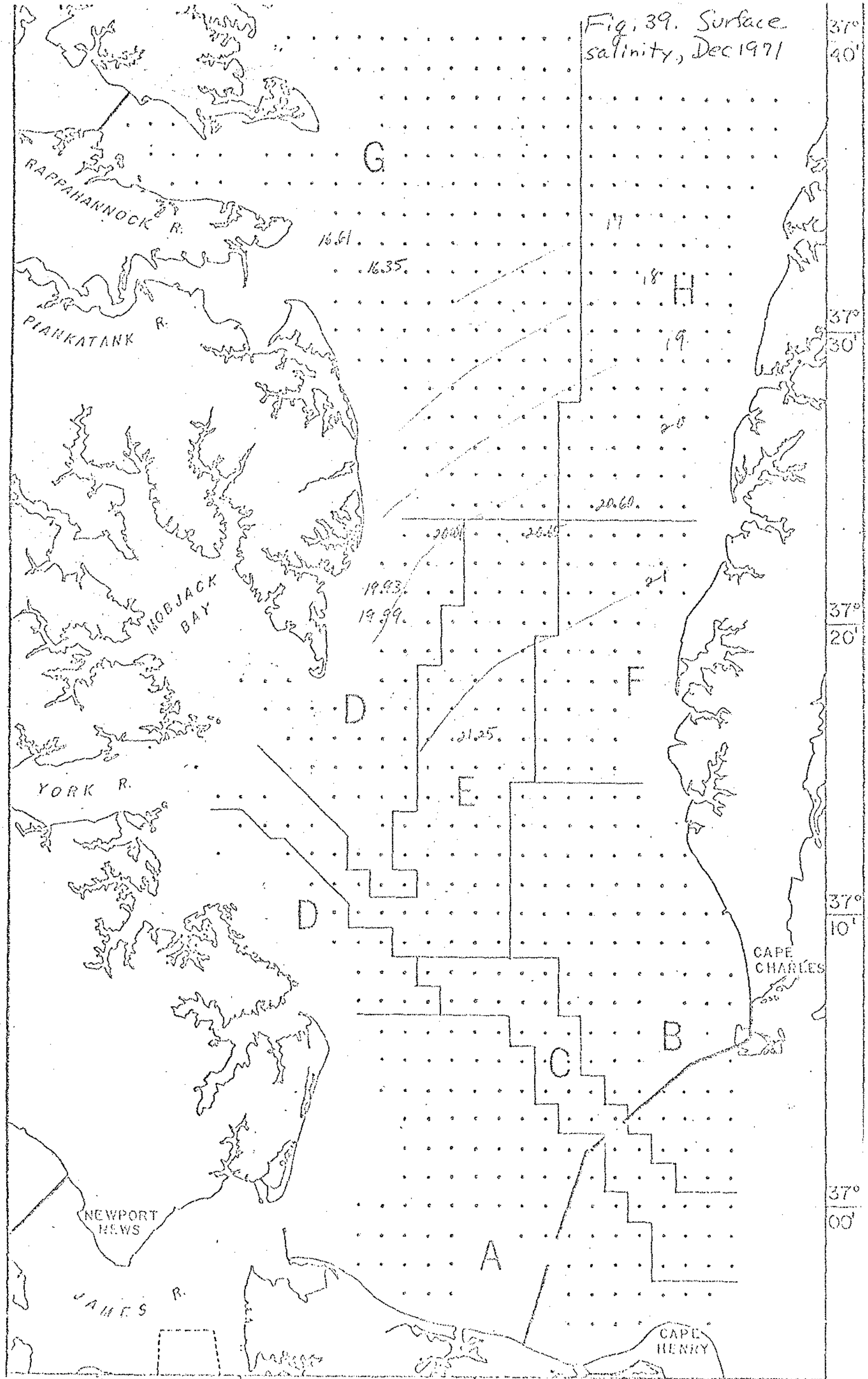


Fig. 39. Surface salinity, Dec 1971

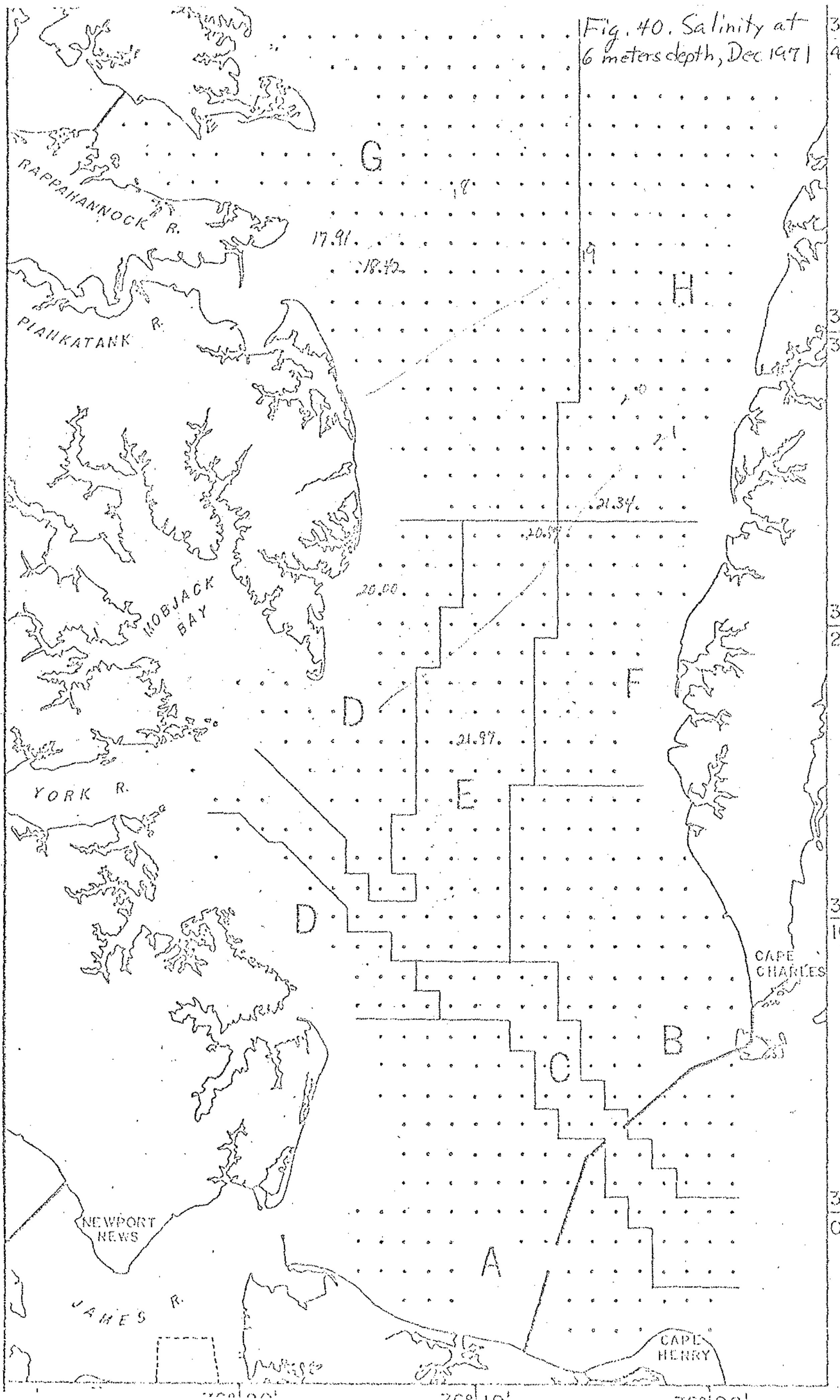


Fig. 40. Salinity at 6 meters depth, Dec 1971

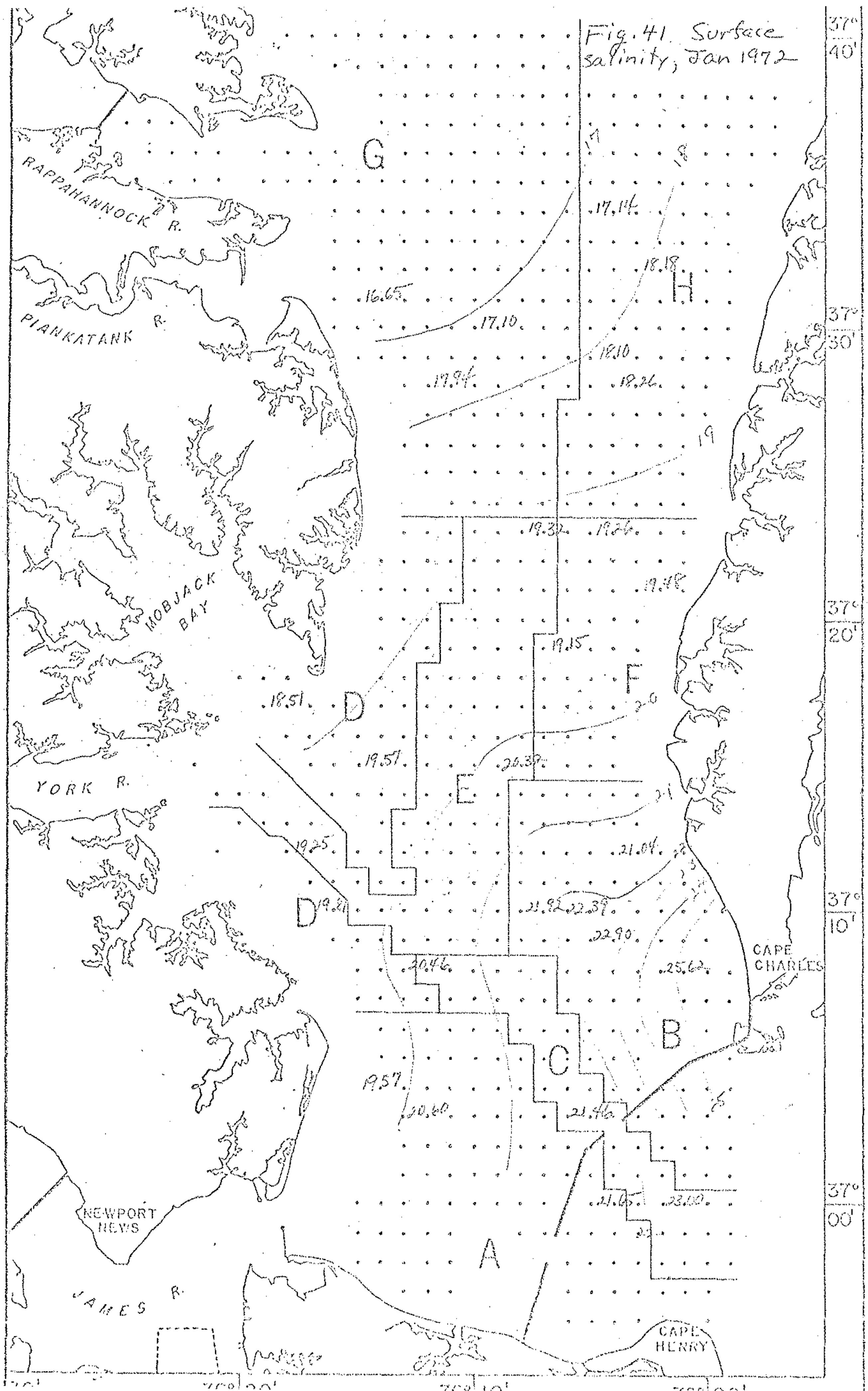


Fig. 41 Surface salinity, Jan 1972

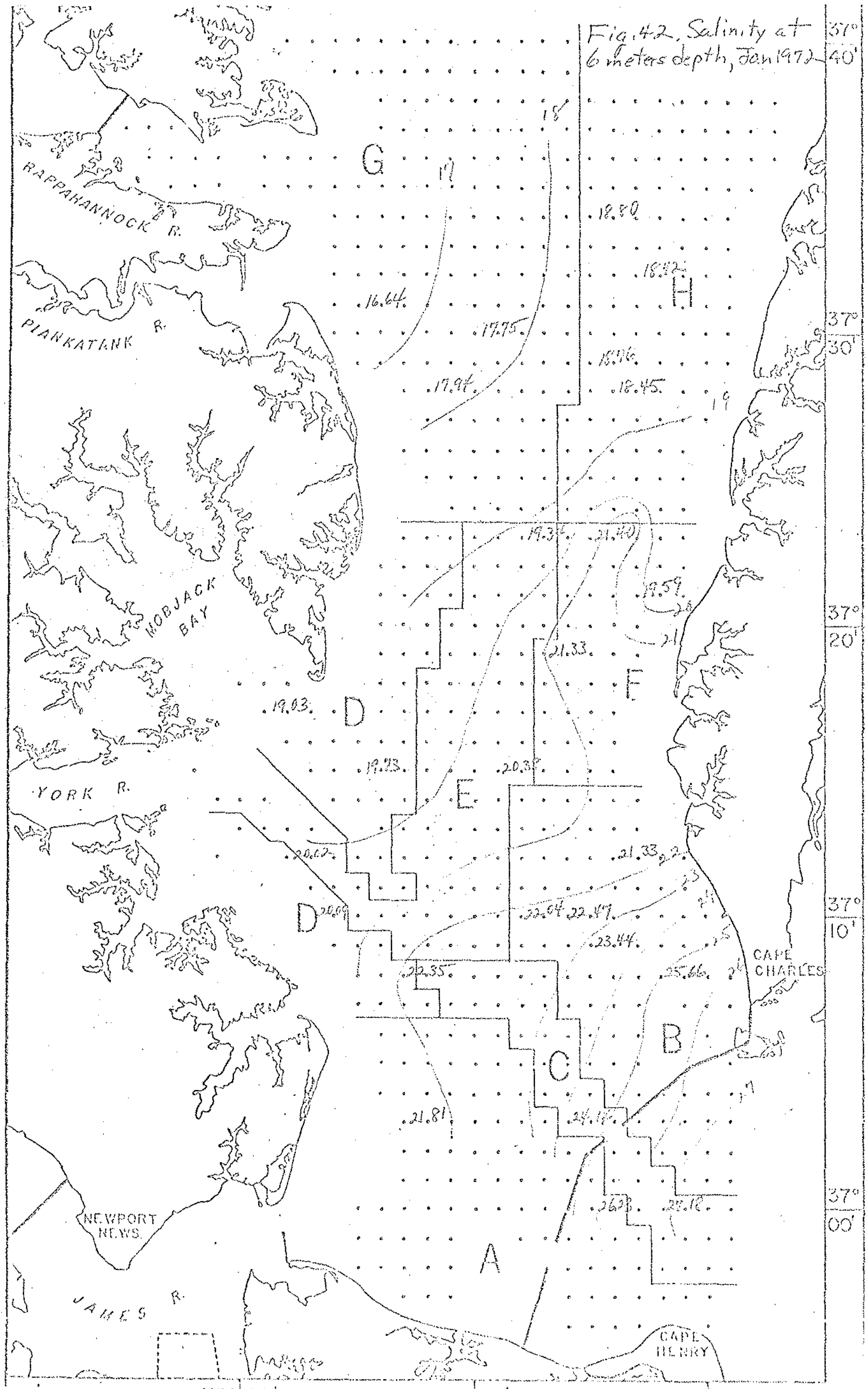


Fig. 4.2, Salinity at 6 meters depth, Jan 1972
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
A
B
C
D
E
F
G
H
18
19
21
22
23
24
25
16.64
17.75
