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THE POTENTIAL FOR RESEARCH AND FISHERY PERFORMANCE DATA ISOPLETHS IN POPULATION ASSESSMENT OF OFFSHORE, SEDENTARY, CONTAGIOUSLY-DISTRIBUTED SPECIES

by

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ABSTRACT

A new technique in scallop data analysis is presented both to improve sampling design in research surveys and to facilitate determination of exploitable scallop biomass. Commercial Canadian fishing logs record daily effort, catch and navigational bearings for locations fished, thereby permitting a high degree of resolution in the analysis of pattern of scallop distribution. Techniques have been developed to permit isopleth mapping of commercial catch, effort and CPUE, and an evaluation of parameters to achieve maximum realism is presented. In particular, degree of data spreading and calendar duration of fishing activity are discussed.

Analysis of commercial log records from the first six months of 1978 are compared with observations from a "ground truthing" research cruise, and general support was indicated for the role of isopleth plotting of research and commercial fishery data as a descriptive stock assessment tool.

RESUME

Nous décrivons une nouvelle méthode d'analyse des données sur les pétoncles, qui permet à la fois d'améliorer la conception de l'échantillonnage dans les relevés de recherche et de faciliter la détermination de la biomasse de pétoncles exploitables. Les journals de bord des bateaux de pêche canadiens enregistrent l'effort quotidien, les prises et la position exacte des lieux pêchés, ce qui donne un haut degré de précision à l'analyse des patrons de distribution des pétoncles. On a mis au point des méthods grâce auxquelles ont peut porter sur carte les isoplèthes de prises commerciales, de l'effort et des PUE. Nous présentons en outre une évaluation des paramètres qui offrent un réalisme maximal. Nous analysons en particulier le degré de déploiement des données et la durée de la saison de pêche.

Nous comparons une analyse des journals de bords de bateaux commerciaux pour les six premiers mois de 1978 avec des observations recuellies au cours d'une campagne de reconnaisance d'un navire de recherche. Les résultats confirment en général l'utilité de porter sur carte les isoplèthes de missions scientifiques et de pêche commerciale, comme outil descriptif d'évaluation des stocks.

INTRODUCTION

This report discusses ongoing research in the development of procedures to delineate the contagious distribution (Elliott, 1977) of scallops. Initial results are presented of a study designed to identify and quantify actual scallop (*Placopecten magellanicus*) concentrations on Georges Bank at a finer resolution (1 min of latitude and longitude [OMS]) than has been previously available (10 min of latitude and longitude [TMS]). As such, it should improve the accuracy of predictions from yield models (e.g., Caddy, 1975) as well as allow both improved stock assessment and better evaluation of the effect of variable effort on population age structure. The basic approach is to utilize actual fishing locations from either research or commercial log data in the determination of isopleths of scallop abundance or fishery performance. In the past, fishing location has been used only to assign a landing to a statistical area for conventional data summation and averaging. Such data has not been used in the delimitation of areas of scallop concentrations, and hence that portion of the stock available for profitable commercial exploitation has not been calculable.

In conventional fisheries population dynamic procedures, both dynamic pool (e.g., Beverton and Holt, 1957; Ricker, 1940) and logistic (e.g., Schaeffer, 1957; Pella and

Tomlinson, 1969) models utilize a unit stock concept in which fishing mortality (F) is, theoretically at least, proportional to fishing effort (f). However, because stocks are often contagiously distributed, an entire stock is not usually vulnerable to fishing effort within any short time interval, and so active dispersal is utilized in models to spread local effects of past effort randomly throughout the stock. Locally depleted areas would thus be replenished by immigration. Caddy (1975) noted that this is obviously impossible for contagiously distributed species of limited mobility, and that the relation between effort and fishing mortality thus departs from simple proportionality. If location of peak recruitment varies annually and dominant year classes are most heavily exploited, then a spatial "mosaic" of annual mortality rate arises.

Caddy's (1975) spatial model (YRAREA) was developed in an effort to overcome these difficulties and impart greater realism in the modelling of shellfish populations. Its general assumptions include: 1) recruitment in patches of random size and location with the constraint that local biomass does not exceed the estimated virgin biomass of each unit area; and 2) the fraction of effort which is expended within each statistical area (one TMS) of a fishing ground is either determined by available biomass alone (proportional effort allocation) or in combination with "traditional fishing practice". The main limitation of his yield model is that of

most deterministic models: maximum realism depends both upon identification and inclusion of the primary processes affecting exploitation and stock status, and the accurate determination of the basic parameters on which the simulation is based. The technique discussed in this paper attempts to improve the realism of the basic parameters relating to stock distribution and density.

THE CANADIAN OFFSHORE SCALLOP FISHERY

The Canadian offshore scallop fishery is centered on Georges Bank, which extends eastward from Cape Cod and has an area of 31,000 square kilometers within the 50 fathom depth contour (Fig. 1). Scallops, although often at low densities, can be found almost anywhere on the Bank. Since 1963, 50-77 Canadian vessels, each 30-40 m in overall length have fished on this ground. Each vessel can operate 24 hours a day, 12 months of the year; and trip duration has been usually 12-15 days (presently restricted by regulation to 12 days dock to dock). Average crew size in recent years has been about 16-17 men. Each vessel tows two, 4.5 m drags, one on either side of the boat; the drag's bag is rope-backed with a linked, 3-inch (7.6 cm) diameter, steel ring belly.

Since the early 1960's, the captain of each vessel has been required to report his daily catch, effort expended, and location fished. Extremely good cooperation is achieved, with

logs completed for virtually every day fished by the fleet. Captains keep a copy of each log, which allows them to assess the potential of different scallop beds based on past experience. Parameters reported in each daily log record include vessel name, date, crew size, Loran or Decca readings of fishing locations, water depth, bottom type, number of bags of scallop meat caught per 6-hour watch, number of tows made per day, average tow duration in minutes, gear width, and comments as to weather, scallop size, and so on. Total catch weight is reported by sales slip.

Previous data analysis (Caddy, 1975) utilized days fished and catch per TMS. The improved precision in locations fished are the result of the use of computer programs which can convert any combination of navigational readings into degrees, minutes, and seconds of latitude and longitude.

Accuracy of reported location of fishing is routinely verified through surveillance records from aircraft on fisheries patrols (Table 1).

METHODS

A. Mapping of Scallop Distribution Patterns

Bearings of latitude and longitude were determined for each set of navigational readings (a minimum of two sets are usually given for each day fished), and the mid point between

the bearings was assumed to be the center of that day's fishing activity. Fishermen often keep one reading constant and vary the other, thus fishing either along a line or, like the spokes of a wheel, through a common point. Bearings can be determined to an accuracy of 1 second (about 25 m); since tows average about 25 minutes duration at 3 knots (5.5 km) per hour, average tow distance is about 2.3 km. Average OMS width (1.38 km) is thus exceeded, and so trials were made averaging each day's catch over a varying number of OMS's immediately surrounding the mid-point fishing location. These OMS's are identified as those surrounding the nearest position of minute intercept (Fig. 2).

Canadian catch and/or effort can be determined for any time period for each OMS. With the isopleth plotting program presently being used, values for border unit areas may be inaccurate, since they do not contain information from fishing locations immediately outside the boundary of the study OMS. Hence, to obtain accurate isopleth contours for a particular area (e.g., a 10-minute square, the unit square of Caddy [1975]), a larger area (e.g., a 30-minute square), with its center the particular area being investigated, must be considered (e.g., Figure 6 is a composite of the centers of three, 30-minute squares). This has been done for the study areas presented.

To permit evaluation of this system, the programs have been designed to permit the specification of alternative

options. Thus, the contours in any specific TMS can be plotted for any calendar time period for either catch, effort, or CPUE. There is also opportunity to specify unit of effort as either "day", "hours gear is on the bottom times unit of drag width (m)", or "hours gear is on the bottom times unit of drag width (m) times men on board".

B. Research Cruise P199

The objective of this cruise on the R/V E.E. Prince was to intensively sample an area of known high scallop yield so that the accuracy of computer-predicted locations of scallop concentrations could be evaluated through "ground-truthing". To limit the size of the survey area, the study (Fig. 3) was restricted to the highest yielding 60 per cent of each of the three highest catch TMS's fished in 1977 (Table 2). The geographical area of each subarea was 82.8 km^2, for a total survey area in the three TMS's of 248.4 km^2. Since scallop distribution in border unit areas cannot be accurately described with present techniques, research data isopleths (Fig. 8) could only be determined for 69% of the surveyed area (171.4 km^2).

A priori determination of contour isopleths for each subarea, using 1978 log data received as of May 14, 1978, allowed the randomized establishment of 50 stations (Table 3) in each subarea: 15, 15, and 20 stations were assigned to the low, medium, and high CPUE strata respectively.

