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Two-Phased Survey Design for Shrimp off Labrador

by

D. G. Parsons
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland A1C 5X1

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Abstract

A two-phase survey for northern shrimp was conducted in the Hopedale and Cartwright channels off Labrador during the summer of 1987. The methodology, described by Francis (1984), proved useful in allowing flexibility in the allocation of fishing stations to better reflect current shrimp distribution. Variance was substantially reduced in the final biomass estimates, compared to the results obtained from Phase 1 of the survey, alone, while the mean values were similar. Problems associated with the diel variation in shrimp catches were not solved, however, by this method.

The design is briefy described as well as its application in the 1987 research survey in both areas.

Résumé

Un relevé portant sur la crevette nordique a été réalisé en deux phases, pendant l'été 1987, dans les chenaux Hopedale et Cartwright, au large du Labrador. La méthodologie retenue, décrite par Francis (1984), s'est révélée utile car elle a permis de disposer les stations avec une souplesse adaptée à la répartition actuelle des crevettes. La variance a été nettement réduite dans les estimations finales de la biomasse, par rapport aux résultats obtenus à la phase I du relevé seulement, tandis que les valeurs moyennes étaient similaires. Cette méthode n'a cependant pas permis de régler les problèmes posés par les variations nycthémérales dans les prises de crevettes.

L'étude décrit brièvement la conception du relevé ainsi que son application à la campagne de 1987 dans les deux zones.

Introduction

A CAFSAC review of the research trawl survey design for northern shrimp in the Labrador Channels (as described by Parsons, 1984) has been carried out because of concerns that some of the assumptions of the stratified random design were possibly being violated. In summary, it was recommended that:

1. the area covered should be the same from year to year;

2. if the stratified random design is continued, strict adherence to its rules should be followed;

3. the arithmetic mean should be continued to be used as the best measure of central tendancy, at present;

4. the practice of droppping sets in strata where few shrimp are found should not be continued;

5. the practice of fishing in areas of apparent low shrimp abundance at night should not be continued.

It was also noted that the possibility of combining strata in order to increase sample size should be examined as well as investigating the use of alternate sampling designs.

Faculty of the Department of Applied Statistics at Memorial University of Newfoundland were consulted about a more flexible but statistically valid survey design. It was further suggested that the efficacy of the stratification scheme should be examined and compared to simply contouring the catch data. Also, by using time as a factor, the diel problem might be addressed in a factorial design, with day/night being crossed with area when biomass estimates are being made.

Subsequent to these discussions, the author was referred to a paper by Francis (1984), addressing strategies for stratified random trawl surveys. The problems dealt with in this paper were very similar to the ones encountered in designing surveys for northern shrimp. Consequently, the two-phase survey design described by Francis (1984) was used for the shrimp surveys in Hopedale and Cartwright Channels in 1987. This paper briefly summarizes the method and gives examples of its application as used in the 1987 research survey. The results of the two-phase design are compared with those of the stratified random design which was completed during Phase 1.

The Method

As the name implies, this type of survey is conducted in two parts, the first of which is a conventional, stratified random design. Based on the results obtained in Phase 1, additional sets can be allocated to selected strata in Phase 2. According to Francis (1984), Phase 2 stations can be allocated using the following procedure.

Step 1. Calculate the estimated relative gain (reduction in variance) G_i from adding one station to $stratum_i$ by,

$$G_i = A_i^2 V_i / (n_i(n_i+1))$$

where A_i is the area of $stratum_i$, and n_i and V_i are the number of stations and variance of the catch rate for the Phase 1 survey in $stratum_i$, respectively.

Step 2. Allocate 1 station to the stratum with the highest value of G_i.

Step 3. Add 1 to n_i and recalculate G_i for the stratum just chosen.

Step 4. Repeat steps 2 and 3 for as many times as necessary.

If V_i is approximately proportional to M_i^2 (mean of the catch rate in $stratum_i$), then the quantity

$$G'_i = A_i^2 M_i^2 / (n_i(n_i+1))$$

will be proportional to G_i, and may be used in its place. Francis states that, because of the high degree of skew in catch rates, M_i^2 is more stable than V_i so there is some reason to believe that the G'_i allocation will be superior. He also states that in estimating biomass and its variance, two-phase survey data are treated as if they came from a conventional survey. The question of how many stations should be occupied in Phase 1 was addressed and it was suggested that about 75 % of the total number of stations might be appropriate.