17.94
18.80
18.92
18.96
18.45
19.34
21.40
19.59
21.33
19.03
19.23
20.37
20.02
20.09
21.33
22.04
22.47
23.44
22.35
25.66
21.81
24.17
26.23
28.18

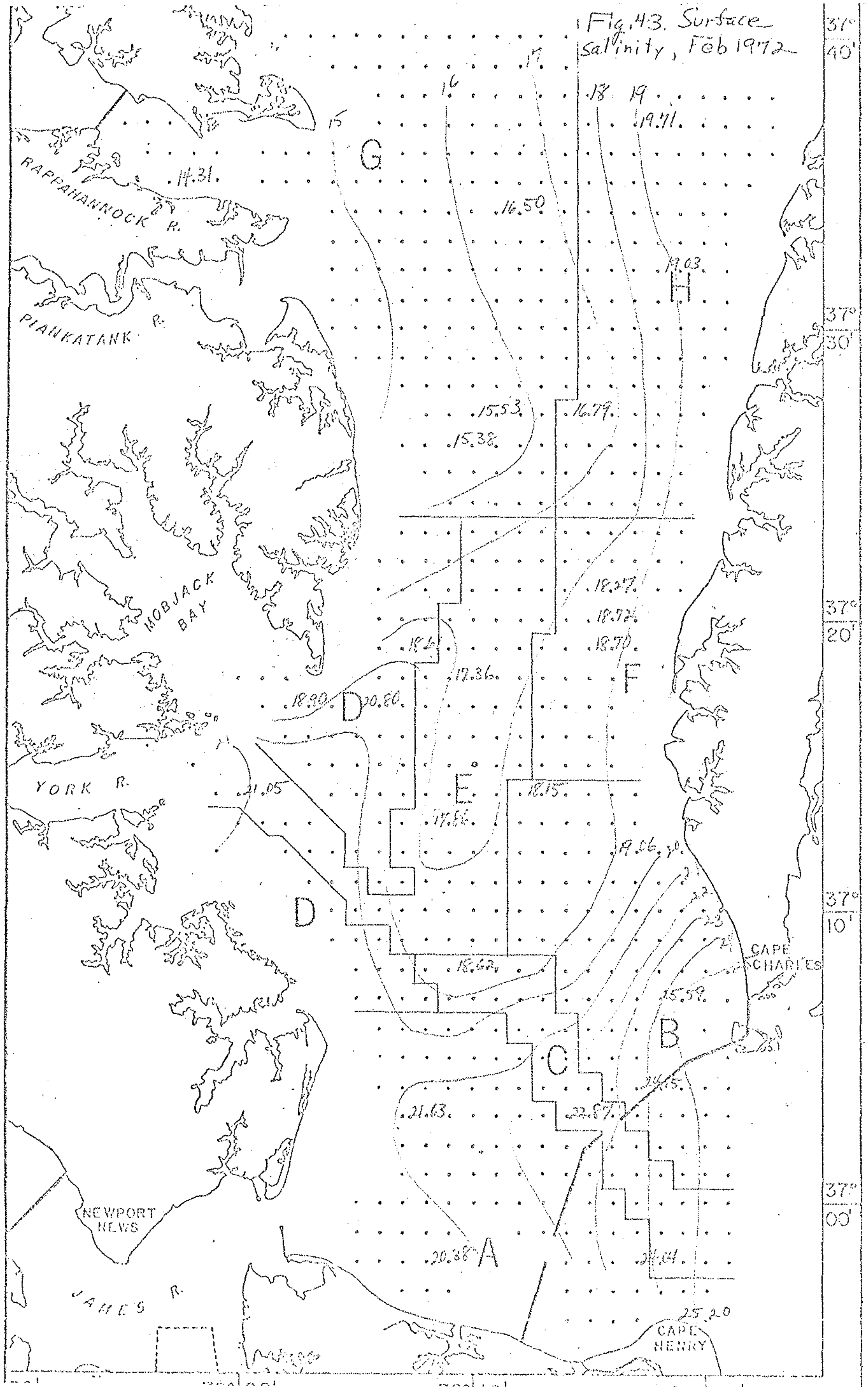


Fig. 43. Surface salinity, Feb 1972
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
F
E
D
D
C
B
A
14.31
16.50
15.53
15.38
16.79
19.71
19.03
18.27
18.72
18.70
18.6
17.36
18.90
20.80
21.05
17.66
18.15
19.06
18.62
25.59
21.63
22.87
24.15
20.38
24.04

