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Analysis of Subsampled Catches From Trouser Trawl
Size Selectivities Studies

by

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Abstract

An analysis of a trouser trawl experiment with subsampled catches is presented. The standard analysis used for full sampled catches involves conditioning on the total catch for each size; however, it is found only to be applicable for a single subsampled haul and not for multiple subsampled hauls. Procedures are proposed to modify the data for each haul and to modify the analysis to accommodate subsampling with multiple hauls. The results extend easily to other selectivity experiments.

Introduction

A size selectivity study involves estimating the catch efficiency of a fishing gear and requires information on how many fish contact the test gear. The trouser trawl has been developed for this purpose, it basically consists of a trawl with an experimental and control mesh that are separated so that the selectivity of the experimental mesh can be determined through comparison of catches from this mesh and the control mesh. A description of the trouser trawl is given in Cooper and Hickey (1989) and Walsh *et al.* (1992). The trouser trawl was developed as an alternative procedure to the covered codend and alternate haul methods and came into widespread use in the mid 1980s when researchers in Norway, Britain and Canada began observing the covered codend with underwater cameras and discovered severe masking of the codend mesh by the cover, and also when the alternate haul method was found to require too many sets for valid comparisons.

Gear Selectivity/Technical Interactions Symposium

Selectivity curves have, in the past, been estimated from trouser trawl data by eye or by scaling the data for a logistic regression analysis (Pope *et al.*, 1975). These procedures were found to be unsatisfactory for several reasons (e.g. uneveness in warps or bridle lengths cause unequal fishing for the two sections of the trouser trawl, species like plaice often enter a trawl more on one side than the other, etc.) and resulted in Millar (1992) (also Miller and Walsh, 1992) proposing a more rigorous statistical methodology that essentially works by conditioning on the total catch in both the experimental (large mesh) and control (small mesh) codends for each size or length class of fish measured. The method has been shown by Cadigan and Millar (1992) to be superior to other methods. Miller (1991) has shown that the method is applicable for a variety of size selectivity studies and has called it SELECT (Share Each LEngth class's Catch Total).

Subsampling of catches is usually carried out in experiments of this type whenever catches are large. The sampling procedure varies according to the conditions encountered on the vessel such as freezing, volume of fish, space for sampling and manpower available. One procedure is to first place the fish in *baskets then 'Dutch Shuffle' the baskets and select the appropriate number to* sample.

The purpose of this paper is to explore the analysis of subsampled selectivity data. SELECT is shown to be appropriate for the analysis of one subsampled haul but not for a combination of multiple subsampled hauls. The current practise is to scale the data from each haul according to subsampling effort (e.g. Suuronen and Millar, 1992), however the standard errors of parameter estimates and the estimated selectivity curves may be incorrect in doing so. A more rigorous procedure is proposed that is free of these deficiencies. Methods and modifications for subsampling are developed here in terms of the trouser trawl and a fish species; however, applications to other selectivity experiments are straightforward.

Methods

SELECT for a full sampled haul

The version of SELECT that estimates the split of fish into either codend is first developed assuming full sampling and is referred to as the standard method. The split of fish refers to the proportion (p) of the total catch by both codends that is caught in the experimental codend. A version of SELECT exists where the split is assumed to be 0.5 (Miller and Walsh, 1992).

Let N_{l1} and N_{l2} be random variables representing the number of fish of length class l caught in the experimental and control codends respectively. Let λ_l be the rate at which length l fish enters the trawl. If the retention probability of length l fish in the experimental codend is denoted as $r(l)$ and all fish that enter the control codend are caught then

$$\begin{aligned} \mathrm{E}(N_{l1}) &= pr(l)\lambda_l, \\ \mathrm{E}(N_{l2}) &= (1-p)\lambda_l. \end{aligned}$$

