ANNUAL MEETING - JUNE 1968

RESULTS OF THE JOINT USA-USSR GROUNDFISH STUDIES

Part I. Comparative Fishing Experiments

by

R. C. Hennemuth

Introduction

The advent of extensive USSR fisheries in Subarea 5 on species which are also fished by USA fleets has led to the necessity of combining observations on abundance obtained by both nations in order to assess the effects of fishing. A coordinated study was arranged to make some direct comparisons of effects of different gear on estimates of groundfish abundance.

Part of the joint USSR-USA groundfish survey operations was concerned primarily with experiments to measure the relative catch rates between vessels and trawls. The experiments were designed to estimate separately the effects of the vessels and trawls, and to estimate and interactions of the two factors. We desired these estimates both to calibrate the relative catch rates for purposes of comparing results of previous and future independent surveys of the two nations, and to elucidate behavioral and distributional aspects of fish in the area of operations.

The experiments were conducted from 3-11 October, 1967 in the area off Block Island and Marthas Vineyard. The operations were smoothly coordinated, and special tribute is due the Soviet captain, crew and scientists for their diligent efforts and ready adaptability to an unfamiliar procedure.

The characteristics of the two vessels and trawls are described in detail by Grosslein in the companion document, Part II. In this study characteristics of primary concern are as follows:

Vessels: USSR Albatros - side trawler

USA Albatross IV - stern trawler

Nets: USSR - Headrope height of approximately 5 m., no rollers on groundrope.

USA - Headrope height of approximately 3 m., 30 cm., rollers on groundrope.

The net characteristics were measured after the joint survey on the M. V. Delaware, a side trawler, using instrumentation developed by the Exploratory Fishing Base, BCF, Gloucester, Mass. Measurements were made while towing at a speed and scope similar to that used during the experiments; 3.5 knots and 2:1, respectively.

Design and Analysis

The Model

The assumed model is:

$x_{ijk} = \mu \alpha_i \beta_j \iota_{ij} e_{ijk}$, where

x_{ijk} = observed catch per 30-minute tow with the i^{th} vessel, j^{th} net and k^{th} tow.

μ = overall population mean

α_i = true effect of the i^{th} vessel, $i = 1, 2$

β_j = true effect of the j^{th} net, $j = 1, 2$

ι_{ij} = true interactive effect

e_{ijk} = error for k^{th} tow, $k = 1, r$

For purposes of analysis, we shall use a linear model obtained by taking logarithms, which we shall write as:

$y_{ijk} = \log_e x_{ijk} = M + A_i + B_j + I_{ij} + E_{ijk}$, where $M = \log_e \mu$, etc.

Both factors are qualitative to some degree, the nets less so than vessels. We arbitrarily assigned the USSR gear the lower level of the two for both factors. Thus, in the notation of Davies (1963), where the absence of a small letter indicates the lower level of the factor was used, the four possible observations, i.e. the total catch of all tows with the combination, are given as follows:

Observation	Vessel	Net
(1)	USSR	USSR
a	USA	USSR
b	USSR	USA
ab	USA	USA

With this notation, the estimated total effects are obtained as follows:

$$[A] = \frac{1}{2r}\,(a + ab - (1) - b) = \bar{y}_{2..} - \bar{y}_{1..} = \hat{A}_2 - \hat{A}_1$$

$$[B] = \frac{1}{2r}\,(b + ab - (1) - a) = \bar{y}_{.2.} - \bar{y}_{.1.} = \hat{B}_2 - \hat{B}_1$$

$$[AB] = \frac{1}{2r}\,((1) + ab - a - b) = \bar{y}_{22.} + \bar{y}_{11.} - \bar{y}_{21.} - \bar{y}_{12.}$$

$$= \frac{1}{4r}\,(\hat{I}_{22} + \hat{I}_{11} - \hat{I}_{21} - \hat{I}_{12})$$

$[A]$ and $[B]$ as given above hold only if $[AB]$ is negligible. A main effect cannot, of course, be directly measured if interactive effects are large.