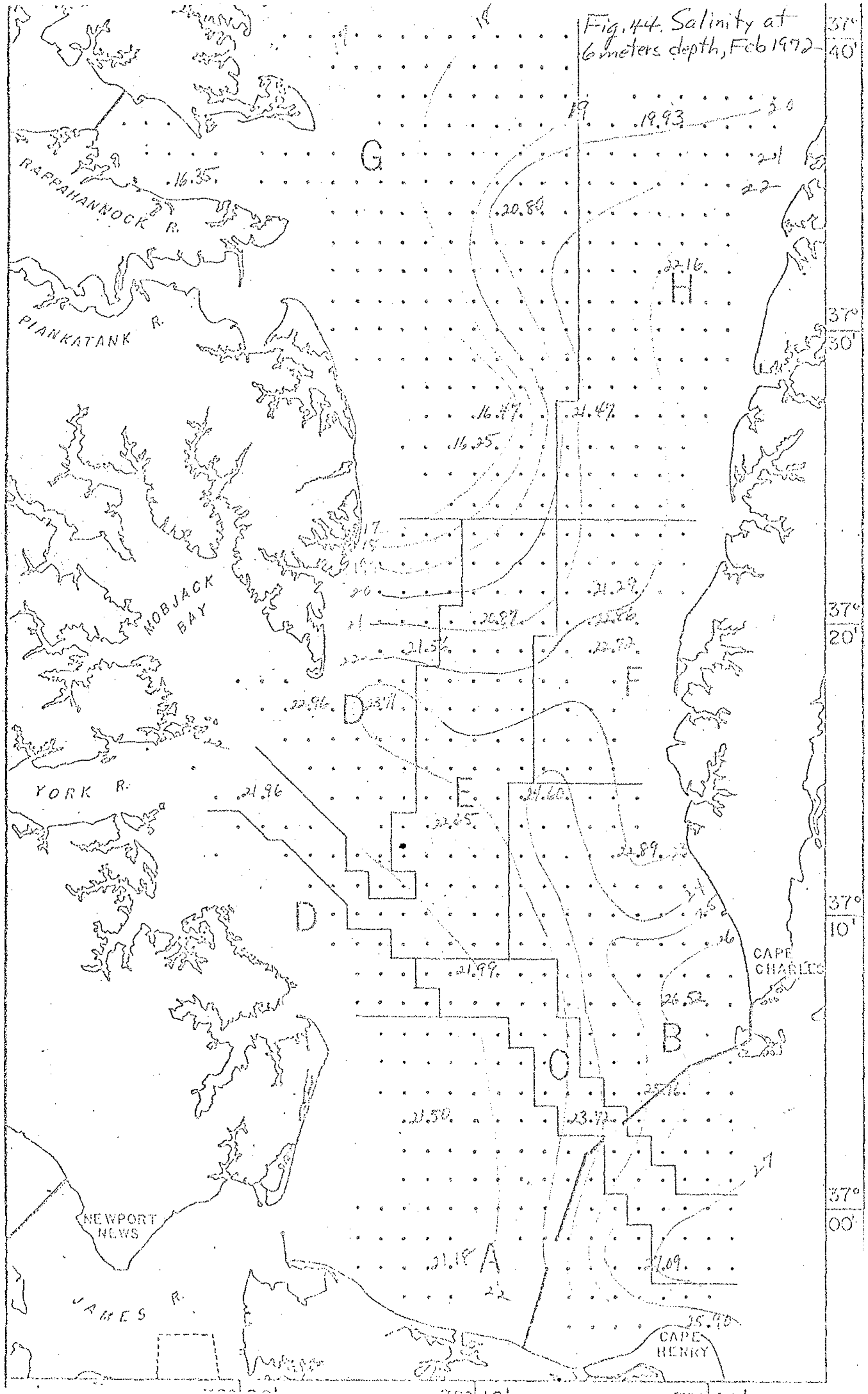


Fig. 44. Salinity at 6 meters depth, Feb 1972

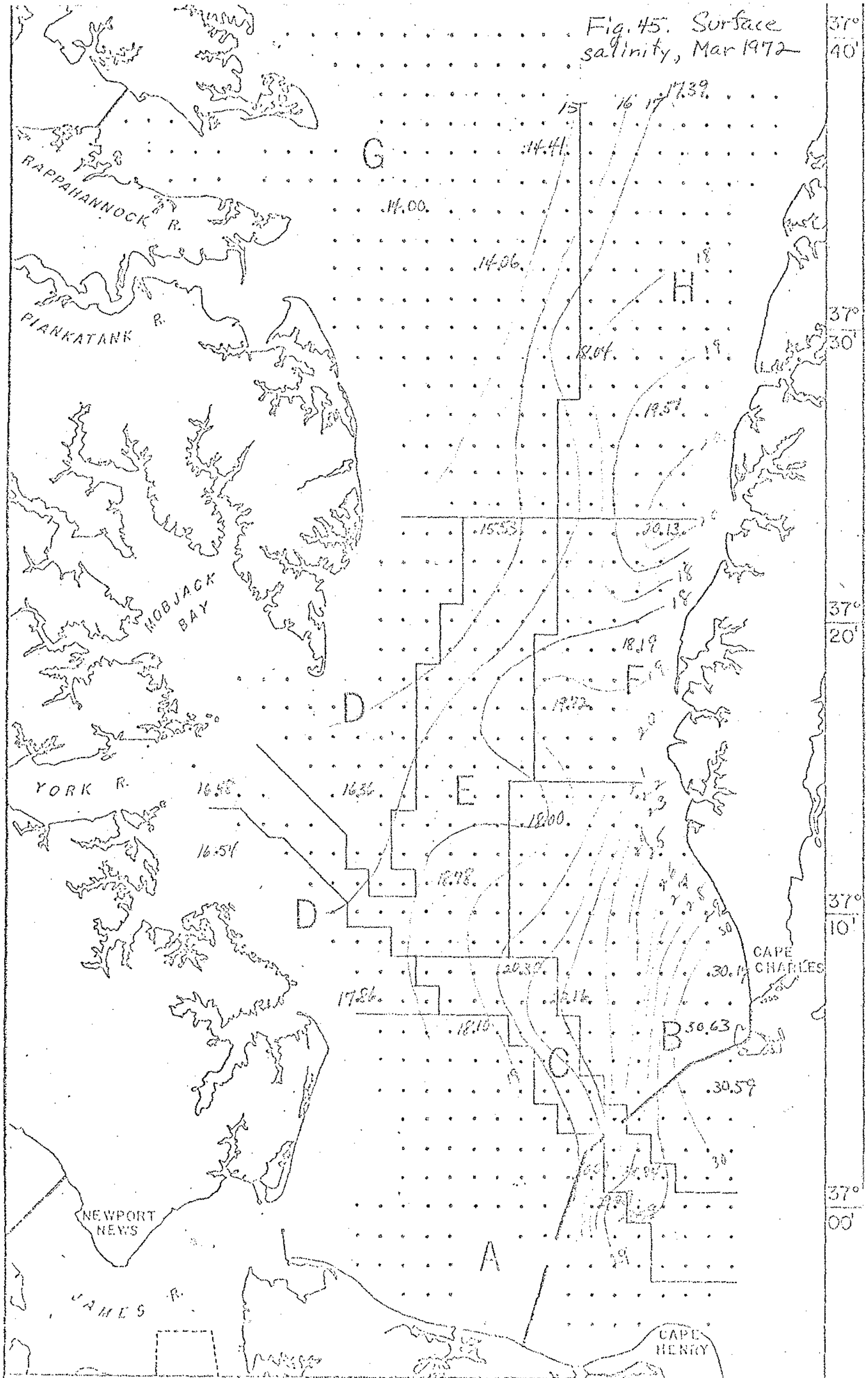


Fig. 45. Surface salinity, Mar 1972

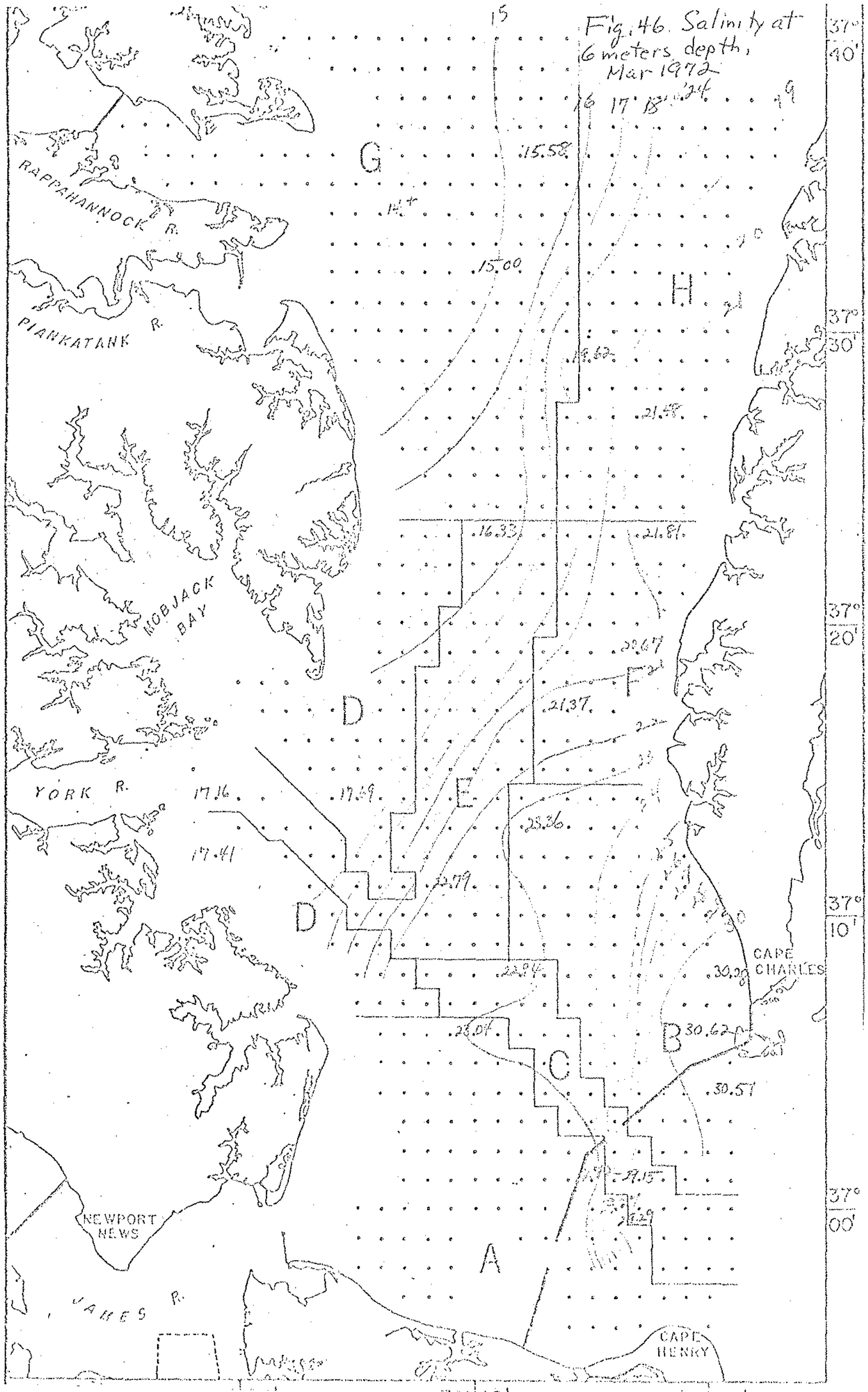


Fig. 46. Salinity at 6 meters depth, Mar 1972

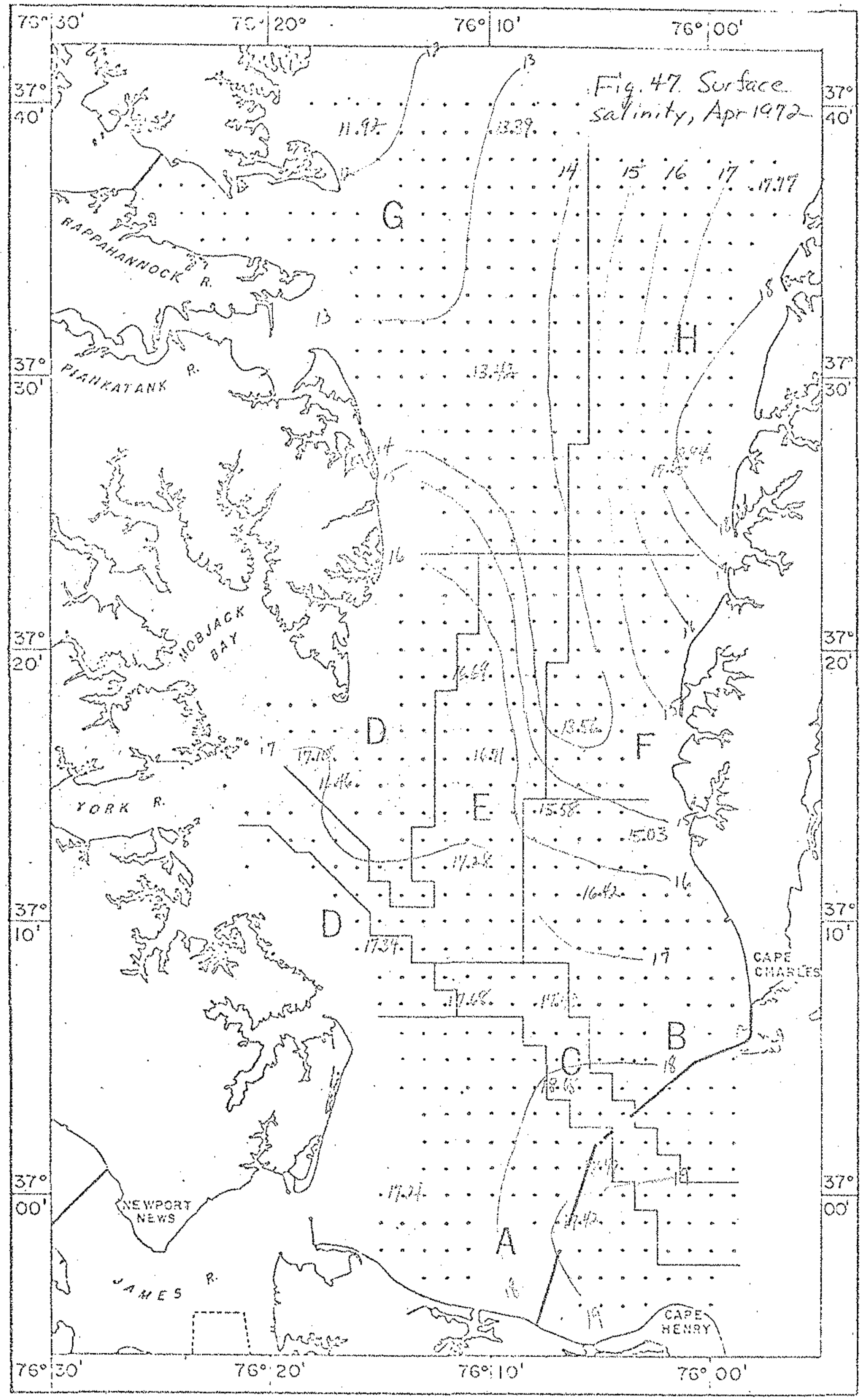


Fig. 47 Surface salinity, Apr 1972

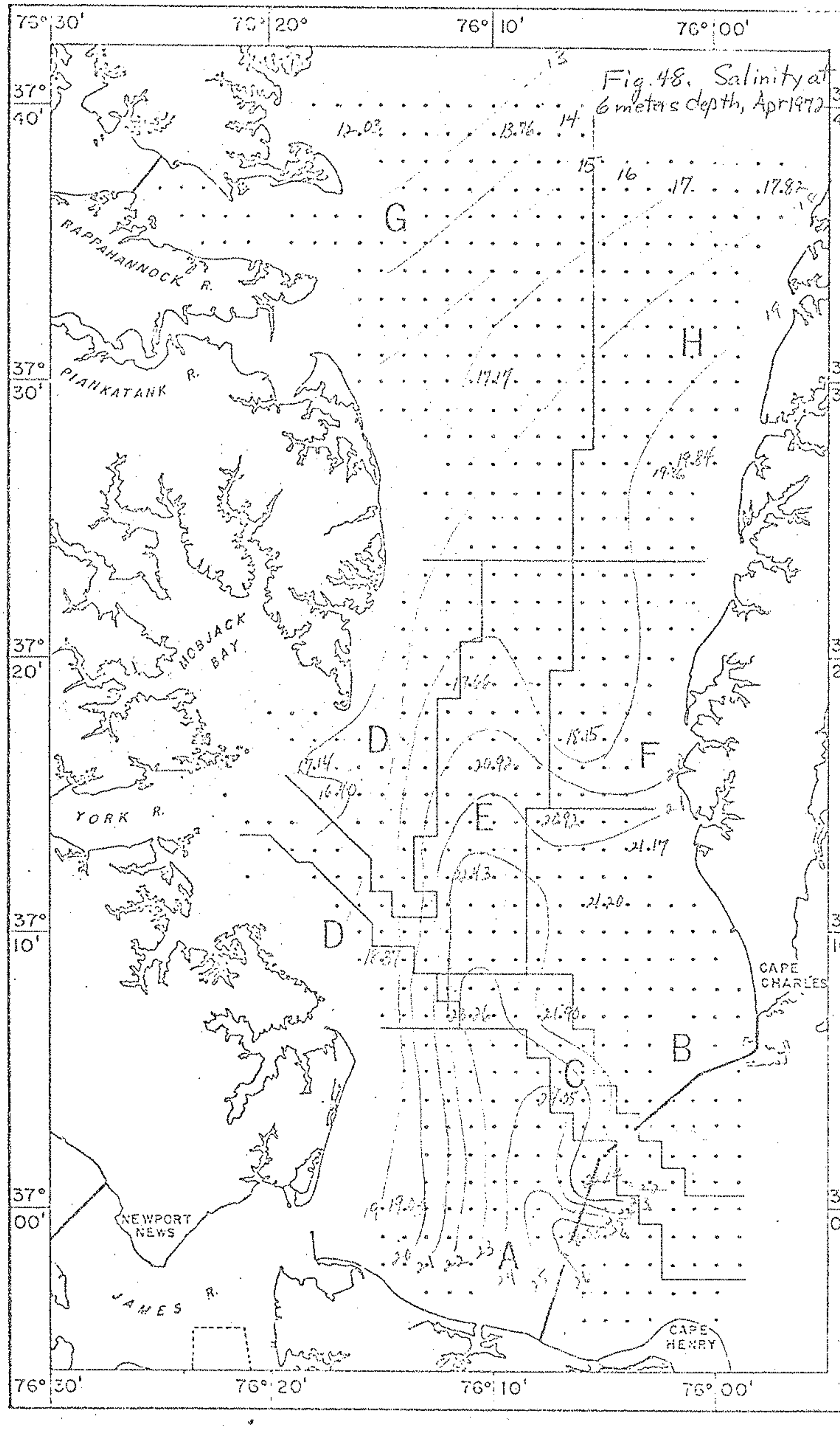