One advantage of the design is the apparent flexibility provided for in the second phase. Once Phase 1 has been completed, there is no problem if all Phase 2 stations cannot be completed for various reasons. Time remaining in Phase 2 can also be used most effectively by evaluating the relative gains in relation to steaming time, rough trawling grounds, ice, etc.

Application

It should first be noted that due to shortage of survey time available in 1987 it was not possible to complete all the stations planned for the second phase. In conducting such a survey, it is essentially necessary to cover the grounds twice. Therefore, extra time is needed, compared to the conventional design. When vessel requests were made in 1987, the design of the survey had not been decided and additional days were not requested. Nevertheless, it was decided to go with the two-phase strategy in 1987 to see if it could be carried out without experiencing major problems.

Phase 1 for the Cartwright Channel required 39 sets spread over 17 depth strata (Table 1). It was intended that 11 more could be done in Phase 2 for a total of 50. After Phase 1 was completed, the G and G′ values were calculated according to the method of Francis (1984). The results clearly indicated that a large number of extra sets were required in stratum 807, a relatively large area where the mean catch and associated variance were very high. However, the time remaining only allowed for five additional sets. Two were completed in stratum

807, one in 710 and one was attempted in 809 but experienced damage and was Both the G and G′ values were considered in making these choices. Another set was also made in stratum 708, not based on the two-phase strategy, but to reconcile a low catch in a previous set which experienced some damage.

A total of 63 sets spread over 26 strata were assigned to Phase 1 of the survey in Hopedale Channel (Table 2). An extra 17 were anticipated for Phase 2 but only 11 were completed in the time available. Both the G and G′ values indicated that most additional sets should be made in stratum 204 with a substantial number in 203, as well. Of the 11 Phase 2 sets, 6 were made in stratum 204, 3 in 203 and 2 in 104.

Biomass

Esimates of biomass were obtained for both areas using all sets and were compared with the estimates from Phase 1 sets, alone. Biomass in Cartwright Channel, based on the two-phase design, was 4578 t with the upper and lower confidence intervals at 5662 and 3494 t, respectively (± 24%). This compares with 4370 t from Phase 1, alone, but confidence intervals associated with the latter were ± 236% (14,702; -5963 t)! Details of the calculations from both data sets are given in Table 3.

The effect of two-phase sampling in Hopedale Channel was not so pronounced as that observed in Cartwright, but variance was greatly reduced after the extra sets were added. The final estimate was 6037 t, with upper and lower confidence intervals of 8788 and 3287 t, respectively (± 46%) (Table 4). The mean esimate from Phase 1 was higher (6496 t) but less precise with confidence limits at ± 87% the mean value (12,127; 865 t).

Discussion

The two-phase survey design described by Francis (1984) appears to be quite appropriate for northern shrimp and addresses a number of the problems that have been encountered and dealt with in the past by using the stratified random method with some flexibility. Essentially, the rationale for the two methods is similar but Francis′ design eliminates, for the most part, the subjectivity in selecting extra sets and formalizes the approach. The improvements in precision shown in the above examples indicate that this methodology should be continued in any future trawl surveys for shrimp off Labrador. In fact, the design might well be used for other stocks, not only shrimp, but finfish as well.

By using this methodology, most of the concerns expressed previously have been met (see Introduction). The possibility of combining strata in order to increase sample size was not considered appropriate because of the changes in mean size and maturity that occur with depth. Also, because the depths of highest shrimp concentration vary from year to year, it was felt that the 50 m precision should be maintained in order to account for such differences. Caddy (1986) stated that it is vital in sampling crustacean populations to know where and when spatial segregation by size and maturity occurs and that the population is correctly defined and samples properly weighted by area before pooling and analysis. Simple contouring of the research catch data also was considered to be inappropriate for the same reason. Previous attempts at contouring have not been successful, mainly due to the extreme variability in the catch data over small geographic areas.

Unfortunately, the diel variation still remains a problem. Because day/night is so difficult to define in terms of trend in catch data, it was not considered feasible to include time of day as a factor. Also, it would be very difficult to sample sufficiently in a factorial design, given the importance of maintaining the depth stratification. Other approaches to this problem include the use of acoustic methods and/or the use of trawls with a much higher vertical lift than the ones currently used for research surveys. Industry has made substantial changes in gear over the last several years and one major change has been the dramatic increase in vertical opening. Some of the trawls now used reportedly have lifts of over 20 m which have resulted in better catches at night when the shrimp move off the bottom. It is hoped that in 1988 some comparative fishing can be conducted between the research and commercial gear to determine how profound these changes have been. Perhaps, by using a higher lift trawl during research surveys, a significant amount of the diel variation can be removed from the catch data. It is also hoped that, in 1988, acoustic and trawl surveys will be conducted for *Pandalus montagui* in the eastern Hudson Strait area. By combining the results of the two, more meaningful estimates of shrimp abundance and availability might be obtainable.