In the absence of interaction, efficient estimates of the main effect ratios, $\alpha = \frac{\alpha_2}{\alpha_1}$ and $\beta = \frac{\beta_2}{\beta_1}$, may be obtained as follows if the y_{ijk} are normally distributed (Finney, 1941):

$$\hat{\alpha} = \exp^{[A]}, \quad \hat{\beta} = \exp^{[B]}.$$

Variances may be approximated by:

$\frac{1}{4r\,\bar{x}_{1..}}\left(v_2 + \rho^2 v_1\right)$, where $\bar{x}_{1..}$ is the lower level mean estimated from the mean and variance of $\bar{y}_{1..}$, v_i is the variance associated with the i^{th} level of x, again estimated as a function of the mean and variance of y, and ρ is the estimated effect $\hat{\alpha}$ or $\hat{\beta}$.

Experimental Procedures

The effects of vessels and nets on catches, and their interactions, were measured in a series of completely randomized block designs, with replication. Two experimental units were utilized. In the first phase, three 20 x 20 km. areas were selected to provide the best balance with regard to density and kinds of fish (Fig. 1). Within the areas, a block was defined as a 12-hour period of daylight (0600-1800 hours) or darkness. Within the block, each vessel-net combination was fished for a series of three consecutive tows, the change of combination taking place about midway through the 12-hour period. The starting combinations were selected at random, as were the station positions for each tow. All four possible combinations were fished in each block, i. e. these were complete factorials, so that 12 tows were made in each block, and three blocks were completed.[1/]

The second type of unit was based on depth stratification, and the geographical areas were larger than those of the first type (Fig. 1). The depth boundaries of the three strata were 15, 30, 60 and 100 fathoms. Again, a 12-hour period of daylight or darkness within a stratum defined a block. Because of the greater running time between stations, and the desire to maintain as great a degree of replication within blocks as possible, all four vessel-net combinations were not fished within each block. Instead, a 1/2 fractional factorial was employed.

In the first series of six blocks (the two 12-hour periods in each of the three strata) the interaction effect was confounded with the differences between blocks, and, hence, was not measurable. In this design only two of the four possible combinations are fished within a block, again with a series of three consecutive tows with the same combination, and two blocks are required to provide estimates of the main effects. The combinations were randomized over the six blocks, as were the stations within blocks. A total of 36 tows, 6 tows within each block, were made.

In a second series of 4 blocks (two 12-hour periods in Strata 5 and 6), the net effect was confounded with blocks, providing estimates of vessel and interactive effects. The scheme of operations was the same as above, except, of course, with different vessel-net combinations. A total of 24 tows resulted.

1/ Five blocks were attempted, but two were not completed for technical reasons and not analysed herein.

The operation is summarized in Table 1. All tows were one-half hour long.

We have chosen the total weight of catch as the variate of prime interest. The effects on the catch of certain species groups and individual species has also been analyzed; however, because the catches of the latter are not independent, the probabilities ordinarily associated with the F-ratios are not exact. Certain segments of data could not be analized because of poor catches.

Results

The results of the analyses of variance, and the estimated effects, means and variances in $\log_e$ units, i.e. for the linear model, are presented in Table 2. The main effect ratios, means and variances, retransformed to original units (pounds per tow), are given in Table 3. Finally, a summary of weight and numbers of fish in the catches by species for all experiments is presented in Table 4, wherein the species composition of the various groups is also defined.

Looking first at total catch (Table 2), the results quite clearly indicate no interaction and a significant net effect. The catches with the USA net were 40 percent of those with the Soviet net (Table 3). A significant vessel effect was found in experiment two, where the USA vessel out-fished the Soviet vessel by a factor of 2, but the other two experiments yielded catch ratios near unity.

The vessel effect for total catch has no apparent explanation and may, in fact, not be real since it was large in only one of the three experiments. Checking down the results for species groups, it is apparent that the large catch ratio for pelagic fish in the second experiment may be mostly responsible. We are left with a marginal result, the stern trawling US Albatross IV may be more efficient than the side trawling Soviet Albatros.

The net effect corresponds closely to what might be expected based solely on the physical configurations of the nets. The Soviet net has about twice the headrope height, and nearly the same effective spread as the USA net. Thus the latter filters nearly half the water volume as the former, and would obtain nearly half the catch in the absence of any other contributing factors.

It is of some interest to examine the net effects for the various species groups. As mentioned before, the F-ratio probabilities are not exact, but, nonetheless, we can draw some inferences. The net effects for dogfish and flounders are not enough different from 50 percent to lead us to conclude that the Soviet net out-fishes the Yankee trawl more than might be expected. However, the catches of skates, red and silver hake, and pelagic fish with the Yankee trawl are from 10 to 25 percent of those with the Soviet trawl. These results lead to questions of fish behavior and distribution which are intriguing, but not answerable by the experiments reported herein.