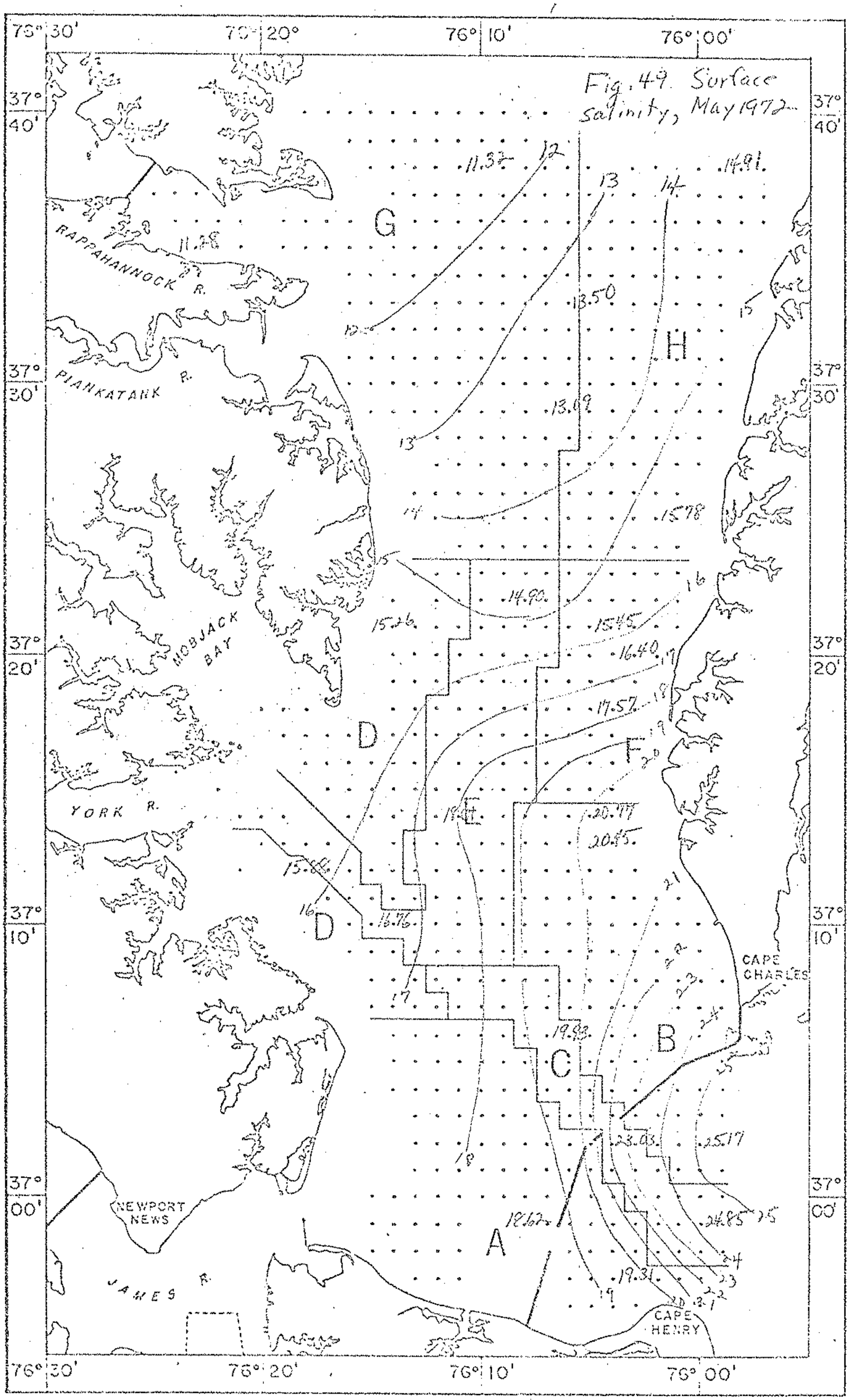


Fig. 48. Salinity at 6 meters depth, Apr 1972.


76° 30'
76° 20'
76° 10'
76° 00'
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
Fig. 49. Surface salinity, May 1972
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
F
C
B
A
11.37
11.28
14.91
13.50
13.09
15.78
14.90
15.45
15.26
16.40
17.57
15.06
16.76
20.77
20.85
19.93
23.03
25.17
24.85
18.62
19.31