If N_{l1} and N_{l2} are considered as Poisson random variables then, conditional on the observation of $N_{l1} + N_{l2}$ (denoted as $n_{l1} + n_{l2}$), $N_{l1}/(N_{l1} + N_{l2})$ is distributed as a Binomial random variable. The expectation of this random variable is the probability that a fish of length class l is caught in the experimental codend, given that it is caught. Let $\phi(l)$ denote this probability, then

$$\phi(l) = \frac{pr(l)}{1 - p + pr(l)}. \tag{1}$$

The function $r(l)$, which is the selection of the experimental gear, is commonly taken as the logistic function:

$$\frac{exp(a + bl)}{1 + exp(a + bl)}.$$

SELECT for a subsampled haul

If the catches were subsampled then the procedure is modified as follows. Let f_1 and f_2 denote the subsampling fractions (computed from weights or numbers) of the experimental and control codends respectively. Then

$$\begin{aligned} \mathrm{E}(N_{l1}) &= f_1 pr(l)\lambda_l, \\ \mathrm{E}(N_{l2}) &= f_2(1 - p)\lambda_l. \end{aligned}$$

The distribution of N_{l1} is Binomial (using the same conditioning procedure as in the previous section) with probability

$$\phi(l) = \frac{f_1 pr(l)}{f_2(1 - p) + f_1 pr(l)}. \tag{2}$$

Note that if $f_1 = f_2$ then (1) and (2) are the same. Otherwise let

$$p^* = \frac{f_1 p}{f_2(1 - p) + f_1 p}.$$

Then (2) may be rewritten as

$$\phi(l) = \frac{p^* r(l)}{(1 - p^*) + p^* r(l)},$$

which is identical to (1) except for p^*. If p is estimated then no modifications are necessary for subsampled data in a standard SELECT analysis, however p must be interpreted in terms of p^* rather than the split of fish.

A problem with this procedure is that one cannot use the SELECT version with p fixed at 0.5. If the split is indeed 0.5 then the procedure developed here still requires p to be estimated, even when information on the subsampling fractions exists. This procedure is also not applicable to the combined analysis of multiple subsampled hauls.

SELECT for subsamples from multiple hauls

Consider a selectivity experiment consisting of K hauls. The notation used is modified by introducing k which indexes the kth haul, $k = 1, ..., K$. For example, p_k is the proportion of the total catch in haul k that is caught in the experimental codend. Start, as with a single haul experiment, by defining

$$\begin{aligned} \mathrm{E}(N_{kl1}) &= f_{k1} p_k r_k(l)\lambda_{kl}, \\ \mathrm{E}(N_{kl2}) &= f_{k2}(1 - p_k)\lambda_{kl}. \end{aligned}$$

The λ_{kl} parameters are considered as nuisance parameters (Miller, 1992) and are removed in the single haul experiment by conditioning on $n_{kl1} + n_{kl2}$. Combining multiple hauls and dividing by the totals will remove the nuisance parameters only if the following conditions are met (for all k):

1. $r_k(l)$'s are equal,

2. p_k's are equal and

3. $f_{k1} = f_{k2}$.

Otherwise the λ_{kl}'s must all be equal which is an unreasonable assumption.

The first two conditions are assumed here (Fryer (1991) and Suuronen and Millar (1992) have considered the case where these conditions may not hold) but the last condition is not assumed because often $f_{k1} > f_{k2}$. When this is so, in practise, the numbers in either:

a. the experimental codend are scaled down so that $f_{k1} = f_{k2}$ (Suuronen and Millar, 1992), or

b. the control codend are scaled up so that $f_{k1} = f_{k2}$.

Both methods will produce the same parameter estimates, however the standard errors of parameter estimates will either be too large using (a) or too small using (b). This is easy to show using the results in the **Appendix** of Miller and Walsh (1992).

Another difficulty with scaling is that if no fish of length class l are caught in either codend then the proportion retained remains the same even after adjustment. The scaling approach can lead to a differential adjustment of the proportions retained in the experimental codend while (2) suggests an adjustment for all lengths is required.

If there are not many zero catches in either codend then an approximate procedure is to scale the numbers in both codends so that the total numbers caught remain the same. The total numbers caught in each length class is a leading term in the variance approximation of the parameter estimates; therefore, by keeping the total before and after scaling the same, the estimates of standard errors should be reasonable. This procedure has the advantage that available software can still be used (e.g. Miller and Cadigan, 1991) to estimate the selectivity curves because only a modification of the data is required. Note that this procedure is applicable to the single haul experiment as well.