Since fishing in the offshore scallop fishery is often prevented by bad weather during the months December to March inclusive, the data base used in a priori isopleth determination can be limited and hence possibly unreflective of the actual pattern of scallop distribution at the time of the survey. As a result, in the comparative evaluation of the data, isopleths determined from cruise catches were compared to catch and CPUE isopleths derived from log data for a varying number of preceeding months between May, 1977, and April, 1978, inclusive, i.e. preceeding the survey. This was done to determine how many months of log data prior to a spring survey would be required for a realistic plotting of scallop distribution.

Survey tows were made with a standard 2.4 m offshore drag with 7.6 mm diameter rings and a 3.8 mm stretch mesh net liner. Live scallops and cluckers (dead scallops with both valves still hinged together) were weighed whole; and depending on catch magnitude, either the entire catch or a subsample was set aside for individual scallop height measurement, with categorization by 5 mm divisions. Each tow attempted to cover 0.8 km of ocean bottom, as measured from Loran A bearings. Tow direction varied, both as a result of tidal current flow and the location of the next station.

Scallop ages were inferred from height by using the Von Bertalanffy growth parameters given in Caddy and Jamieson (1977).

RESULTS AND DISCUSSION

A. Mapping of Scallop Distribution Patterns from Log Data for Predictive Purposes

1) Data Base Effects

Accuracy of log record fishing location data was compared with aerial surveillance records in an effort to describe overall data quality. A comparison of 243 fishing locations as reported by log and surveillance records indicated an average discrepancy in 1978 of 36 km (Table 1). Although this appears excessive, it must be noted that some differences were extraordinarily large (the maximum was 260 km), suggesting that some recording errors may occur. Incorrect identification of vessels by surveillance planes can occur, as in nine cases, surveillance records reported a specific vessel fishing when it was in port. Also, while a surveillance record provides a vessel's location at one point of time, a fishing log record provides the main location of fishing activity that day. Since for each year there are about 6,000 complete, daily log records, error differences in any direction are felt to cancel out.

Although precise navigational bearings are provided in daily logs, it is recognized that fishing activity is spread over a larger area, if for no other reason than average tow length exceeds OMS width. The effect on catch isopleth calculation of varying the number of unit areas (Fig. 4) over

which the data are spread was investigated. Results indicate that on the basis of anecdotal reports of contagion from fishing captains and observed clumping of scallops from the research cruise (see below), predicted densities are lost if data are spread over more than four unit areas. Since no spreading is difficult to reconcile, spreading over four unit areas, i.e. one unit area in each direction from the unit point identified from the navigational bearing, has been used in all subsequent data analyses.

Scallop concentrations are of only temporary duration, as fishing both reduces scallop abundance and causes scallops to scatter through escape swimming activity (Caddy, 1971). There is thus a certain recent time period beyond which log data cannot be expected to predict accurately a scallop distribution. This time period is both a function of expended fishing effort as well as actual calendar duration. Since scallop resource surveys have been routinely undertaken in May or June, varying calendar time periods prior to May 1 were used (Figs. 5, 6) to evaluate the calendar duration and number of days of data required to permit realistic contagion definition. Because of reduced fishing activity in the winter due to inclement weather, a relatively greater number of calendar days is required at this time of year than might be expected during the summer. Effort during the winter is also more concentrated on the northeastern edge of Georges Bank (the area shown in Figs. 5 and 6), and so for the northern

part of the Bank as a whole, a compromise between data quantity and quality is required. With existing temporal fishing patterns, six months of log records prior to a spring survey is felt to be optimal for data analyses. Four months of data for the northeastern edge appears to produce results similar to that observed in "ground-truthing" (see below); but the inclusion of an additional two months of data does not generally alter the pattern of scallop distribution and is expected to improve accuracy for the northern port as a whole. CPUE isopleth pattern varies more greatly data quantity than does catch isopleth pattern.

The temporal distribution of CPUE for three, adjacent six month periods (Fig. 7) provides an indication of clumping variation with time. CPUE varies as scallop concentrations are depleted through both removal (fishing) and dispersal, and new concentrations form through recruitment and movement to favourable habitats.

2) Commercial Log : research survey isopleth comparison

Comparison of the isopleths determined from commercial log records with those from the observations of cruise P199 (Fig. 8) indicate that for both catch and CPUE isopleths, general agreement exists as to geographical locations of recruited (age 4^+ yr) scallop concentrations. Since cruise sampling location was randomized, cruise effort isopleths do not reflect scallop abundance but rather approach

unity throughout. The pattern of research CPUE isopleths, as expected, is thus almost identical to research catch isopleths.

B. Mapping of Abundance at Age from Survey Data

a) Age class spatial distribution

An isopleth mapping of scallop abundance by age (Fig. 9) for the three, intensively surveyed areas in Cruise P199 indicates that at the time of the survey, the pattern of contagion for each age class was unique, with the locations of greatest age class abundance often spatially separate and for the youngest scallops at least, distinct. The extent of contagion is inversely correlated with increasing age.

b) Relative age class abundance

Abundance at age by CPUE stratum (Table 4) suggests that prerecruit scallop abundance (4^+ year old scallops) is directly proportional to CPUE strata magnitude. However, there was little direct correlation between magnitudes of CPUE strata and recruited scallop abundance. In contrast, recruited, but not prerecruit, scallop abundance is directly correlated with catch strata magnitude.

Why commercial CPUE strata should indicate locations of prerecruit abundance is not clear, and this may be an artifact of this particular data set. Although scallop density per unit area typically decreases with age (Fig. 9), older

scallops have a greater individual meat yield, and this can compensate for low numerical abundance in overall yield. This was the case in 1978, a time when five to six year old scallops were above average in abundance. Scallops yielding small meats require more labour in shucking, which reduces CPUE. With a lower CPUE, they would only be fished when compliance with a meat count regulation could be achieved or to reduce other real or potential costs. An example of the latter is the occasional fishing of small meat yielding scallops on the Scotian Shelf; being closer to port, fuel costs are reduced and shelter is more readily available in times of frequent bad weather.

The correlation between survey abundance of recruits and magnitude of commercial catch strata is more readily explainable, as it was expected that greatest commercial catches would come from locations having the highest meat overall yields.

Relative average age class abundance per tow (Table 4), should decrease logarithmically with increasing age because of both natural and fishing mortalities. Four year old scallops are poorly represented, thus suggesting that the 1974 year class is below average in abundance. Three year old scallops appear particularly abundant, but in the absence of an historical data base, it can not be stated at this time how a specific prerecruit abundance will be reflected in the future in magnitude of commercial landings. Indirect fishing mortality is suspected to be high (Caddy, 1971), and strategy of exploitation can significantly influence year class yield.

CONCLUSIONS

Two important factors to consider in a comparison of commercial log and research survey data are: 1) the necessity for commercial vessels to land scallop meats below a regulated number of meats per unit weight (44 meats per 500 g with a 10% tolerance in 1978); and 2) the roughness of the sea bottom and its effect on gear integrity and performance. Since research cruises are not required to comply with meat count regulations, and because there is no documented data relating substrate type or quality to location, research effort was not applied in the same manner as commercial effort. No effort was made in the research cruise to avoid rough bottom, and when a high scallop catch was made, no repeat tows were attempted.

If station location is randomized within a defined area and number of stations is sufficient, research data can now provide a projection of biomass above any specified animal density per unit area. The approach described allows determination of the distribution of scallop abundance, which includes the area of ground covered by a minimum scallop density. Summation of the "volumes" of scallops between each strata level can then indicate the biomass available for exploitation. Because lined gear is used, this is particularly valuable in indicating relative prerecruit abundance and distribution as prerecruits are poorly sampled with commercial gear.

Knowing the distribution of scallop age classes over the entire fishing area will allow evaluation of the degree to which meats of different sizes can be landed. Study of past commercial effort and scallop age class distributions should allow analysis of the way in which different distribution patterns of scallops can be exploited. For example, in a comparison of Figures 8 and 9, it appears that in the commercial fleet was concentrating on five year old scallops. Similar information for Georges Bank as a whole is required to estimate what proportion of the whole scallop population can be fished, yet achieve compliance with existent legal meat size regulations.

ACKNOWLEDGEMENTS

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Table 1: Distance (km) discrepancies in 1978 between daily vessel location as reported by fisheries logs and Department of National Defence surveillance reports. A. Analysis of record quality. B. Distance discrepancy statistics.