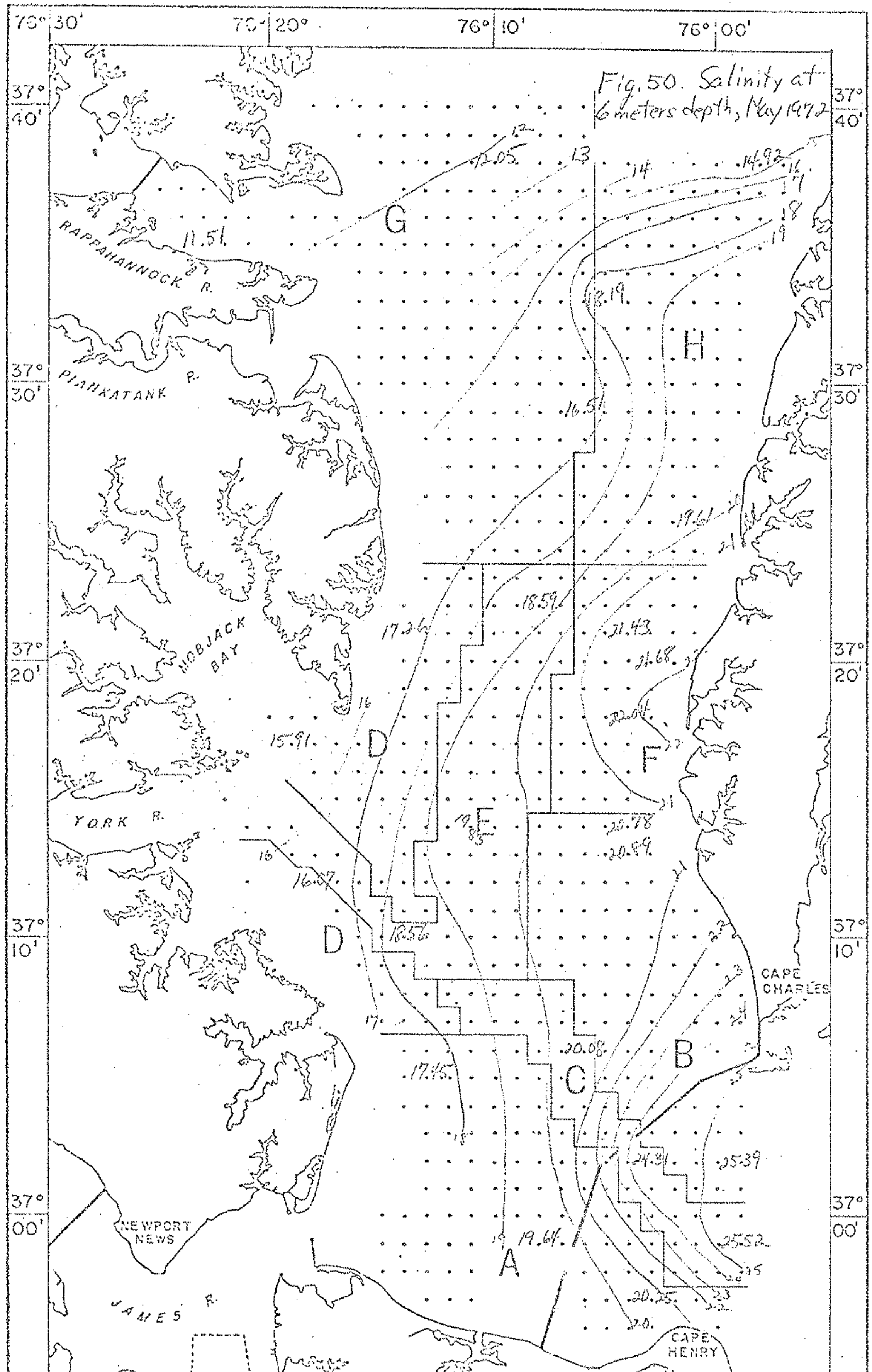


Fig. 50. Salinity at 6 meters depth, May 1972

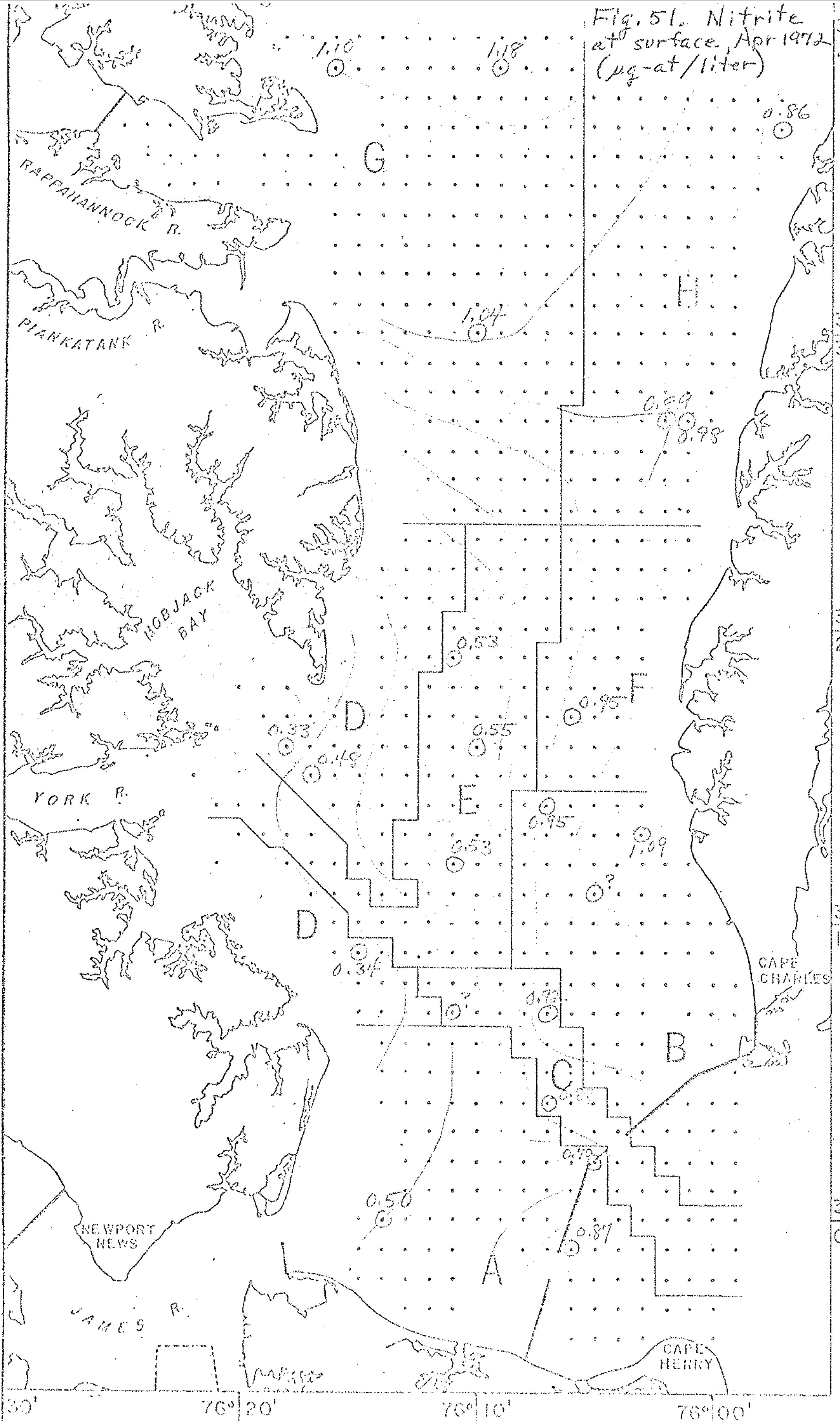


Fig. 51. Nitrite at surface, Apr 1972 (μg-at/liter)

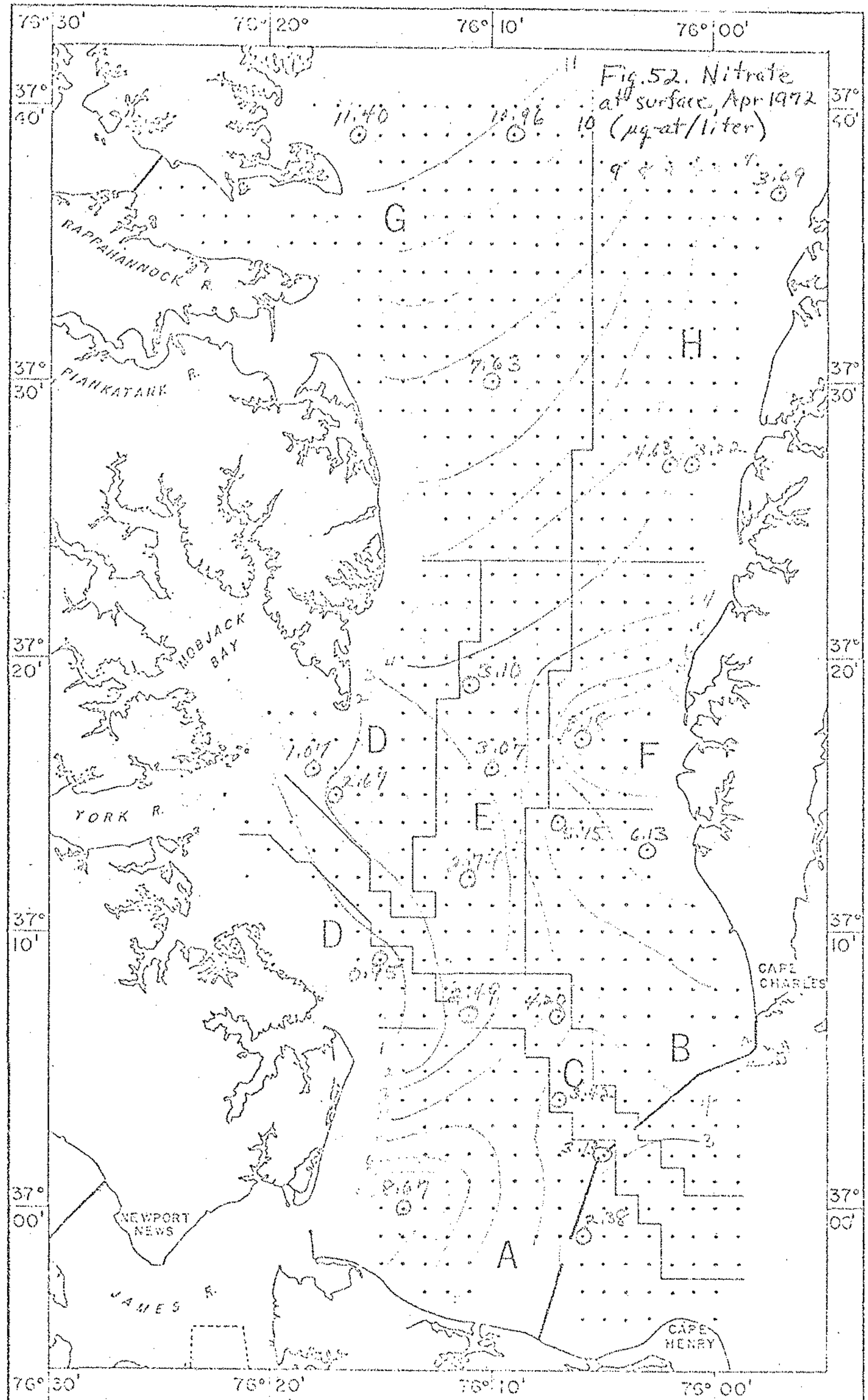


Fig. 52. Nitrate at surface, Apr 1972 (µg-at/liter)
76° 30'
76° 20'
76° 10'
76° 00'
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
F
C
B
A
11.40
11.96
3.69
7.63
3.10
3.07
2.64
6.13
2.49
2.38

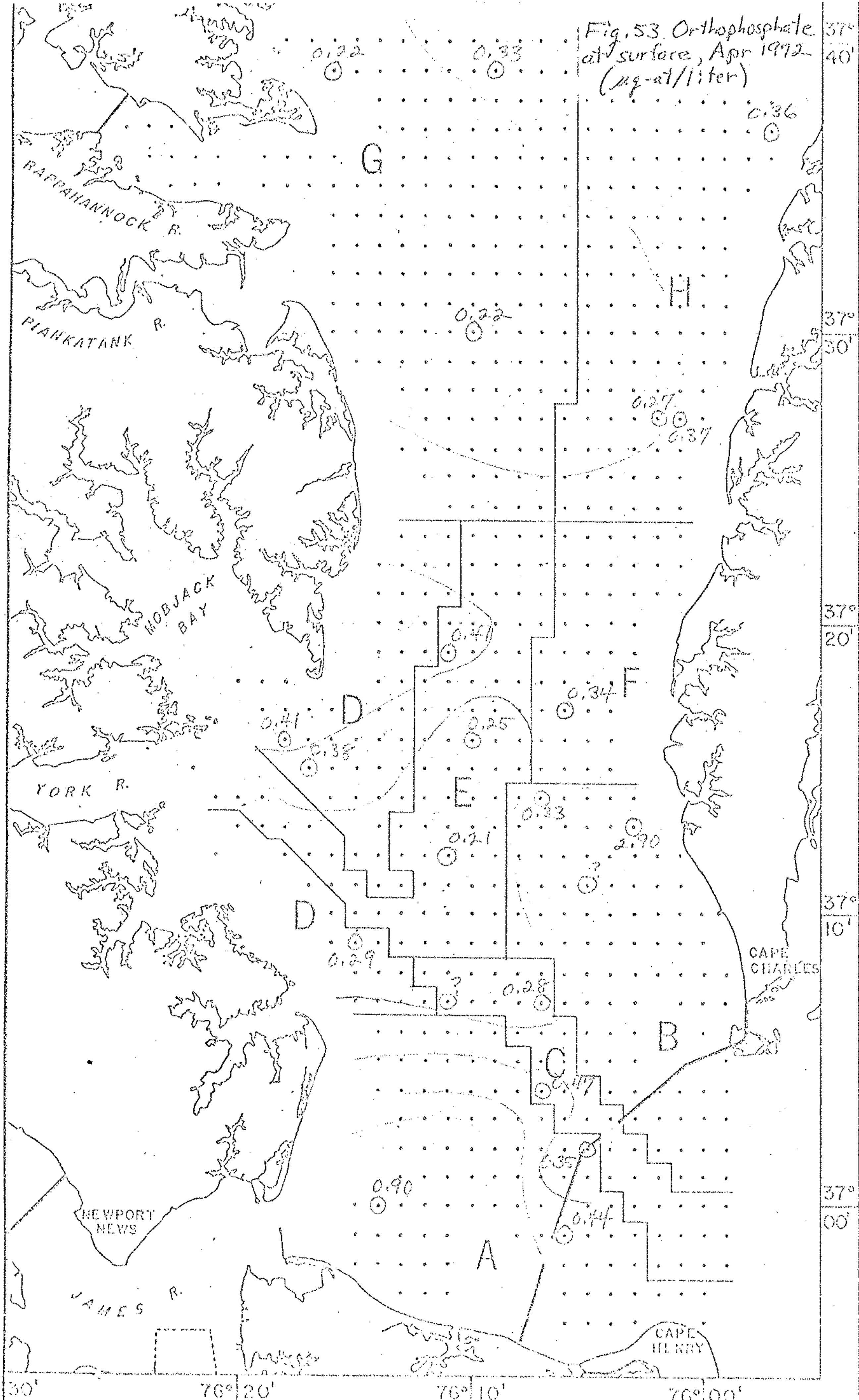


Fig. 53 Orthophosphate at surface, Apr 1972 (μg-at/liter)