Let $\tilde{}$ denote the scaled data. The procedure is applied haul by haul so the k subscript is now dropped. The scaled data are given by:

$$\begin{aligned}
\tilde{n}_{l1} &= \tilde{f}_1 n_{l1}, \\
\tilde{n}_{l2} &= \tilde{f}_2 n_{l2}, \\
\text{where}\quad \tilde{f}_1 &= \frac{n_{l+}}{n_{l1} + n_{l2} f_1/f_2}, \\
\tilde{f}_2 &= \frac{n_{l+}}{n_{l2} + n_{l1} f_2/f_1}.
\end{aligned}$$

With this scaling $\tilde{n}_{l1} + \tilde{n}_{l2} = n_{l1} + n_{l2} = n_{l+}$. Note that the new subsampling fractions ($f_1\tilde{f}_1$ and $f_2\tilde{f}_2$) are equal so the standard SELECT analysis is now appropriate. If $f_1 > f_2$ then $\tilde{f}_1 < 1$ and $\tilde{f}_2 > 1$ so that the net result is a reduction in the numbers in the experimental codend and an increase in the numbers in the control codend.

If $f_1 >> f_2$ then one will encounter many zero catches in the control codend, especially for large length classes. Scaling may result in an inaccurate estimate of p which in turn influences the estimate of the selection curve. A better procedure is to use (2) directly in the model with the implicit assumption that the f's are known exactly. This is a straightforward procedure and is identical to that developed in Miller and Walsh (1992) except that the last row and column of the information matrix developed in their **Appendix** must be multiplied by $\frac{\partial p^*}{\partial p}$.

Data

A selectivity experiment was conducted during a commercial fishing trip to NAFO subdivisions 2J3KL in January, 1992. The purpose of the experiment was to evaluate the selectivity of a measured 138.3 mm diamond mesh codend with 20% shortened lastridge ropes. The trawl used during the cruise was a Hampidjan 154'8" Hi-Rise groundfish trawl with a 154'8" headline and a 200' footrope. Test fishing using two codends with identical mesh revealed that the two sides of the trawl were not fishing equally and after the cruise it was discovered that the warps were unequal by 50 feet.

Three hauls were conducted and sampling carried out by two fisheries representatives. Samples were obtained either on deck or on the ramp if temperatures were below freezing. If samples were obtained on deck they were randomly selected from three or four parts of the codend. If samples were obtained from the ramp the required amount was let out onto the conveyer belt and then placed in baskets for measurement. Sample weights were determined by weighing several baskets to obtain an average weight to apply to each basket in the sample. The data are presented in Table 1.

Results

Five analyses were conducted and are indicated as:

i. Haul by haul analyses using the standard SELECT method with subsampling fractions subsumed in the estimated split, i.e. estimate with (1).

ii. Haul by haul analyses using the modified SELECT method, i.e. estimate with (2).

iii. Combined analysis using (2).

iv. Haul by haul analyses using the standard SELECT method with catches scaled to account for subsampling.

v. Combined haul analysis of the scaled data in (iv) using the standard SELECT approach.

Except for the p's, the first two methods produce identical results which are combined and referred to as (i). The parameter estimates, estimates of some retention lengths and standard errors for each haul are presented in Table 2 for (i), (ii) and (iii). Equivalent estimates from (iv) and (v) are presented in Table 3. The estimated retention lengths from (i) and (iii) are always less than those obtained from (iv) and (v).

The observed and estimated proportions of the catch retained in the experimental codends for each analysis are presented in Figure 1. The estimated selectivities from (i) and (iii) are presented in the upper panel of Figure 2 and from (iv) and (v) in the lower panel. Scaling resulted in slightly flatter estimated selection curves.

Discussion

Two procedures have been presented to combine data from multiple subsampled hauls. It appears that scaling catches to account for subsampling does not work if there are many zeros. In general, if the subsampling fraction of the experimental codend is much larger than the control codend then quite a few zero's may be reported for large length classes in the experimental codend and scaling may cause estimates to be positively biased. Better results will be obtained from subsampled catches using the modification to SELECT proposed if accurate information on subsampling fractions exists. Errors in the subsampling fractions will influence the estimate of the split which in turn will influence the estimates of retention lengths.

We would be amiss not to mention the problem of between haul variation in selectivities and splits in the example. Haul number 3 appears to have a large split compared to the other hauls and in (iii) this results in an overall poor (Figure 1, modified SELECT - combined hauls) fit especially to the data from the third haul. Obviously there is more involved in combining subsampled multiple hauls than incorporating subsampling fractions but this is beyond the scope of this paper; however, for this reason, the estimated selectivities from the example are not recommended for use.