A	Number	%
Log navigation record incomplete	29	9.9
No log record to match against surveillance record	8	2.7
Not fishing on day of observation	9	3.1
Steaming to fishing ground	4	1.4
Log and surveillance records matched	243	82.9
Total number of surveillance records	293	

B

	Distance Apart (km)						
	n						
Fishing Ports	records	vessels	Min	Max	Avg	SD	SE
Lunenburg/Riverport/ Liverpool	195	48	1.3	260.5	36.2	24.1	3.5
Yarmouth/Saulnierville/ Meteghan	48	14	2.6	96.8	35.8	16.7	4.5
All combined	243	62	1.3	260.5	36.0	31.3	2.0

TABLE 2. Catch distribution by 10-minute squares in the period January to Dec., inclusive, 1977. TMS = ten minute squares.

Lat.	Long.	TMS catch (lb)	Cum. catch (lb)	% TMS/total	% Cum. total	Rank in Jan.-June 1978
420	664	3989947	3989947	14.95	14.95	5
420	670	2926286	6916233	10.97	25.92	4
420	665	2737478	9653712	10.26	36.18	2
415	661	2387726	12041438	8.95	45.12	1
420	663	2112725	14154164	7.92	53.04	11
415	663	1665456	15819620	6.24	59.28	12
414	660	1221228	17040848	4.58	63.86	6
415	662	1069401	18110248	4.01	67.86	10
414	661	912711	19022960	3.42	71.28	13
420	662	774541	19797500	2.90	74.19	8
413	664	704894	20502396	2.64	76.83	17
420	671	617495	21119892	2.31	79.14	9
413	661	494786	21614680	1.85	81.00	8
415	660	486939	22101620	1.82	82.82	3
411	663	433155	22534776	1.62	84.44	26
420	672	415918	22950696	1.56	86.00	14
414	662	334024	23284720	1.25	87.25	21

Table 3. Station location and catch for cruise p199 to Georges Bank, May, 1978.

STN#	LAT	LONG	DEPTH (M)	WEIGHT(KG) TOTAL	WEIGHT(KG) SAMPLE	#AT AGE(YR) 1-3	#AT AGE(YR) 4-7	#AT AGE(YR) 8+	TRASH (TUBS)
1	420637	665737	119.0	22.	22.	12.	74.	0.	9.5
2	420651	665759	119.0	29.	29.	18.	104.	1.	10.5
3	420635	665858	117.1	49.	23.	31.	161.	0.	15.0
4	420607	665840	113.5	33.	22.	259.	118.	1.	15.0
5	420554	665811	113.5	17.	17.	157.	103.	0.	5.5
6	420448	665741	113.5	28.	28.	6.	55.	9.	13.0
7	420359	665826	109.8	64.	24.	59.	170.	9.	5.5
8	420418	665908	108.0	115.	27.	413.	248.	10.	9.5
9	420247	665841	93.3	1.	1.	0.	3.	0.	.2
10	420233	665835	100.7	0.	0.	0.	0.	0.	0.0
11	420223	665826	100.7	18.	18.	0.	68.	16.	1.0
12	420302	665813	113.5	45.	24.	4.	221.	18.	2.0
13	420336	665747	111.6	76.	28.	46.	231.	6.	12.0
14	420337	665731	115.3	6.	6.	1.	24.	7.	1.8
15	420342	665711	111.6	24.	24.	22.	56.	7.	10.5
16	420357	665643	117.1	33.	29.	5.	58.	6.	23.5
17	420431	665618	115.3	53.	26.	4.	101.	21.	8.5
18	420505	665608	119.0	5.	5.	45.	15.	0.	1.5
19	420529	665606	120.8	34.	21.	101.	171.	1.	10.0
20	420615	665635	119.0	29.	29.	17.	96.	0.	9.0
21	420649	665625	119.0	10.	10.	15.	72.	0.	6.0
22	420700	665545	124.4	37.	23.	0.	320.	3.	7.5
23	420648	665435	119.0	55.	24.	8.	351.	2.	11.5
24	420619	665449	119.0	121.	19.	83.	247.	3.	21.5
25	420529	665343	120.8	45.	14.	157.	204.	0.	12.0
26	420627	665316	119.0	147.	25.	10.	639.	8.	28.0
27	420627	665300	117.1	195.	22.	58.	470.	7.	22.0
28	420512	665220	120.8	23.	23.	35.	57.	1.	17.0
29	420644	665018	128.1	265.	20.	8.	884.	9.	20.0
30	420559	665042	128.1	108.	15.	90.	633.	8.	22.5
31	420548	665122	122.6	115.	23.	42.	452.	0.	27.0
32	420542	665150	120.8	149.	13.	207.	366.	0.	29.0
33	420456	665056	122.6	107.	16.	48.	239.	8.	24.5
34	420400	665026	128.1	18.	18.	0.	59.	0.	3.0
35	420157	665058	140.9	68.	18.	3.	356.	2.	11.0
36	0	0	120.8	0.	0.	0.	0.	0.	0.0
37	0	0	129.9	0.	0.	0.	0.	0.	0.0
38	420153	665253	122.6	12.	12.	0.	38.	2.	2.0
39	0	0	113.5	0.	0.	0.	0.	0.	3.0
40	420153	665535	122.6	4.	4.	1.	9.	4.	9.0
41	420217	665549	122.6	5.	5.	0.	24.	3.	2.0
42	420231	665603	120.8	4.	4.	0.	16.	4.	2.0
43	420254	665658	117.1	7.	7.	1.	17.	1.	3.0
44	420313	665700	119.0	15.	15.	7.	157.	14.	3.0
45	420335	665548	111.6	24.	24.	5.	27.	10.	19.0
46	420424	665503	115.3	29.	29.	139.	94.	2.	17.0
47	420444	665432	120.8	47.	10.	244.	137.	0.	21.0
48	420445	665416	120.8	34.	25.	74.	99.	2.	19.0
49	420436	665334	117.1	70.	14.	188.	174.	1.	29.0
50	420358	665314	120.8	65.	28.	125.	161.	12.	22.0
51	420523	665419	122.6	41.	11.	146.	169.	4.	16.0
52	420517	665456	126.3	60.	12.	0.	210.	3.	11.0
53	420540	665502	124.4	73.	28.	18.	212.	1.	14.0
54	420544	665523	126.3	40.	18.	5.	122.	0.	18.0
55	420608	665545	126.3	32.	11.	8.	157.	0.	7.0
56	420511	670245	108.0	149.	12.	526.	474.	0.	20.0

Table 3 Con't.

STN#	LAT	LONG	DEPTH (M)	WEIGHT(KG) TOTAL	WEIGHT(KG) SAMPLE	#AT AGE(YR) 1-3	#AT AGE(YR) 4-7	#AT AGE(YR) 8+	TRASH (TUBS)
57	420626	670233	109.8	83.	12.	852.	254.	0.	25.5
58	420637	670121	115.3	63.	10.	91.	179.	0.	20.5
59	420658	670239	117.1	56.	15.	5.	212.	1.	16.0
60	420701	670413	111.6	42.	6.	740.	123.	3.	12.0
61	420652	670453	111.6	37.	10.	651.	178.	0.	15.7
62	420651	670541	104.3	63.	10.	741.	188.	18.	16.7
63	420641	670605	108.0	86.	9.	674.	184.	4.	21.0
64	420651	670614	108.0	27.	7.	284.	63.	0.	10.0
65	420632	670540	104.3	102.	18.	987.	236.	2.	23.0
66	420642	670533	106.1	63.	5.	585.	132.	0.	19.0
67	420638	670456	102.5	85.	6.	743.	165.	0.	13.0
68	420619	670439	102.5	61.	6.	1320.	139.	0.	23.0
69	420541	670517	100.7	11.	5.	460.	68.	0.	4.8
70	420527	670545	98.8	51.	6.	0.	67.	0.	18.7
71	420546	670546	104.3	47.	6.	1021.	160.	0.	23.0
72	420600	670551	104.3	65.	10.	724.	162.	0.	25.5
73	420513	670629	97.0	39.	6.	627.	145.	0.	24.0
74	420508	670705	95.2	51.	10.	405.	115.	0.	25.0
75	420531	670710	95.2	69.	6.	562.	161.	0.	22.5
76	420622	670741	106.1	125.	24.	247.	448.	50.	22.0
77	420645	670835	108.0	9.	9.	0.	5.	9.	16.0
78	420444	670902	93.3	33.	29.	87.	138.	6.	11.0
79	420430	670913	93.3	48.	5.	254.	111.	7.	18.0
80	420401	670928	93.3	43.	6.	175.	145.	8.	18.0
81	420347	670940	93.3	24.	20.	7.	104.	2.	15.0
82	420305	670941	93.3	34.	7.	61.	72.	4.	17.0
83	420329	670922	93.3	8.	8.	1.	23.	5.	4.0
84	420338	670915	93.3	7.	7.	1.	31.	8.	5.0
85	420402	670831	93.3	64.	10.	104.	160.	11.	19.0
86	420357	670713	102.5	89.	5.	1293.	131.	9.	19.5
87	420421	670557	97.0	34.	8.	303.	78.	4.	19.0
88	420340	670340	102.5	43.	6.	37.	121.	0.	16.0
89	420325	670407	104.3	22.	15.	5.	95.	1.	12.0
90	420238	670404	106.1	27.	6.	226.	112.	16.	10.5
91	420238	670339	102.5	28.	5.	184.	72.	0.	139.0
92	420336	670222	104.3	33.	15.	13.	84.	2.	7.5
93	420208	670808	100.7	12.	12.	0.	25.	5.	4.0
94	420227	670745	84.2	0.	0.	0.	0.	0.	0.0
95	420149	670734	98.8	27.	24.	0.	33.	7.	8.0
96	420140	670603	95.2	2.	2.	0.	6.	1.	1.0
97	420130	670538	98.8	24.	24.	24.	72.	11.	2.0
98	420135	670509	97.0	33.	7.	131.	64.	6.	8.5
99	420223	670513	102.5	45.	9.	58.	113.	4.	10.0
100	420204	670447	104.3	35.	8.	106.	89.	4.	6.5
101	420140	670441	104.3	53.	12.	96.	132.	26.	5.0
102	420135	670428	102.5	24.	24.	8.	44.	8.	5.0
103	0	0	0.0	0.	0.	0.	0.	0.	0.0
104	420123	670033	115.3	1.	1.	1.	2.	0.	21.0
105	420128	670029	108.0	2.	2.	0.	3.	1.	12.0
106	0	0	0.0	0.	0.	0.	0.	0.	0.0
107	0	0	0.0	0.	0.	0.	0.	0.	0.0
108	420308	670155	111.6	51.	15.	93.	147.	17.	9.0
109	420328	670026	109.8	54.	12.	33.	142.	25.	7.5
110	420309	670017	115.3	34.	10.	13.	66.	7.	7.5
111	420102	664904	128.1	88.	10.	710.	436.	8.	17.0
112	420038	664840	120.8	80.	11.	404.	370.	8.	12.5