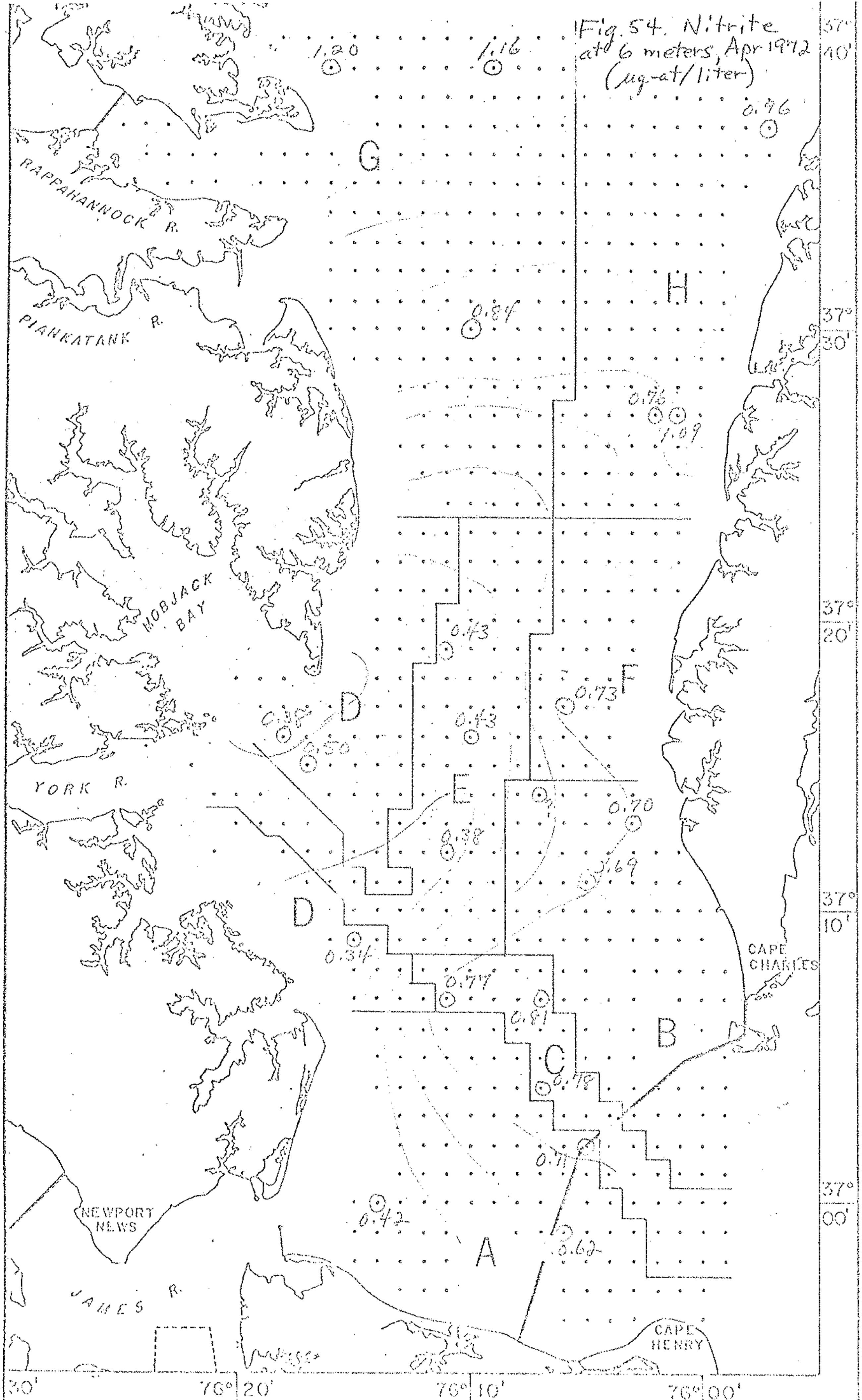


Fig. 54. Nitrite at 6 meters, Apr 1972 (µg-at/liter)
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
A
B
C
D
D
E
F
G
H
1.20
1.16
0.96
0.84
0.76
1.09
0.43
0.73
0.38
0.50
0.43
0.70
0.38
0.69
0.34
0.77
0.81
0.78
0.71
0.42
0.62
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
30'
76° 20'
76° 10'
76° 00'

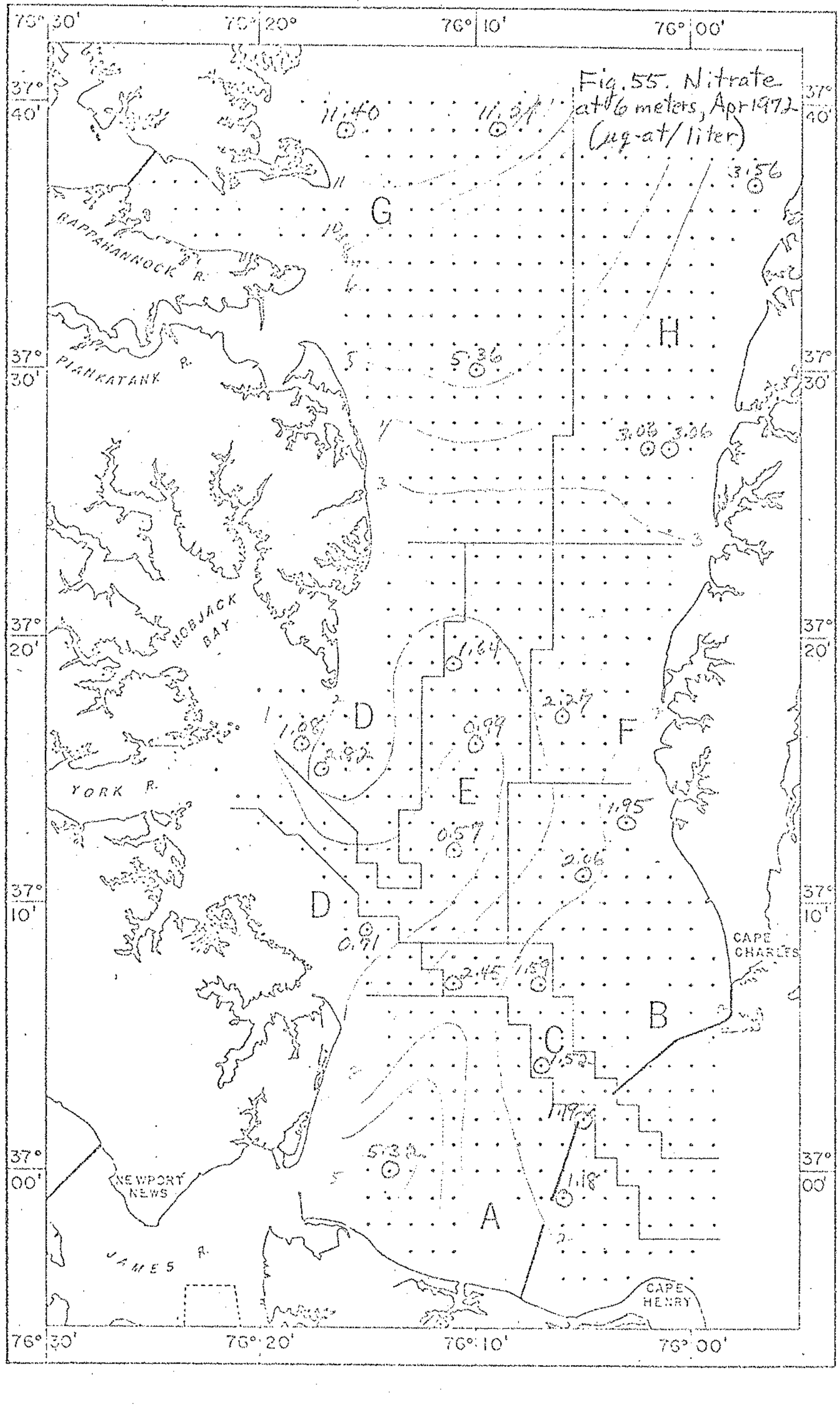


Fig. 55. Nitrate at 6 meters, Apr 1972 (μg-at/liter)

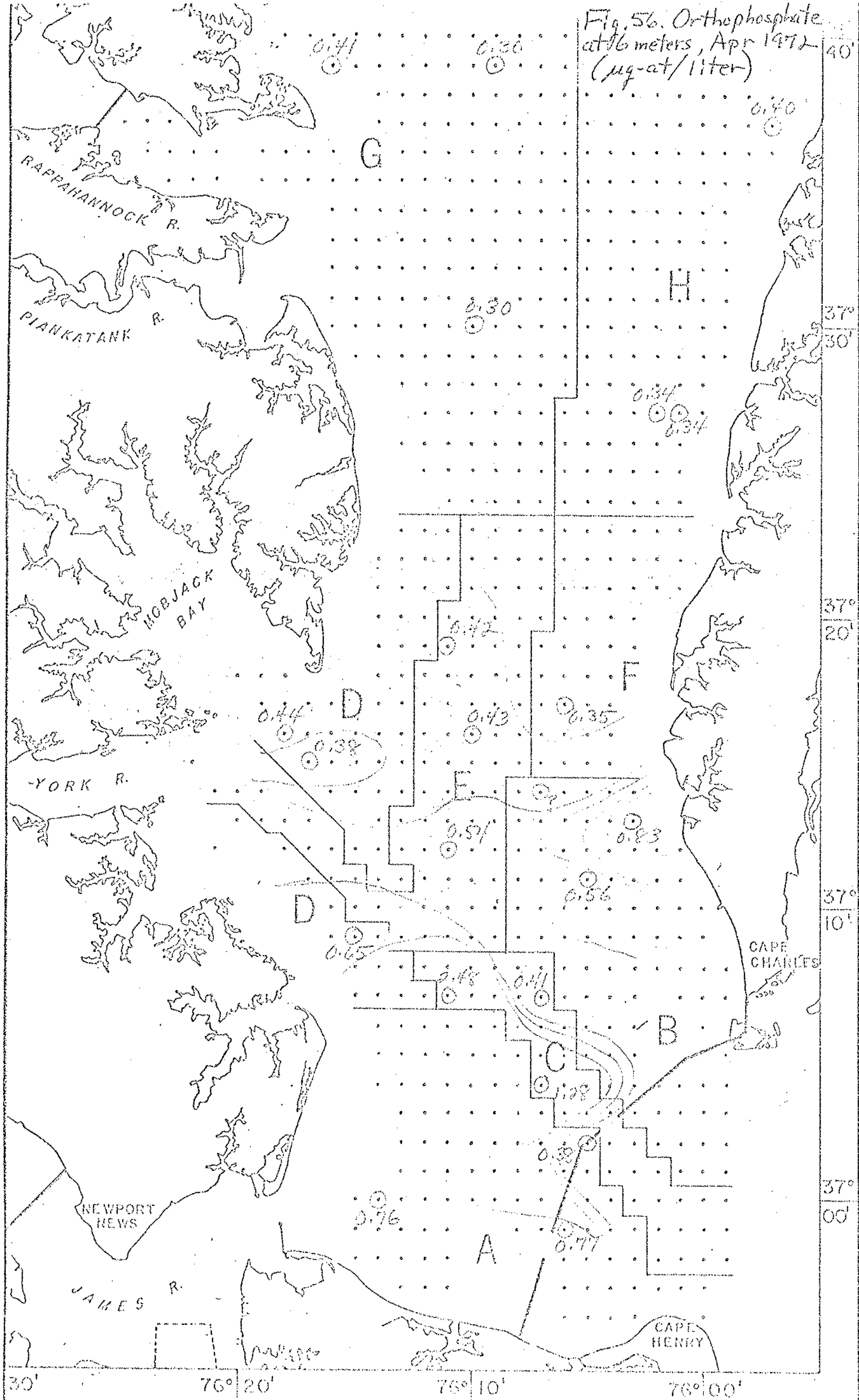


Fig. 56. Orthophosphate at 16 meters, Apr 1972 (μg-at/liter)
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
F
E
D
D
C
B
A
0.41
0.36
0.40
0.30
0.34
0.34
0.42
0.43
0.35
0.44
0.38
0.57
0.83
0.56
0.65
0.48
0.41
1.28
0.38
0.76
0.77
40'
37° 30'
37° 20'
37° 10'
37° 00'
30'
76° 20'
76° 10'
76° 00'