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Table 1. Data for the trouser trawl experiment investigating the selectivity for cod of a measured 138.3 mm diamond mesh with 20% shortened lastridge ropes, n_{kl1} and n_{nl2} are the numbers at each length class (l) caught in the experimental and control codends of the k'th haul (k = 1, ...,3). The fraction subsampled (fs) is in the last row.

length class	n_{1l1}	n_{1l2}	n_{2l1}	n_{2l2}	n_{3l1}	n_{3l2}
20	-	-	-	1	-	-
27	-	-	-	3	-	-
28	-	1	-	1	-	1
29	-	-	-	8	-	-
30	-	3	-	6	-	1
31	-	1	-	7	-	-
32	-	3	-	7	-	1
33	-	2	-	9	-	2
34	-	6	-	11	-	2
35	-	11	-	21	-	8
36	-	9	-	19	-	7
37	-	17	-	18	-	10
38	-	20	-	28	-	22
39	-	21	-	30	-	30
40	-	17	-	34	-	31
41	-	20	-	30	-	30
42	-	22	2	32	1	33
43	1	21	1	39	6	35
44	2	25	1	29	2	23
45	3	20	3	28	5	33
46	1	12	6	26	7	39
47	3	17	9	27	10	24
48	8	15	5	22	11	29
49	4	13	10	16	7	22
50	12	13	13	15	12	19
51	12	14	13	14	15	15
52	9	8	21	21	14	10
53	3	11	16	11	7	14
54	11	9	14	10	14	19
55	13	6	18	2	19	4
56	17	1	19	7	13	5
57	19	10	18	5	13	4
58	12	4	14	6	10	2
59	16	3	18	6	13	4
60	13	3	11	3	7	2
61	12	5	11	-	10	2
62	8	3	10	1	10	1
63	5	2	10	1	8	3
64	6	3	7	3	7	1
65	8	1	12	1	3	2
66	5	1	2	-	3	1
67	2	2	9	1	2	1
68	4	-	5	1	4	1
69	2	1	1	-	3	-
70	1	-	2	-	1	-
71	4	1	-	-	2	-
72	1	-	1	-	1	-
73	-	-	2	-	-	-
74	1	-	-	-	1	-
76	-	-	1	-	-	-
80	-	-	1	-	-	-
fs	0.07	0.02	0.14	0.02	0.06	0.03

Table 2. Parameter estimates and standard errors (in parentheses) obtained from the modified SELECT analysis of separate hauls and all hauls combined for the trouser trawl experiment investigating the selectivity for cod of a measured 138.3 mm diamond mesh with 20% shortened lastridge ropes. Parameters are defined in the text.

haul	a	b	p	p^*	L_{25}	L_{50}	L_{75}
1	-21.7	0.40	0.78	0.49	51.18	53.91	56.64
	(2.68)	(0.06)	(0.04)	(0.06)	(1.06)	(1.35)	(1.68)
2	-21.3	0.38	0.86	0.50	52.61	55.47	58.32
	(1.87)	(0.04)	(0.03)	(0.07)	(1.16)	(1.38)	(1.63)
3	-17.8	0.32	0.83	0.75	52.78	56.25	59.73
	(1.63)	(0.04)	(0.05)	(0.06)	(1.63)	(1.95)	(2.30)
combined	-20.6	0.37	-	0.58	52.13	55.07	58.01
	(1.14)	(0.03)	-	(0.04)	(0.70)	(0.85)	(1.02)

Table 3. Parameter estimates and standard errors (in parentheses) obtained from the SELECT analysis of separate hauls and all hauls combined with scaled catches for the trouser trawl experiment investigating the selectivity for cod of a measured 138.3 mm diamond mesh with 20% shortened lastridge ropes. Parameters are defined in the text.

haul	a	b	p	L_{25}	L_{50}	L_{75}
1	-21.5	0.39	0.53	51.68	54.47	57.26
	(3.66)	(0.08)	(0.05)	(1.15)	(1.52)	(1.97)
2	-18.3	0.31	0.66	55.87	59.44	63.01
	(2.09)	(0.04)	(0.07)	(1.79)	(2.18)	(2.60)
3	-17.6	0.31	0.76	53.16	56.69	60.22
	(1.78)	(0.04)	(0.06)	(1.64)	(1.99)	(2.37)
combined	-17.8	0.32	0.63	52.89	56.36	59.84
	(0.89)	(0.02)	(0.04)	(0.94)	(1.11)	(1.30)