References

Caddy, J.F. 1986. Modelling stock-recruitment processes in Crustacea: some practical and theoretical perspectives. Can. J. Fish. Aquat. Sci. 43: 2330-2344.

Francis, R.I.C.C. 1984. An adaptive strategy for stratified random trawl surveys. N.Z. Jour. Mar. Freshw. Res. 18: 59-71.

Parsons, D.G. 1984. Estimation of abundance of shrimp (*Pandalus borealis*) from stratified random surveys - Problems of variation in distribution and availability. CAFSAC Res. Doc. 84/26. 18p.

Table 1. Results of Phase 1 and calculation of relative gain (G, G[1]) for the selection of sets in Phase 2 in Cartwright Channel, 1987.

MAXIMUM NUMBER OF SETS IS 50 NUMBER OF SETS FOUND IS 39

STRATUM	TOTAL # SETS	NAUTICAL SQUARE MILES	MEAN CATCH WT	VARIANCE	CATCHES RELATED TO G	CATCHES RELATED TO G*
701	2	48.00	0.97	0.57	0	0
702	2	73.00	19.75	170.02	0	0
703	3	71.00	0.47	0.12	0	0
705	2	33.00	1.64	5.31	0	0
706	2	46.00	63.80	219.45	0	0
707	2	36.00	42.06	151.03	0	0
708	3	45.00	100.25	4,883.31	0	0
709	3	54.00	137.45	4,130.41	0	0
710	3	90.00	79.96	6,059.56	2	0
711	2	16.00	129.00	7,129.37	0	0
712	2	44.00	68.95	3,042.78	0	0
801	2	89.00	26.40	680.44	0	0
806	3	78.00	101.58	4,560.61	0	1
807	2	67.00	318.65	70,703.04	9	7
808	2	47.00	125.76	3,642.31	0	1
809	2	37.00	259.36	10,695.99	0	2
810	2	7.00	54.87	37.32	0	0

SEQUENCE #	G STRATUM	G VALUE	G* STRATUM	G* VALUE
11	807	52,897,657.76	807	75,967,214.20
10	807	26,448,828.88	807	37,983,607.10
9	807	15,869,297.33	807	22,790,164.26
8	807	10,579,531.55	809	15,348,226.26
7	807	7,556,808.25	807	15,193,442.84
6	807	5,667,606.19	807	10,852,459.17
5	807	4,408,138.15	807	8,139,344.38
4	710	4,090,203.00	809	7,674,113.13
3	807	3,526,510.52	807	6,330,601.18
2	807	2,885,326.79	808	5,822,768.49
1	710	2,454,121.80	806	5,231,477.67

Table 2. Results of Phase 1 and calculation of relative gain (G, G[1]) for the selection of sets in Phase 2 in Hopedale Channel, 1987.

MAXIMUM NUMBER OF SETS IS 80 NUMBER OF SETS FOUND IS 63

STRATUM	TOTAL # SETS	NAUTICAL SQUARE MILES	MEAN CATCH WT	VARIANCE	CATCHES RELATED TO G	CATCHES RELATED TO G*
102	2	46.00	21.93	748.85	0	0
103	2	40.00	58.90	3,519.60	0	0
104	2	40.00	388.06	40,700.90	0	3
105	3	54.00	98.61	653.85	0	0
106	3	52.00	86.31	6,908.97	0	0
107	3	66.00	67.40	12,747.55	0	0
108	3	177.00	34.65	2,644.66	0	0
109	3	41.00	25.50	345.44	0	0
202	2	84.00	0.69	0.56	0	0
203	2	174.00	139.26	29,115.26	6	6
204	4	398.00	70.56	16,968.42	10	6
205	4	319.00	1.80	5.86	0	0
206	4	304.00	56.70	4,344.03	1	2
207	2	173.00	2.17	0.28	0	0
208	2	187.00	2.67	7.45	0	0
209	2	185.00	3.03	9.86	0	0
210	2	305.00	3.02	16.99	0	0
211	2	184.00	0.54	0.24	0	0
212	2	124.00	0.02	0.00	0	0
214	2	42.00	1.77	0.09	0	0
303	2	37.00	0.98	0.13	0	0
304	2	30.00	49.38	2,326.30	0	0
305	2	20.00	13.39	148.61	0	0
306	2	25.00	27.45	1,459.08	0	0
307	2	31.00	3.22	19.59	0	0
308	2	60.00	1.86	3.86	0	0