For example, the Yankee trawl equipped with rollers on the ground rope should tend bottom less closely than the Soviet net which lacked them. Mud, shells and bottom invertebrates (primarily the cancer crab) were much more evident in the Soviet net, confirming this tendency. Catches of skates and flounders should be less with the rollers; the skate catch ratio conforms to this hypothesis, but that for flounders does not. Behavior, in this case differential response to the trawl, must to some extent be involved. Conversely, the other species groups, particularly the pelagic fish, tend more to be distributed upwards through the water column. Thus, the Soviet net, with twice the headrope height, would be expected to catch more than twice as much as the Yankee trawl if the vertical distribution of species concerned was such that the more dense concentrations were off the bottom. This is pretty much borne out by the catch ratios of the pelagic fish and the hakes, but not by that of the dogfish. The latter certainly are distributed upwards through the water column, but apparently in a more uniform manner than the former.

In experiment one, two blocks of complete factorials were run at night and one block during daylight. The results in day or night were similar for all but one species, the red hake, for which the Yankee trawl catch was greater than that of the Soviet trawl in the day block. However, the red hake catches were very small in this block in both nets, and the experiment rather inconclusive.

Design of Further Experiments

The data of Table 2 indicates that differences of about half or double in catch rates could be detected in the experiments. The question arises as to the number of tows required for detecting a given difference at a given level of significance.

Uding the linear model, we need to specify the following information:

$\bar{D}$ = the minimum size of the difference we want to detect.

P = probability of a significant result, given $\bar{D}$ (i. e. the power of the test)

a = size of rejection region (for one or two tailed test)

r = number of observations in each group (if $\bar{D}$ is the effect, each of the two groups represent observations in two of the four possible combinations (1), a, b, ab.)

Now $r = 2S^2 (z_a + z_p)^2 / \bar{D}^2$, where S^2 is the variance of an observation, z_a and z_p are the normal deviates corresponding to the two types of errors.

Consider the net effect for total catch. If we wanted to detect a difference of half the catch rate for the US net, using a single tail test, with p = 0. 9, a = . 05, we have from Table 2, $\bar{D}$ = 0. 69 (= $\log_e$ 0. 5), S^2 = 0. 138, whence r = (. 276) (7. 9) / 0. 4761 = 5

Thus, in a complete factorial experiment, we would need 10 observations per block. In order to detect a difference of at least 2/3 for the US net, the same calculation gives 30 observations per block, which is more than can be done within 12 hours. Using a 24 hour period to accommodate the 30 observations may not help because of the larger error variance introduced through day-night differences in catch.

It appears, therefore, that differences of half or double can be easily detected within the framework of present design, but not much greater or less than this can be practically achieved.

Bibliography

Davies, O. L., 1963 Ed., The design and analysis of industrial experiments, 637 pp., Hafner Pub. Co., N. Y., 1963.

Finney, D. J., 1941, On the distribution of a variate whose logarthim is normally distributed. Suppl. Journal Royal Stat. Soc., Vol VII (2), pp. 155-161.

Table 1. Number of 1/2-hour tows made with various vessel-net combinations within blocks.

Block	USSR Vess USSR Net	USA Vess USSR Net	USSR Vess USA Net	USA Vess USA Net
	COMBINATION			
Complete Factorials	COMPLETE FACTORIALS			
Exp. Area 1 Darkness	3	3	3	3
Exp. Area 2 Daylight	3	3	3	3
Exp. Area 3 Darkness	3	3	3	3
	INTERACTION CONFOUNDED			
Stratum 5 Darkness	3	-	-	3
Stratum 5 Daylight	-	3	3	-
Stratum 6 Darkness	-	3	3	-
Stratum 6 Daylight	3	-	-	3
Stratum 7 Darkness	3	-	-	3
Stratum 7 Daylight	-	3	-	3
	NET EFFECT CONFOUNDED			
Stratum 6 Darkness	3	3	-	-
Stratum 6 Daylight	-	-	3	3
Stratum 5 Darkness	-	-	3	3
Stratum 5 Daylight	3	3	-	-

Table 2. Summary of estimated effects, mean catch per tow and variance in $\log_e$ units of pounds per tow for three experiments.