Table 3 Con't.

STN#	LAT	LONG	DEPTH (M)	WEIGHT(KG) TOTAL	WEIGHT(KG) SAMPLE	#AT AGE(YR) 1-3	#AT AGE(YR) 4-7	#AT AGE(YR) 8+	TRASH (TUBS)
113	420019	664805	120.8	80.	12.	237.	364.	6.	21.0
114	415959	664802	120.8	59.	11.	19.	160.	9.	27.5
115	420036	664704	122.6	33.	7.	112.	69.	0.	17.0
116	420112	664648	122.6	70.	7.	169.	168.	7.	27.0
117	420121	664657	122.6	33.	4.	235.	99.	0.	15.0
118	420135	664736	124.4	73.	9.	322.	256.	0.	21.0
119	420201	664654	126.3	34.	15.	0.	108.	3.	5.0
120	420153	664611	129.9	52.	8.	5.	206.	5.	6.0
121	420118	664611	128.1	86.	16.	0.	183.	23.	19.0
122	420111	664512	128.1	15.	15.	0.	17.	10.	10.0
123	420038	664623	126.3	34.	18.	0.	71.	10.	27.0
124	415955	664540	122.6	45.	20.	4.	129.	6.	14.0
125	420006	664524	124.4	68.	20.	12.	176.	3.	14.0
126	420005	664356	135.4	19.	12.	26.	52.	2.	12.0
127	420041	664332	133.6	44.	11.	0.	80.	3.	20.0
128	420037	664310	140.9	92.	15.	49.	227.	8.	22.0
129	420019	664226	140.9	59.	13.	62.	172.	0.	16.5
130	420036	664142	133.6	69.	6.	152.	186.	0.	22.0
131	420017	664131	128.1	63.	8.	101.	162.	0.	15.0
132	420043	664105	129.9	99.	15.	245.	375.	8.	17.5
133	420112	663958	135.4	94.	15.	0.	165.	52.	14.0
134	420242	664011	131.8	54.	15.	18.	285.	14.	30.5
135	420310	664032	133.6	60.	13.	30.	170.	2.	22.0
136	420241	664139	137.3	10.	10.	14.	35.	1.	10.0
137	420305	664154	133.6	71.	15.	64.	199.	0.	20.0
138	420444	664151	133.6	61.	13.	1.	44.	5.	19.0
139	420447	664101	137.3	35.	18.	0.	53.	6.	9.0
140	420525	664004	137.3	69.	15.	0.	140.	45.	19.0
141	420528	664034	135.4	69.	16.	0.	186.	23.	14.0
142	420555	664110	131.8	112.	18.	42.	146.	14.	21.0
143	420544	664142	131.8	74.	19.	0.	82.	13.	33.0
144	420556	664212	135.4	83.	20.	17.	197.	22.	29.0
145	420546	664219	131.8	166.	23.	14.	327.	35.	28.0
146	420436	664411	133.6	161.	20.	0.	367.	5.	17.0
147	420410	664453	139.1	45.	9.	22.	117.	0.	18.5
148	420258	664423	131.8	47.	13.	0.	102.	2.	24.0
149	420406	664558	131.8	98.	23.	0.	273.	11.	23.0
150	420406	664615	129.9	93.	19.	0.	172.	2.	22.0
151	420325	664651	135.4	64.	21.	4.	139.	1.	18.0
152	420300	664653	131.8	58.	9.	10.	111.	0.	25.0
153	420241	664850	129.9	163.	24.	25.	554.	0.	23.0
154	420309	664902	128.1	117.	15.	97.	380.	6.	23.0
155	420401	664753	124.4	80.	17.	3.	205.	0.	23.0
156	420428	664838	122.6	172.	22.	0.	695.	6.	19.0
157	420533	664751	122.6	73.	16.	3.	227.	16.	22.0
158	420533	664617	128.1	34.	16.	0.	38.	15.	12.0
159	420559	664543	128.1	48.	6.	0.	273.	52.	10.0
160	420516	664525	133.6	83.	15.	0.	260.	7.	12.0

Table 4: Average abundance of scallops at age (yr) per tow in each strata type for research cruise P199. Strata ranges are commercial CPUE (kg/hr-m-man) and catch (MT).

			Average Number of Scallops/Tow at Age (yr)												
	Stratum	No. Tows	2	3	4	5	6	7	8	9	10	11+	1-3	4-7	8+
CPUE	.05-.49	21		98	57	52	41	12	3	1	0	2	98	161	6
	.5-.99	33		107	34	74	46	9	2	1	0	1	107	164	5
	1.0-1.49	83	1	61	28	77	47	11	4	1	0	2	61	162	7
	1.5-1.99	14		378	51	49	22	2	1	0	0	0	378	124	1
	>2.0	9		637	59	63	41	10	5	2	1	1	637	173	9
Catch	0-.59	11		7	7	31	38	11	5	2	1	2	7	89	10
	.6-.99	12		25	16	22	17	8	2	1	0	1	25	63	4
	1.0-4.99	65		84	37	44	37	12	4	1	0	2	84	130	8
	5.0-9.99	36		319	48	66	49	9	3	1	0	1	319	173	6
	10.0-14.99	19		182	41	113	56	6	2	0	0	0	182	216	2
	15.0-19.99	13	1	45	41	170	66	7	2	1	0	0	45	283	4
	>20	4	3	82	42	226	56	11	1	1	0	0	85	336	2