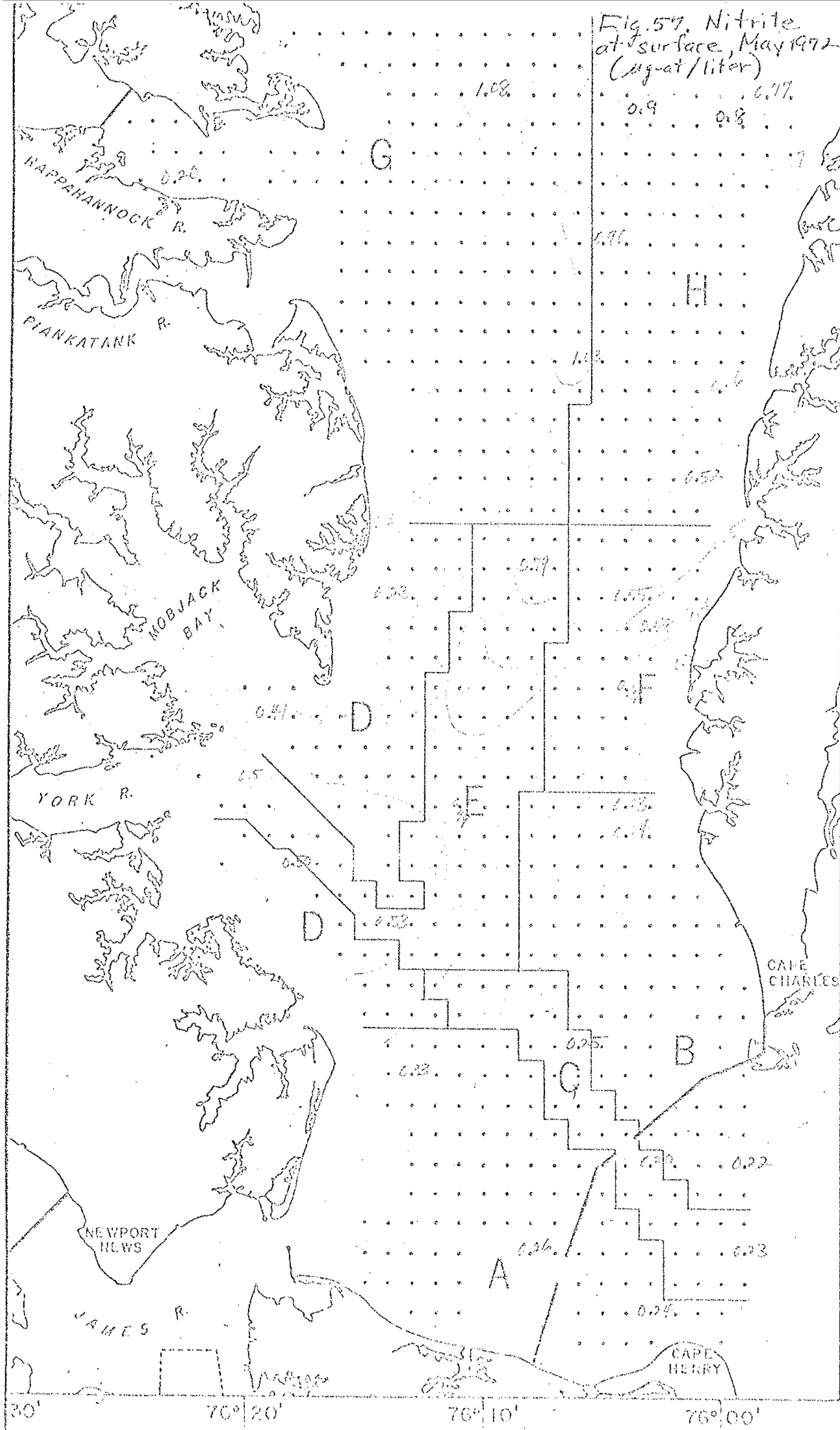


Fig. 57. Nitrite at surface, May 1972 (ug-at/liter)
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
F
D
C
B
A
1.08
0.9
0.8
0.20
0.41
0.5
0.28
0.22
0.25
0.26
0.23
0.22
0.52
0.28
0.53
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
30'
76° 20'
76° 10'
76° 00'

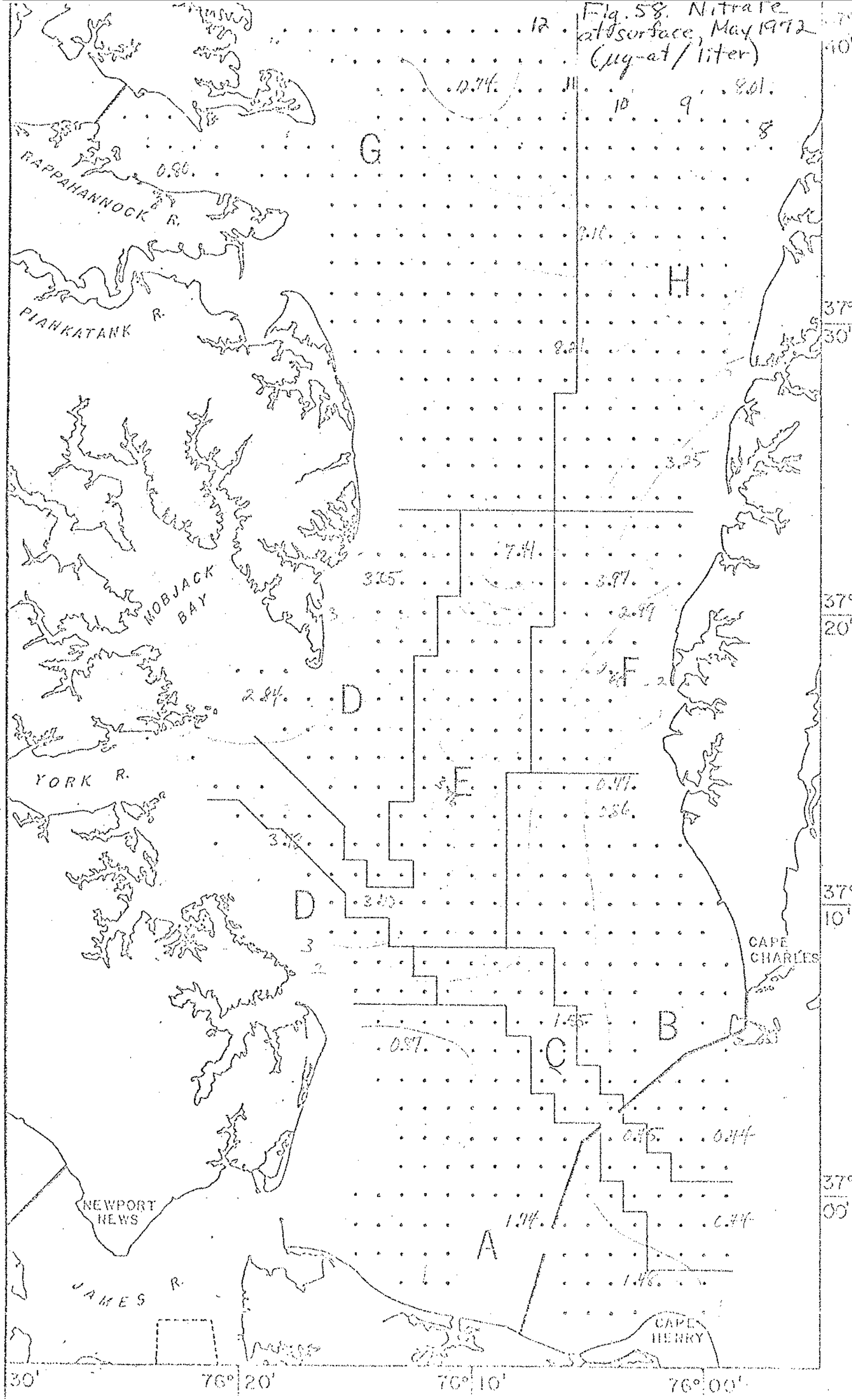


Fig. 58. Nitrate at surface, May 1972 (µg-at/liter)

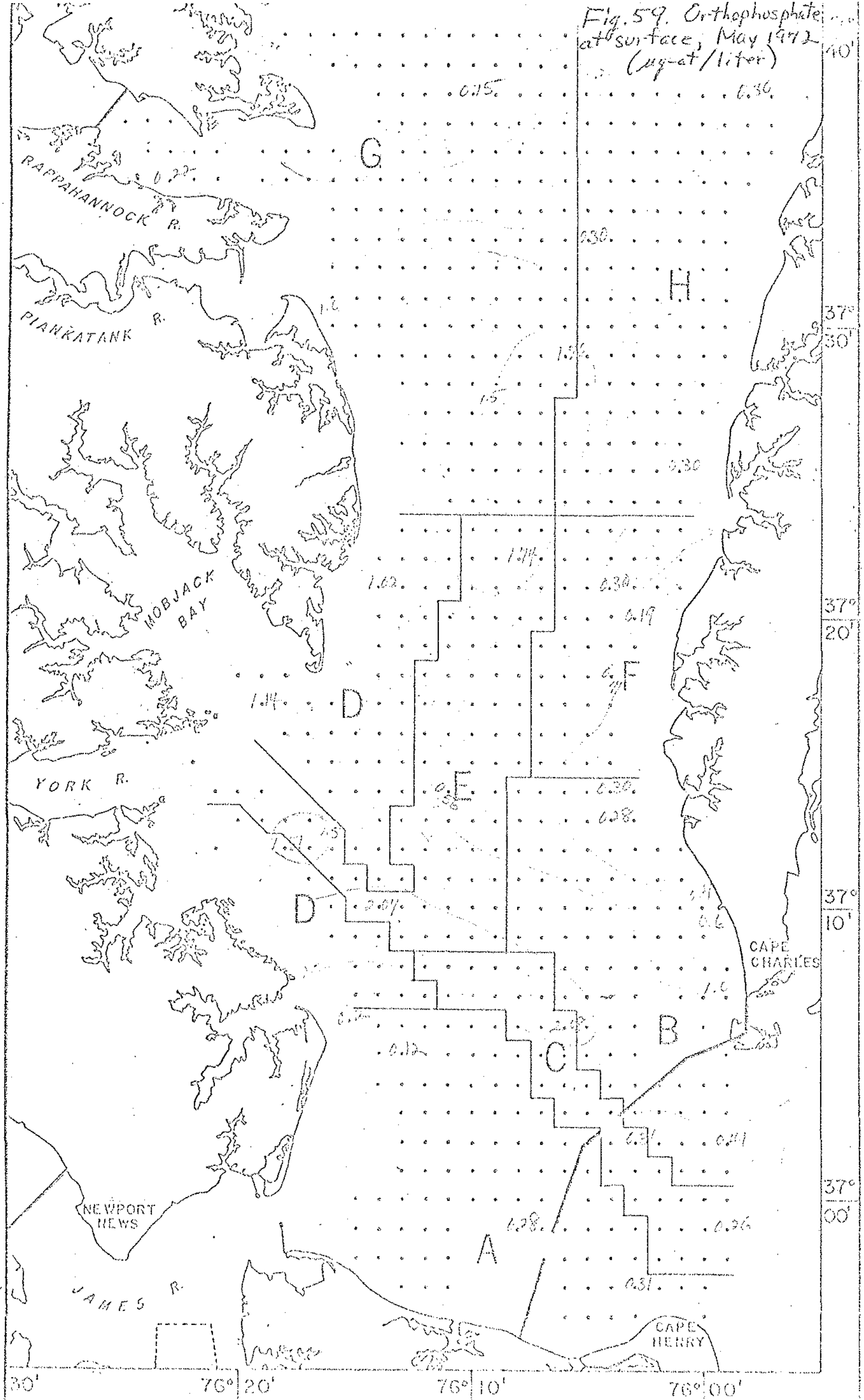


Fig. 59. Orthophosphate at surface, May 1972 (µg-at/liter)
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
D
E
F
D
C
B
A
37° 30'
37° 20'
37° 10'
37° 00'
40'
30'
76° 20'
76° 10'
76° 00'