Variate	Experiment 2/	Effects: Vessels	Effects: Nets	Effects: Vess x Net	Mean Catch	Error Variance	D. F.	Coef. Variation
Total	One	0.042	-0.949**	0.009	6.685	0.138	30	0.06
	Two	0.685**	-0.906**	--	6.160	0.294	18	0.09
	Three	-0.065	--	0.460	6.618	0.212	17	0.07
Dogfishes	One	0.337	-0.632*	0.363	5.895	0.831	30	0.15
	Two	0.333	-0.183	--	4.826	0.816	18	0.19
	Three	-0.001	--	0.370	5.422	0.903	17	0.18
Skates	One	0.181	-2.692**	-0.760*	3.127	1.053	30	0.33
	Two	1.116**	-2.057**	--	2.068	0.771	18	0.42
	Three	0.548	--	-1.389**	3.043	0.398	7	0.21
Flounders	One	0.006	-0.654	-0.922*	3.640	1.053	30	0.28
	Two	0.407	-1.158**	--	3.332	0.893	18	0.28
	Three	0.020	--	-0.792	3.493	0.896	17	0.27
Groundfish	One	0.108	-1.431**	-0.591**	4.513	0.364	30	0.13
	Two	0.049	-1.392**	--	4.670	0.552	18	0.16
	Three	-0.335	--	-0.098	4.461	0.229	17	0.11
Red Hake 1/	One	-0.115	-1.199*	-0.746	2.882	1.731	30	0.46
	Two	0.407	-2.578**	--	3.200	1.626	18	0.38
	Three	--	--	--	--	--	--	--
Silver Hake 1/	One	0.042	-1.565**	-0.532	3.738	0.828	30	0.24
	Two	0.092	-2.038**	--	3.426	0.849	18	0.27
	Three	--	--	--	--	--	--	--
Pelagic Fish	One	0.348	-1.806*	0.160	2.978	2.720	19	0.55
	Two	1.814**	-1.920**	--	2.272	1.816	18	0.19
	Three	0.128	--	0.876	2.763	1.211	17	0.36

1/ Principal species of groundfish group. 2/ One = complete, Two = vess x net confounded, Three = net confounded.

* = $.01 < P \leq .05$ ** = $P \leq .01$

Table 3. Estimated effe. s, experimental mean catch and variance in original units, lbs per tow, for three experiments.

Variate	Experiment	Effects Ratio and Variance: Vessels		Effects Ratio and Variance: Nets		Mean Catch: Pounds	Mean Catch: Kilos	Error Variance (Pounds)
Total	One	1.04	(.0174)	0.39**	(.0024)	855	388	106490
	Two	1.98**	(.2069)	0.40**	(.0086)	544	247	96449
	Three	0.94	(.0325)	--		828	376	155910
Dogfishes	One	1.40	(.2439)	0.53*	(.0351)	542	246	341140
	Two	1.40	(.3691)	0.83	(.1314)	183	83	37046
	Three	1.00	(.2265)	--		337	153	160800
Skates	One	1.20	(.2576)	0.07**	(.0008)	38	17	2316
	Two 1/	3.05**	(1.161)	0.13**	(.0028)	11	5	132
	Three	1.73	(.4614)	--		25	11	293
Flounders	One	1.01	(.1815)	0.52	(.0485)	63	28	6471
	Two	1.50	(.5016)	0.31**	(.0219)	43	20	2269
	Three	1.02	(.2325)	--		50	23	3137
Groundfish	One 1/	1.11	(.0561)	0.24**	(.0026)	109	49	4973
	Two	1.05	(.1200)	0.25**	(.0067)	139	63	12927
	Three	0.71	(.0206)	--		96	43	2308
Red hake	One	0.89	--	.30*	--	41	18	6329
	Two	1.50	(2.805)	.08**	(.0072)	52	24	9964
	Three	--	--	--	--	--	--	--
Silver hake	One	1.04	--	0.21**	--	63	28	4527
	Two	1.10	(.2440)	0.13**	(.0034)	46	21	2451
	Three	--	--	--	--	--	--	--
Pelagic fish	One	1.38	(38.99)	0.16*	(.5540)	71	32	76046
	Two	6.13**	(77.05)	0.15**	(.0440)	23	10	2500
	Three	1.14	(.5724)	--	--	28	13	1560

1/ Interaction present.
* = .01 P .05
** = P .01

Table 4. Total numbers and weight (pounds) of catch by species and vessel-net combination for all experiments.