SEQUENCE #	G STRATUM	G VALUE	G* STRATUM	G* VALUE
17	203	146,915,601.96	203	97,858,831.99
16	204	134,393,280.08	203	48,929,415.99
15	204	89,595,520.06	104	40,157,483.63
14	203	73,457,800.98	204	39,432,407.45
13	204	63,996,800.04	203	29,357,649.60
12	204	47,997,600.03	204	26,288,271.64
11	203	44,074,680.59	104	20,078,741.81
10	204	37,331,466.69	203	19,571,766.40
9	204	29,865,173.35	204	18,777,336.88
8	203	29,383,120.39	206	14,855,363.71
7	204	24,435,141.83	204	14,083,002.66
6	203	20,987,943.14	203	13,979,833.14
5	204	20,362,618.19	104	12,047,245.09
4	206	20,072,893.82	204	10,953,446.52
3	204	17,229,907.70	203	10,484,874.86
2	203	15,740,957.35	206	9,903,575.81
1	204	14,768,492.32	204	8,762,757.21

Table 3. Biomass estimates from Phase 1 (A) and from complete two-phase survey (B) for Cartwright Channel, 1987.

A.

		WEIGHTS				
STRATUM	NO.SETS	TOTAL	AV./SET	UNITS	TOTAL NO	VAR.
701	2	1.92	0.96	3256.	3118.	0.59
702	2	39.50	19.75	5053.	99793.	170.02
A	3	1.42	0.47	3256.	1541.	0.12
705	2	3.22	1.61	1628.	2621.	5.18
706	2	127.62	63.81	2583.	164792.	219.66
707	2	84.12	42.06	2021.	85008.	151.03
708	3	300.77	100.26	2526.	253288.	4881.71
709	3	412.36	137.45	3032.	416714.	4129.42
710	3	239.87	79.96	5053.	404005.	6059.56
711	2	257.99	128.99	898.	115873.	7129.37
801	2	52.79	26.40	4435.	117068.	680.44
806	3	304.73	101.58	4379.	444814.	4560.61
807	2	637.30	318.65	3762.	1198611.	70703.05
808	2	251.52	125.76	2639.	331841.	3643.16
809	2	518.72	259.36	2077.	538759.	10695.99
810	2	109.73	54.87	393.	21562.	37.24
B	2	137.91	68.96	2470.	170337.	3042.78

LOWER CONFIDENCE LIMIT IS LESS THAN
OR EQUAL TO ZERO
****-VARIANCE TOO LARGE FOR VALID
CONFIDENCE INTERVAL AT THIS VALUE OF ALPHA-****

TOTAL	TOTAL UPPER	TOTAL LOWER	AVERAGE MEAN	AVERAGE UPPER	AVERAGE LOWER
4369745.	14702424.	-5962935.	88.35	297.25	-120.56

EFFECTIVE DEGREES OF FREEDOM= 1
STUDENTS T-VALUE= 12.71 ALPHA=0.05

B.

		WEIGHTS				
STRATUM	NO.SETS	TOTAL	AV./SET	UNITS	TOTAL NO	VAR.
701	2	1.92	0.96	3256.	3118.	0.59
702	2	39.50	19.75	5053.	99793.	170.02
B	3	1.42	0.47	3256.	1541.	0.12
705	2	3.22	1.61	1628.	2621.	5.18
706	2	127.62	63.81	2583.	164792.	219.66
707	2	84.12	42.06	2021.	85008.	151.03
708	4	688.97	172.24	2526.	435153.	23982.32
709	3	412.36	137.45	3032.	416714.	4129.42
710	4	379.07	94.77	5053.	478841.	4917.15
711	2	257.99	128.99	898.	115873.	7129.37
801	2	52.79	26.40	4435.	117068.	680.44
806	3	304.73	101.58	4379.	444814.	4560.61
807	4	1222.95	305.74	3762.	1150040.	24470.74
808	2	251.52	125.76	2639.	331841.	3643.16
809	2	518.72	259.36	2077.	538759.	10695.99
810	2	109.73	54.87	393.	21562.	37.24
A	2	137.91	68.96	2470.	170337.	3042.78

TOTAL	TOTAL UPPER	TOTAL LOWER	AVERAGE MEAN	AVERAGE UPPER	AVERAGE LOWER
4577876.	5662219.	3493532.	92.55	114.48	70.63

EFFECTIVE DEGREES OF FREEDOM= 14
STUDENTS T-VALUE= 2.14 ALPHA=0.05

Table 4. Biomass estimates from Phase 1 (A) and from complete two-phase survey (B) for Hopedale Channel, 1987.