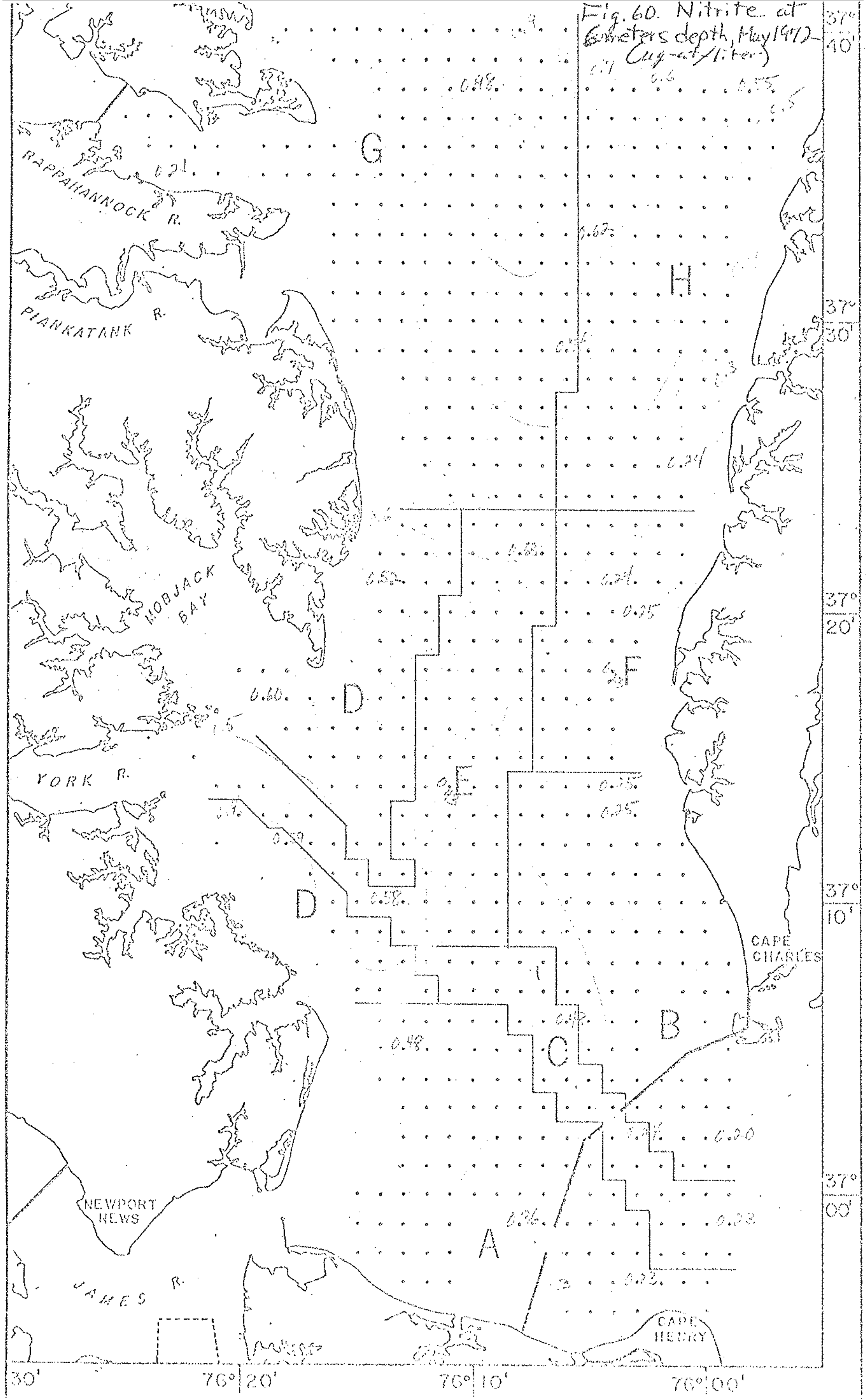


Fig. 60. Nitrite at 6 meters depth, May 1972 (µg-at/liter)

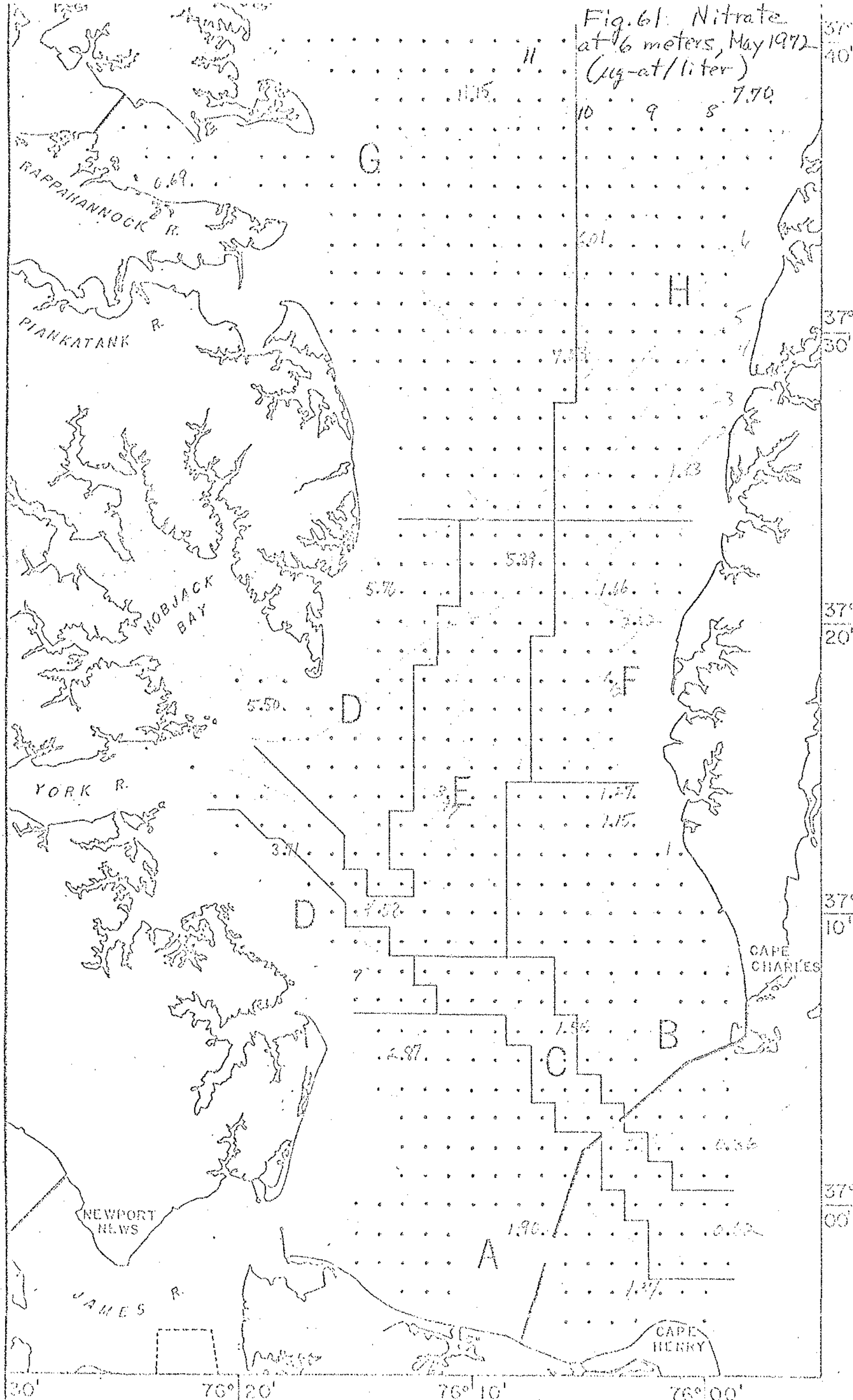


Fig. 61 Nitrate at 6 meters, May 1972 (μg-at/liter)

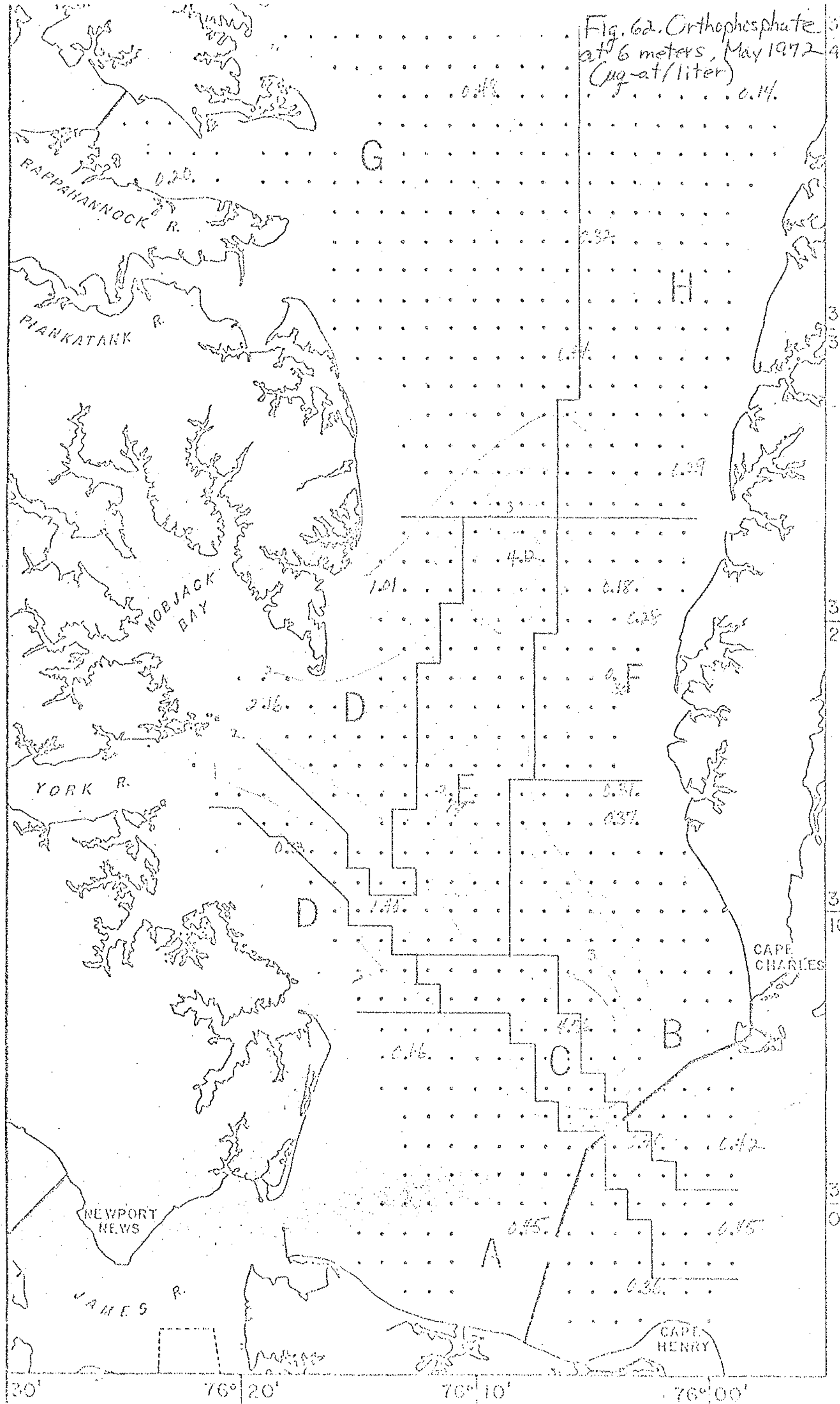


Fig. 62. Orthophosphate at 6 meters, May 1972 (ug-at/liter)
RAPPAHANNOCK R.
PIANKATANK R.
MOBJACK BAY
YORK R.
JAMES R.
NEWPORT NEWS
CAPE CHARLES
CAPE HENRY
G
H
F
E
D
D
C
B
A
0.14
0.20
0.37
4.02
0.18
0.25
1.01
0.29
0.16
0.31
0.37
1.44
0.16
0.12
0.45
0.45
0.36
37° 40'
37° 30'
37° 20'
37° 10'
37° 00'
30'
76° 20'
76° 10'
76° 00'