SPECIES		CRUISE TOTAL							
		USSR-VESS USSR-NET		USA-VESS USSR-NET		USSR-VESS USA-NET		USA-VESS USA-NET	
		(1)		a		b		ab	
		Wgt.	No.	Wgt.	No.	Wgt.	No.	Wgt.	No.
DOGFISH:									
Sand Shark	(012)	4	1						
Smooth	(013)	25	2				1	27	6
Chain	(014)			2	3				
Spiny	(015)	13710	3506	4991	1313	4917	1455	7481	2455
Total		13738	3509	4993	1316	4917	1456	7508	2461
SKATES:									
Torpedo	(021)								
Barndoor	(022)			11	9		1	1	1
Big	(023)	10	9	21	6	64	42	29	13
Leopard	(025)	1	1						1
Little	(026)	1412	1096	1298	890	132	85	361	163
Sm. Tailed	(027)		4				2		
Total		1423	1110	1330	905	196	130	391	178
GROUNDFISH:									
Amer. Hake	(069)	5	6	4	10	1	1	2	5
Silver Hake	(072)	1447	2897	1856	5243	592	1659	511	1306
Cod	(073)	174	78	28	21	127	27	124	76
Haddock	(074)	1	2	2	1	137	56	2	1
Pollock	(075)		7	1	1	50	13	18	29
White Hake	(076)	81	65	128	50	36	26	29	19
Squirrel Hake	(077)	1264	3457	976	3139	525	1823	362	447
Spotted Hake	(078)	2	15	16	32		2	14	26
4-Beard-Rock.	(083)		2	13	95		3		3
Total		2974	6529	3024	8592	1468	3610	1062	1912
FLOUNDERS:									
American Dab	(102)	31	61	37	113	5	16	17	48
Fluke	(103)		1					2	1
4-Spot	(104)	53	158	140	306	75	210	70	176
Yellowtail	(105)	556	1057	500	770	930	1652	530	1090
Winter	(106)	110	166	48	58	64	162	173	235
Witch	(107)	81	58	183	117	10	10	4	2
Sand	(108)	31	94	32	48	11	17	27	27
Gulf Stream	(109)		4	1	34		3	2	81
Total		862	1599	941	1446	1095	2070	825	1660

Table 4. (Cont.)

PELAGIC FISH:									
Round Herring	(031)	73	1217	261	2138			3	48
Sea Herring	(032)		15	3	11	15	45	13	29
Alewife	(033)	3	46	2	5	1	13	130	350
Blueback	(034)	295	680	37	94	105	210	1732	3238
Shad	(035)	122	242	4	5	9	9	34	42
Mackerel	(121)	3211	7752	134	365		2	34	311
Butterfish	(131)	918	4045	1406	15709	526	1197	426	3102
Scup	(143)	863	5045	41	70		12	5	7
Total		5485	19042	1888	18297	656	1488	2377	7127
All Other Fish:									
Lantern Fish	(052)								1
A. Conger Eel	(063)	5	1						
Snake Eel	(065)						3		
3-Brd-Rock.	(085)		1						
Bluefish	(135)			10	1				
Tilefish	(151)					12	1		
B. B. Redfish	(156)								2
L. H. Sculpin	(163)	155	605	91	341	182	670	107	389
Sea Raven	(164)		4	1	4		8	4	4
Allgt. Fish	(165)		10				1		
Grubby	(166)						10		
Lumpfish	(168)				1				
Cm. S. Robin	(171)		11	8	17		4	1	43
S. S. Robin	(172)	2	9						
A. S. Robin	(173)							4	9
Cunner	(176)	13	4				2		
Sand Lance	(181)		1						
Wrymouth	(191)				2				
Ocean Pout	(193)	139	308	400	925	62	169	8	15
Cusk Eel	(194)		20				1	3	65
A. Goosefish	(197)	259	51	595	116	141	25	219	24
File Fish	(201)		1						
Rudderfish	(207)				1				
Round Scad	(211)		1						
Pearl Sides	(230)		8						4
Total-Other Fish		573	1035	1105	1408	397	894	346	556
Total All Fish		25055	32824	13281	31964	8729	9648	12509	13894
Lobster	(301)	18	24	60	60	17	25	23	27
Squid (unclass)	(501)	6	12	97	146		1	24	54
Short-Finn	(502)	3	31	5	35	358	1851	27	104
Long-Finn	(503)	28	87	71	568	201	1006	7	30
Brief Squid	(504)						15		