A.

STRATUM	WEIGHTS NO.SETS	TOTAL	AV./SET	UNITS	TOTAL NO	VAR.
102	2	43.86	21.93	2583.	56635.	748.84
103	2	117.80	58.90	2246.	132271.	3519.60
104	2	776.11	388.06	2246.	871451.	40700.91
105	3	295.84	98.61	3032.	298964.	653.68
106	3	258.96	86.32	2919.	252002.	6909.33
107	3	202.14	67.38	3705.	249674.	12751.27
108	3	103.83	34.61	9937.	343931.	2648.09
109	3	76.49	25.50	2302.	58689.	345.44
202	2	1.39	0.69	4716.	3278.	0.57
203	2	278.51	139.26	9769.	1360346.	29115.26
204	4	282.25	70.56	22345.	1576691.	16968.42
205	4	7.19	1.80	17909.	32192.	5.86
206	4	226.79	56.70	17067.	967669.	4343.05
207	2	4.36	2.18	9713.	21173.	0.29
208	2	5.34	2.67	10218.	27282.	7.45
209	2	6.06	3.03	10386.	31471.	9.86
210	2	5.98	2.99	17123.	51199.	17.29
211	2	1.07	0.54	10330.	5527.	0.24
A	2	0.04	0.02	6962.	139.	0.00
214	2	3.54	1.77	2358.	4174.	0.09
303	2	1.97	0.99	2077.	2046.	0.13
304	2	98.78	49.39	1684.	83186.	2326.98
305	2	26.78	13.39	1123.	15035.	148.61
306	2	54.91	27.45	1404.	38535.	1459.62
307	2	6.44	3.22	1740.	5604.	19.59
308	2	3.73	1.87	3649.	6806.	3.89

TOTAL			AVERAGE		
TOTAL	UPPER	LOWER	MEAN	UPPER	LOWER
6495968.	12126632.	865303.	36.18	67.54	4.82

EFFECTIVE DEGREES OF FREEDOM= 4
STUDENTS T-VALUE= 2.78 ALPHA=0.05

B.

STRATUM	WEIGHTS NO.SETS	TOTAL	AV./SET	UNITS	TOTAL NO	VAR.
102	2	43.86	21.93	2583.	56635.	748.84
103	2	117.80	58.90	2246.	132271.	3519.60
104	4	1042.78	260.70	2246.	585440.	35722.49
105	3	295.84	98.61	3032.	298964.	653.68
106	3	258.96	86.32	2919.	252002.	6909.33
107	3	202.14	67.38	3705.	249674.	12751.27
108	3	103.83	34.61	9937.	343931.	2648.09
109	3	76.49	25.50	2302.	58689.	345.44
202	2	1.39	0.69	4716.	3278.	0.57
203	5	354.76	70.95	9769.	693112.	11185.70
204	10	926.95	92.70	22345.	2071236.	19323.81
205	4	7.19	1.80	17909.	32192.	5.86
206	4	226.79	56.70	17067.	967669.	4343.05
207	2	4.36	2.18	9713.	21173.	0.29
208	2	5.34	2.67	10218.	27282.	7.45
209	2	6.06	3.03	10386.	31471.	9.86
210	2	5.98	2.99	17123.	51199.	17.29
211	2	1.07	0.54	10330.	5527.	0.24
A	2	0.04	0.02	6962.	139.	0.00
214	2	3.54	1.77	2358.	4174.	0.09
303	2	1.97	0.99	2077.	2046.	0.13
304	2	98.78	49.39	1684.	83186.	2326.98
305	2	26.78	13.39	1123.	15035.	148.61
306	2	54.91	27.45	1404.	38535.	1459.62
307	2	6.44	3.22	1740.	5604.	19.59
308	2	3.73	1.87	3649.	6806.	3.89

TOTAL			AVERAGE		
TOTAL	UPPER	LOWER	MEAN	UPPER	LOWER
6037268.	8787697.	3286839.	33.63	48.94	18.31

EFFECTIVE DEGREES OF FREEDOM= 19
STUDENTS T-VALUE= 2.09 ALPHA=0.05