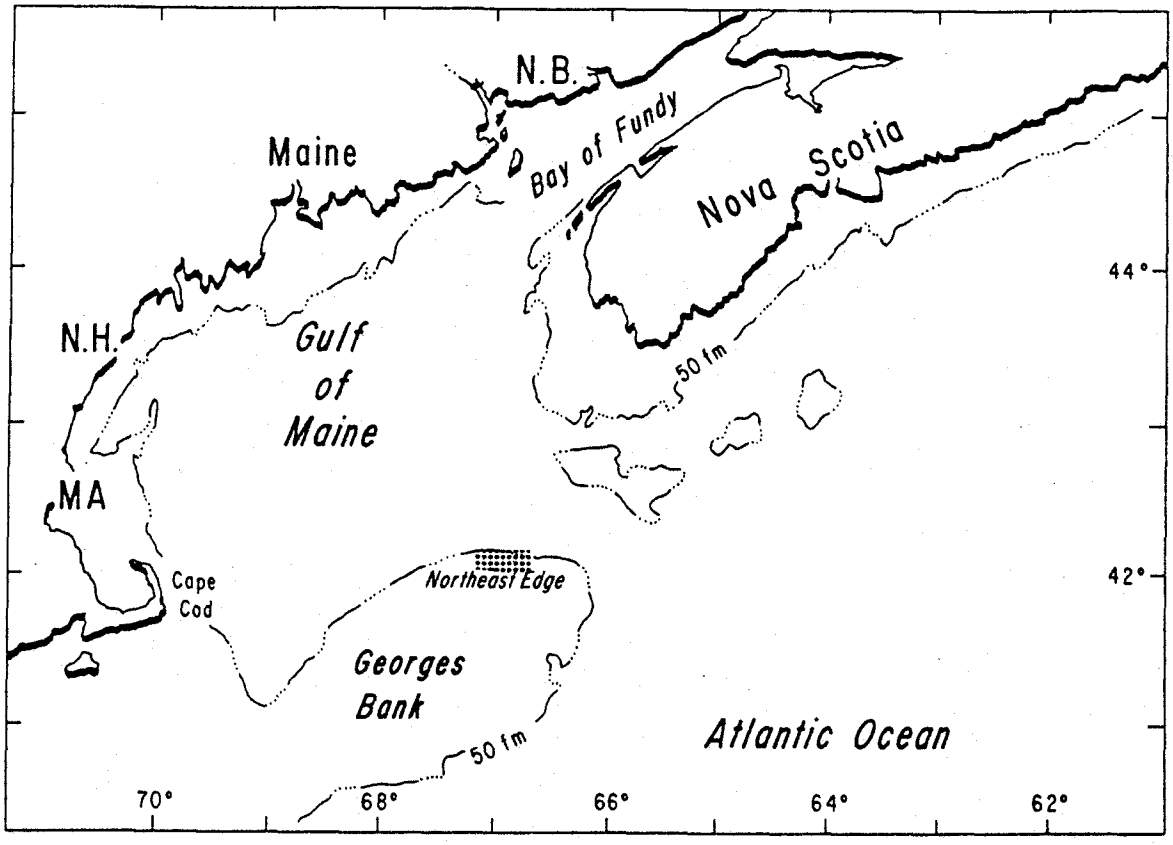


Fig. 1. The relative geographic position of Georges Bank in the northwest Atlantic Ocean. The study area is shaded.

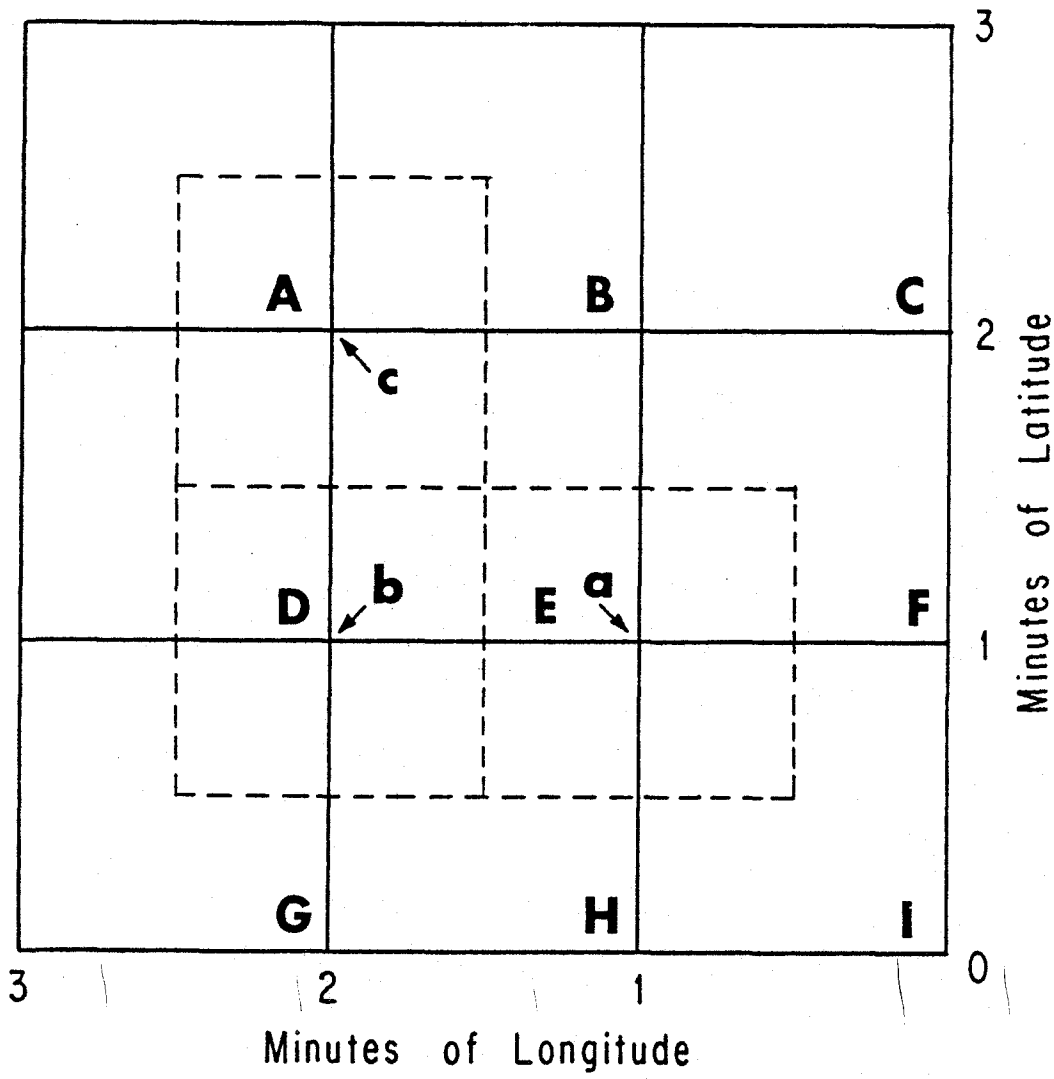


Fig. 2. Strategy used to assign average catch over four 1-minute squares of latitude and longitude (A-I) surrounding the mid-points (a-c) of daily fishing locations. Each catch is assigned to the nearest position of minute intercept, and then averaged over the four surrounding unit areas. Thus, the catch of (a) would be spread equally over unit areas E, F, H, and I; of (b) over areas D, E, G, and H; and of (c) over areas A, B, D, and E.