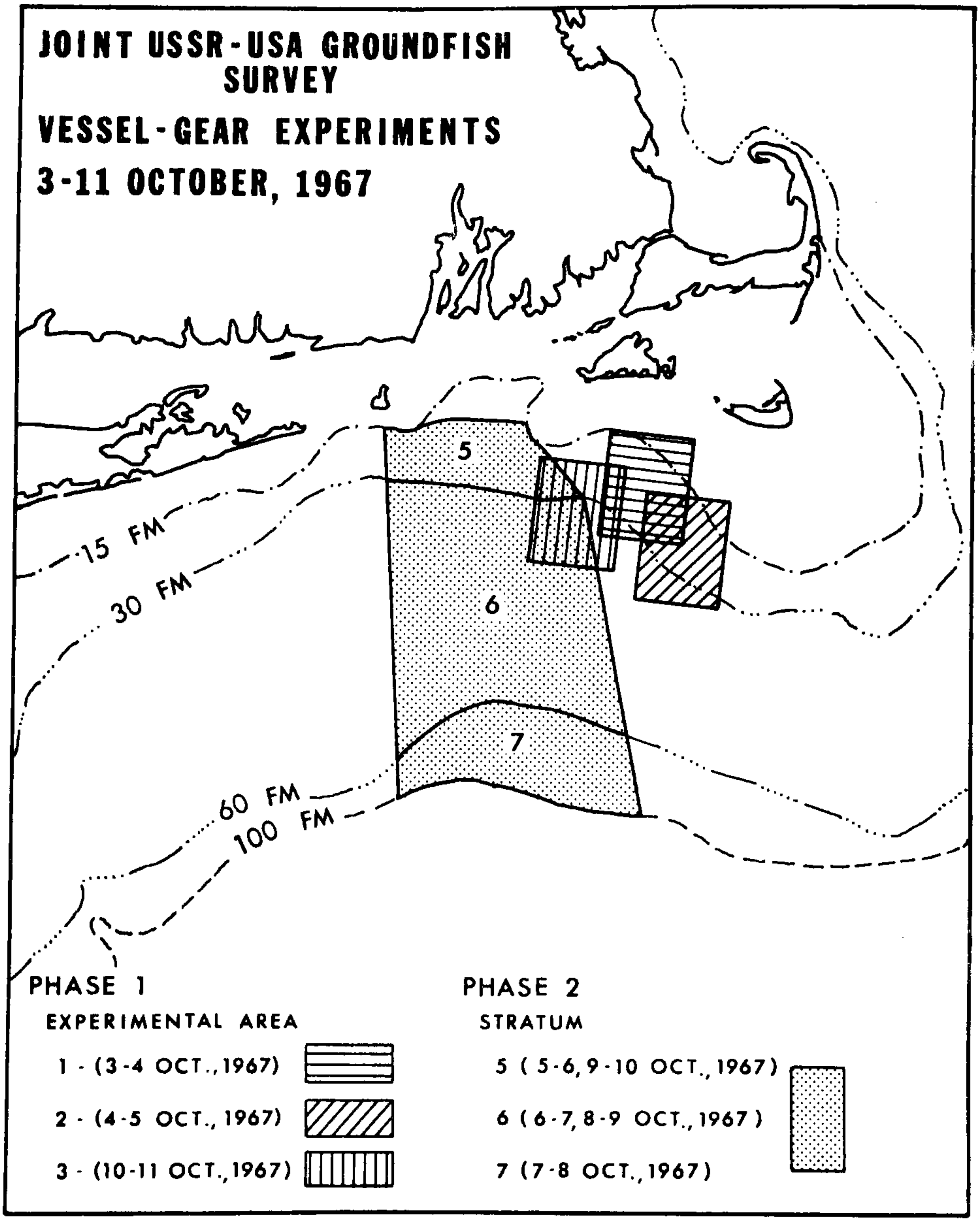

Figure 1. Locations of experimental gear studies.