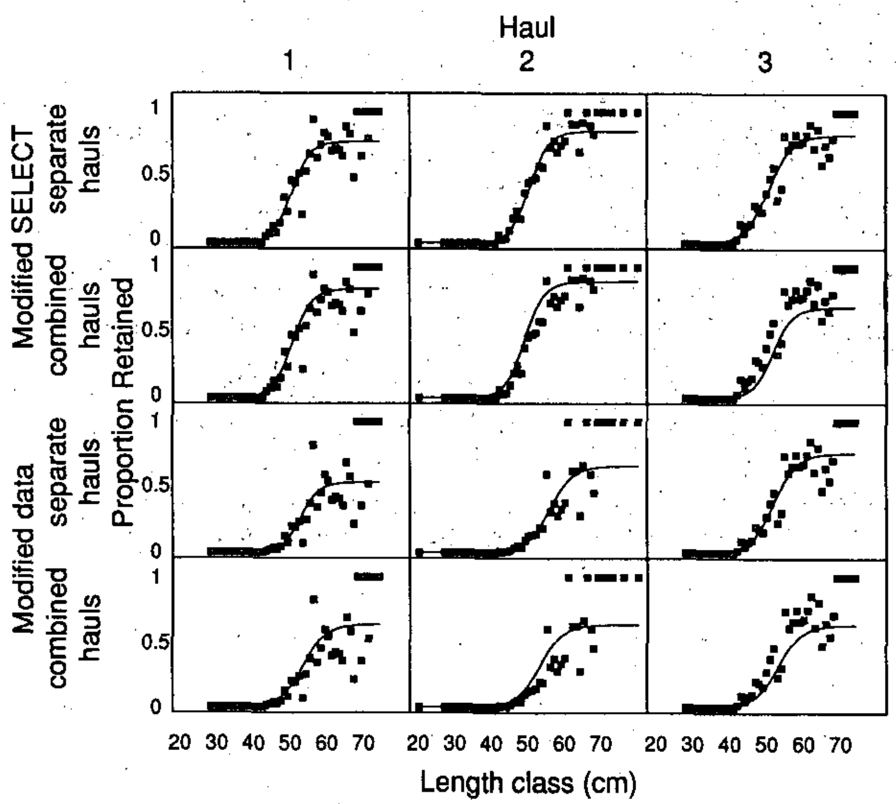

Fig. 1. Estimated (solid line) and observed (points) proportion of the total catch retained in the experimental codend. The columns of plots correspond to hauls. The first and second rows are from the modified SELECT analysis with fractions subsampled for separate and combined hauls respectively. The third and forth rows are from the standard SELECT analysis of data scaled by fractions subsampled.

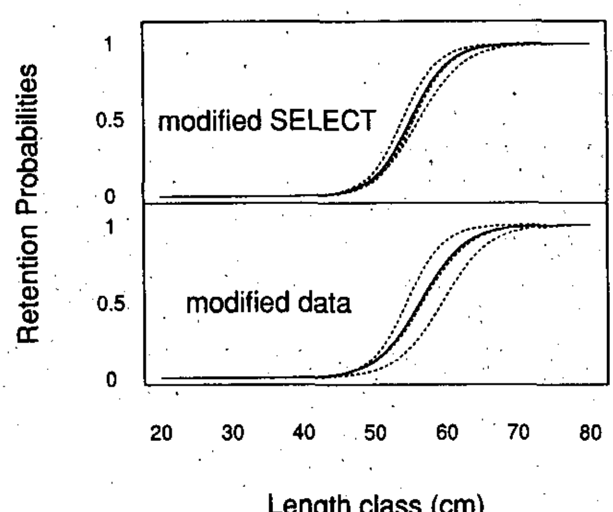

Fig. 2. Estimated selection curves from the combined analysis (solid line) and haul by haul analysis (broken lines). The upper panel is from the modified SELECT analysis with fractions subsampled while the lower panel is from the standard SELECT analysis of data scaled by fractions subsampled.