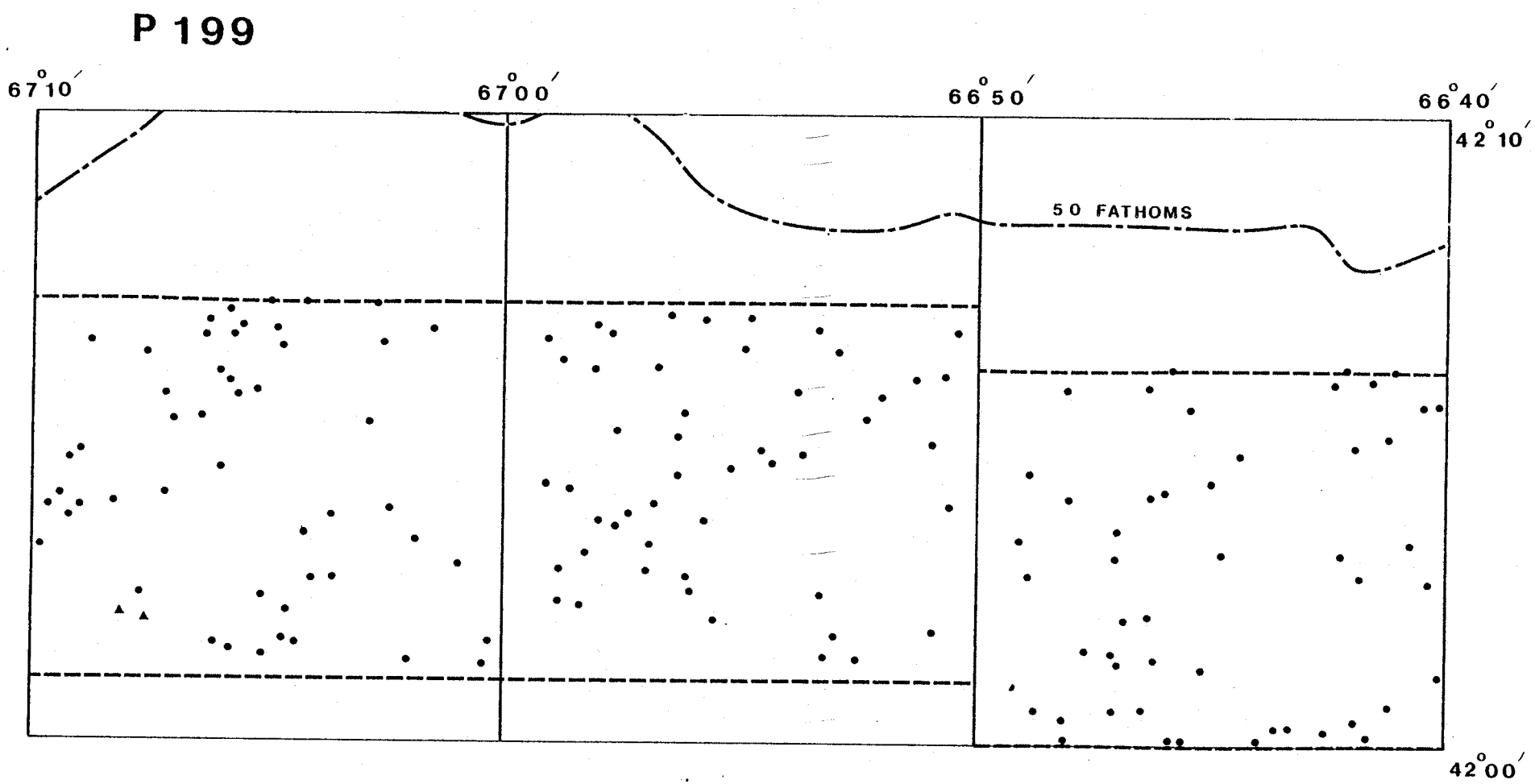


Figure 3. Station distribution (•) in the study area of research cruise p199 = non-randomized locations.

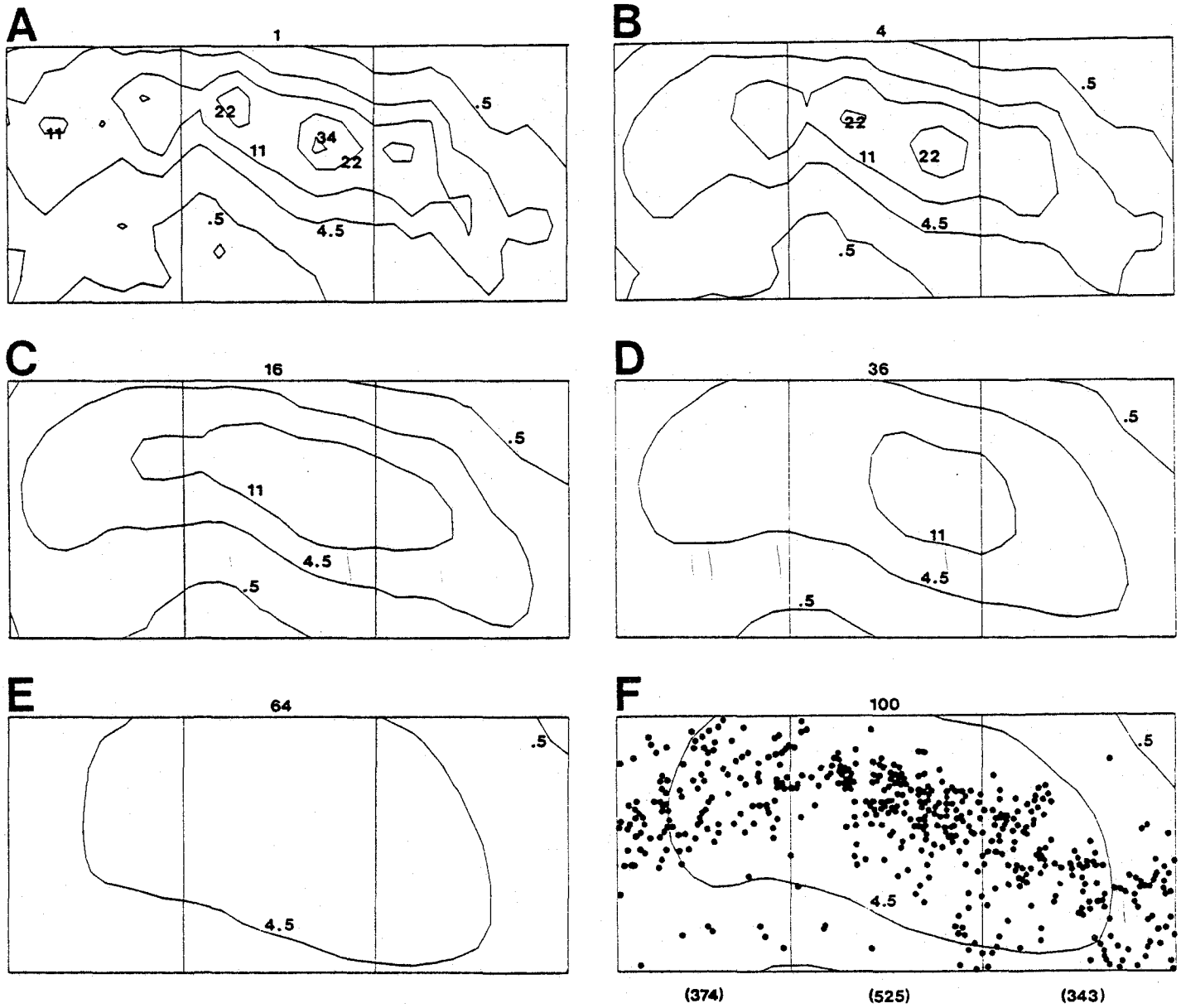


Figure 4. The effect of spreading catch and effort values over varying numbers of number unit squares (values above rectangles) in the study area (three TMSs). Contours are catch (MT) values for 01-06, 1978. F: the distribution o actual daily values ( ). (n) = total number of values per TMS.

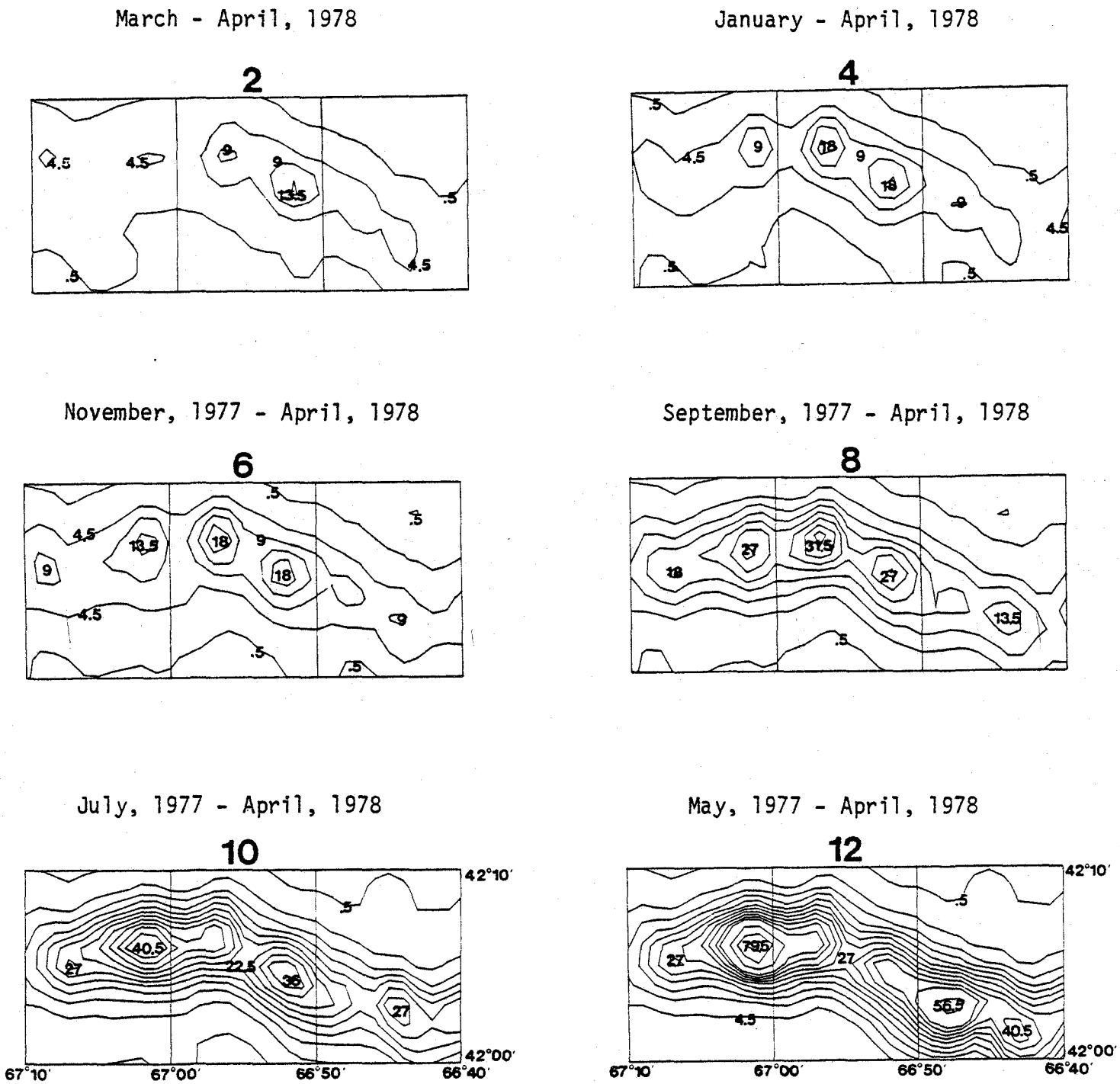
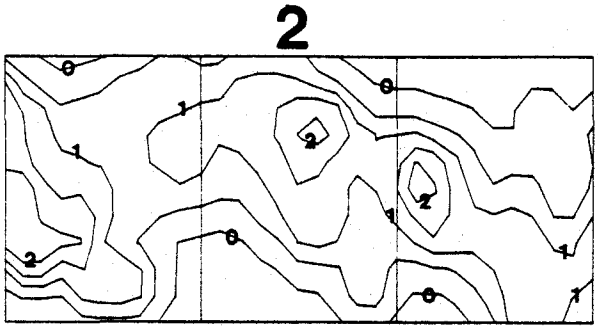
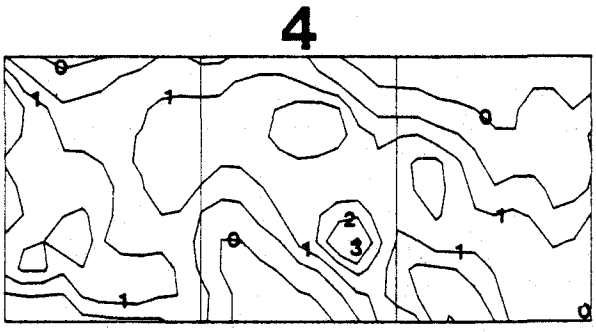


Figure 5. The effect of varying numbers of months of data (large numbers) in catch (MT) isopleths in three TMSs.

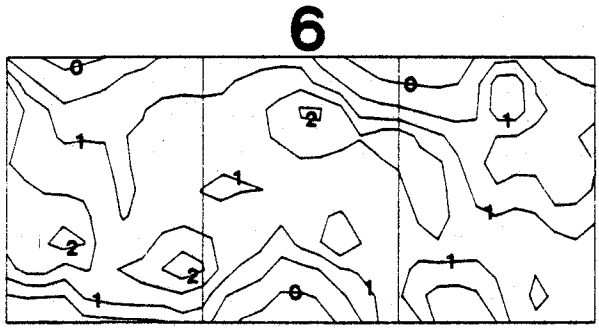
March - April 1978



January - April 1978



November 1977 - April 1978



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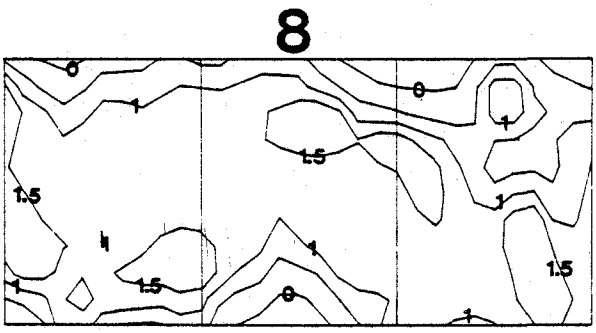
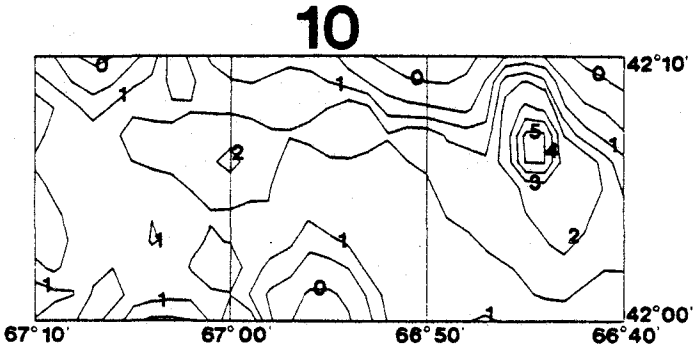


July 1977 - April 1978



May 1977 - April 1978

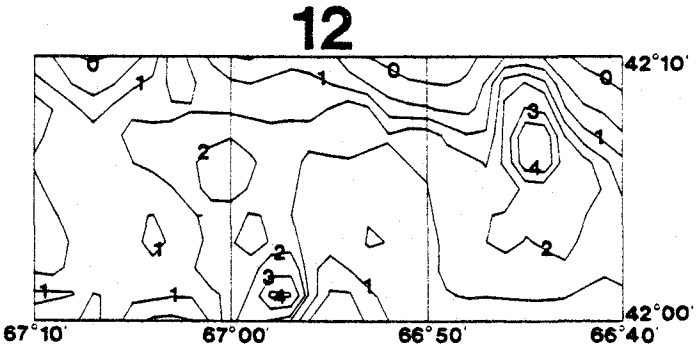


Figure 6. The effect of varying numbers of months of data (large numbers) in CPUE 9kg/hr-m-man) isopleths in the three TMSs.

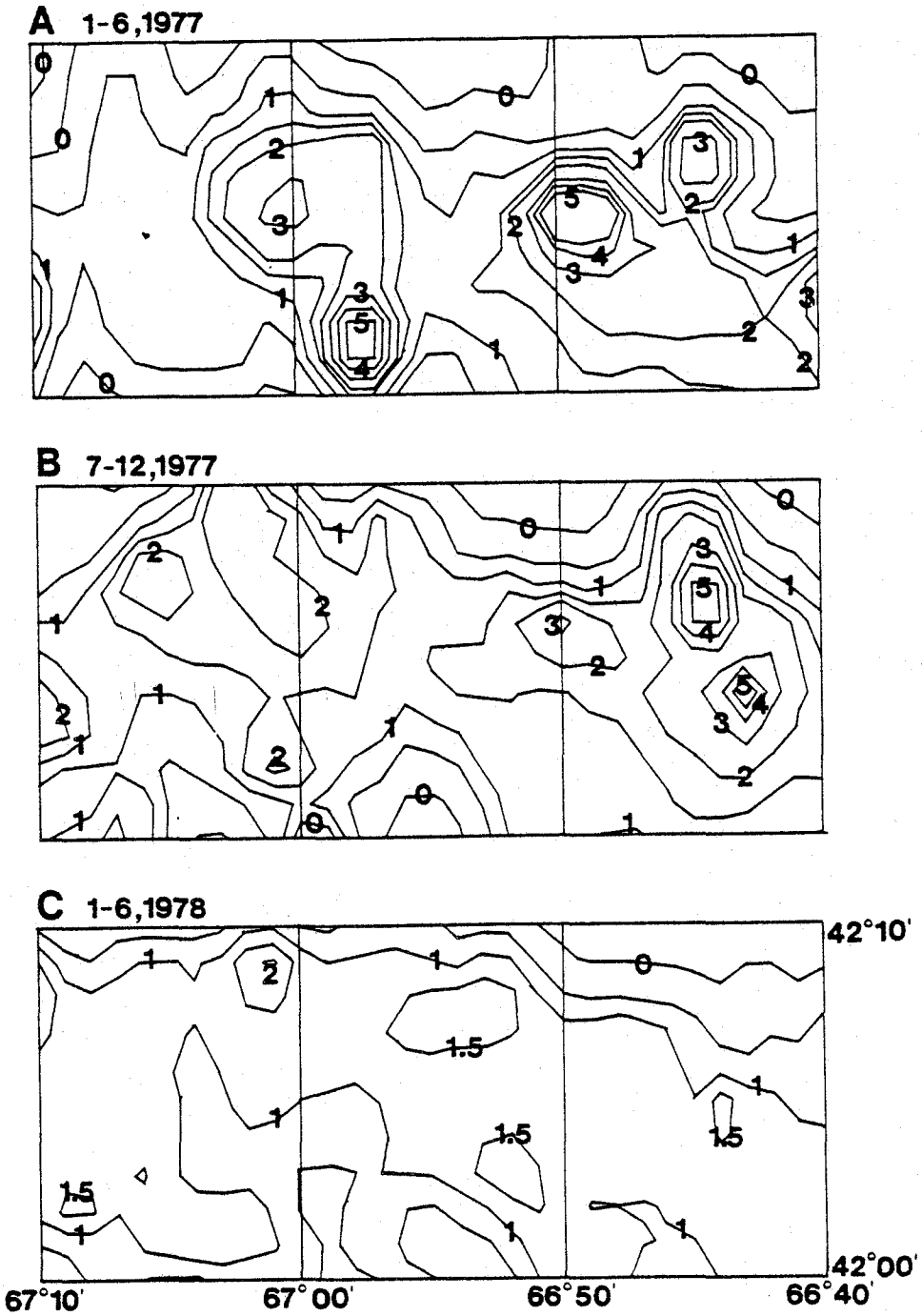


Figure 7: Abundance of scallops at age (yr) per tow with research gear in three TMSs.

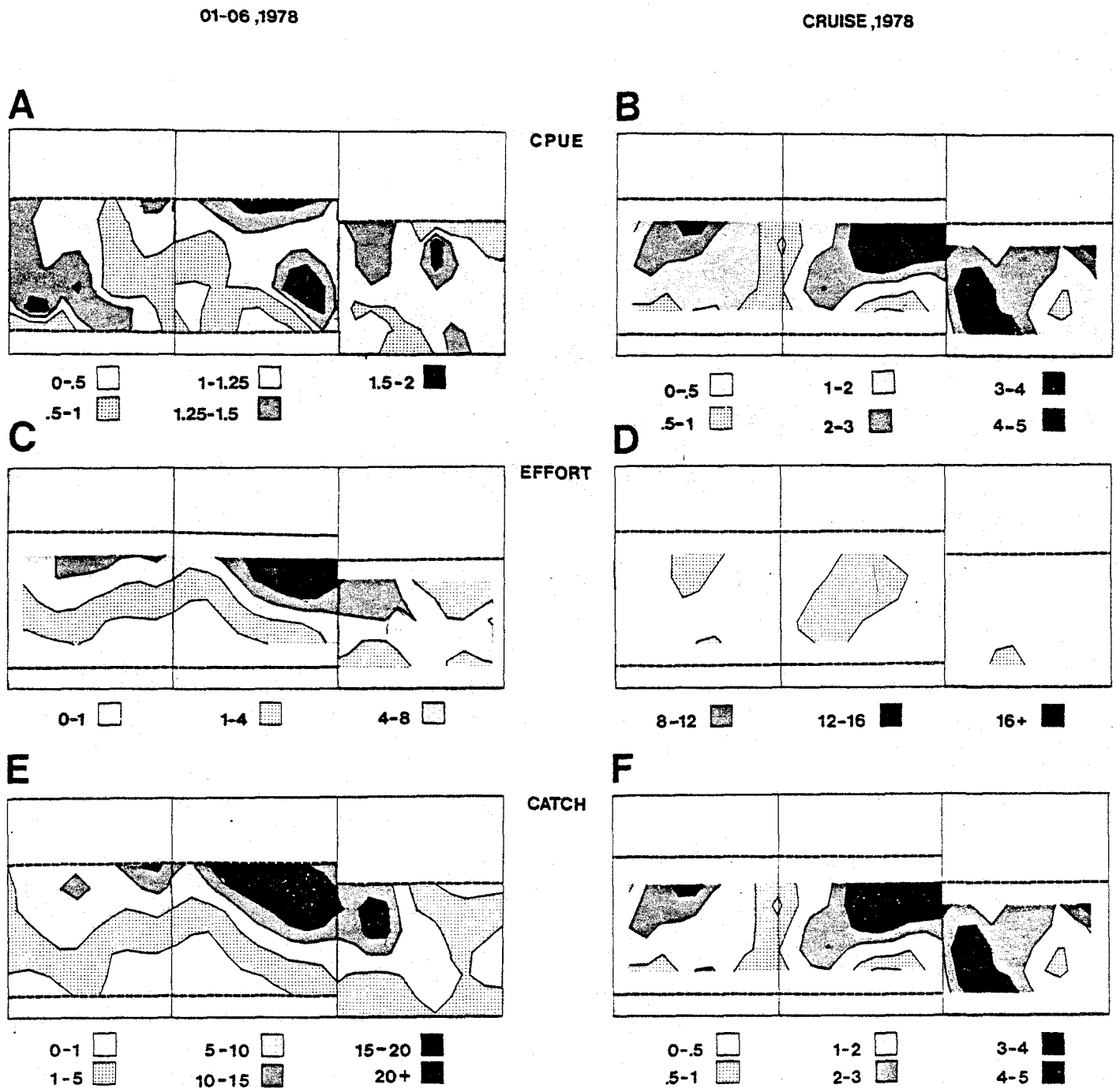


Figure 8. Log and cruise data on the distribution of scallops in three TMSs. A: kg/hr-m-man B: kg/station; C: hr-m-man; D: stations; E: MT; F: kg.

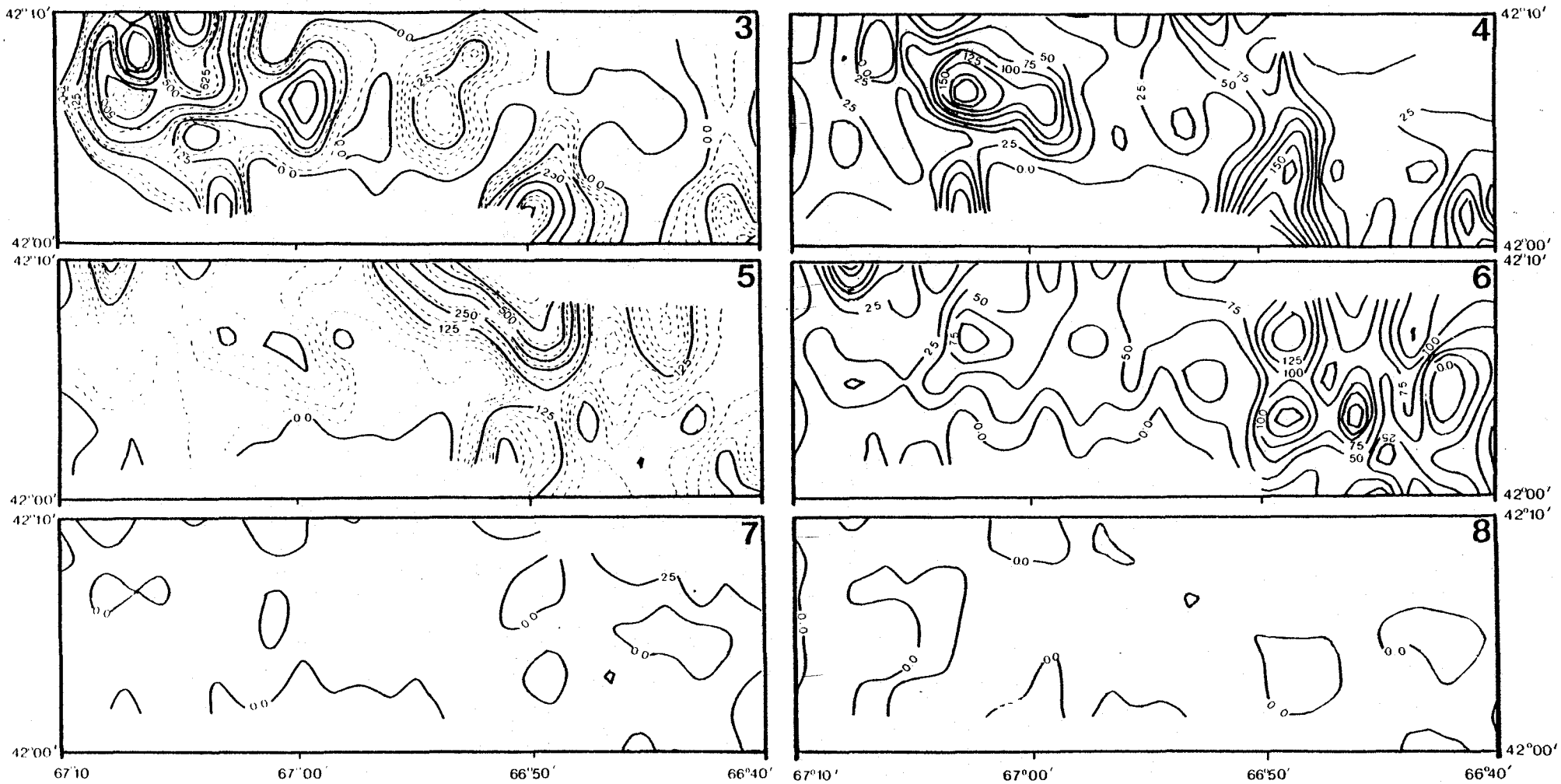


Figure 9: Abundance of scallops at age (yr) per tow with research gear in three TMSs.